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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARD-INDEX

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD INDEX OF PUBLICATIONS

1986–1988

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THE MISSION OF AGARD

According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Exchange of scientific and technical information;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

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PREFACE

This volume provides abstracts and indexes for AGARD unclassified publications published during the period 1986—1988. By an arrangement with U.S. National Aeronautics and Space Administration (NASA) in Washington, D.C., the NASA computerized data base has been used to prepare this publication.

Full bibliographic citations and abstracts for all the documents in this publication are given in the abstract section, which is organized in the major subject divisions and specific categories used by NASA in abstract journals and bibliographies. The major subject divisions are listed, together with a note for each that defines its scope and provides any cross-references. Category breaks in the abstract section are identified by category number and title, and a scope note. Within each category, the abstracts are arranged by series and year.

Six indexes — Subject (based on *NASA Thesaurus* nomenclature), Personal Author, Corporate Source, Panel Report/Accession Number, and Accession Number — are included. Sample entries are shown on the first page of each index.

NB A number of changes have been made to the contents and format for this edition, which it is hoped will facilitate its use:

a. There is now an index by AGARD Panel (to complete publications only).

b. The citations for individual papers in a publication such as a conference proceedings now include a reference to the number of the parent publication, e.g. CP-402.

c. The citations for individual papers now appear in the correct category for their own subject matter, which may not be the same category as the parent.

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SUBJECT CATEGORIES

AERONAUTICS

Includes aeronautics (general); aerodynamics; air transportation and safety; aircraft communications and navigation; aircraft design, testing and performance; aircraft instrumentation; aircraft propulsion and power; aircraft stability and control; and research and support facilities (air).

For related information see also *Astronautics.*

01 AERONAUTICS (GENERAL) 1

02 AERODYNAMICS 4

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

For related information see also *34 Fluid Mechanics and Heat Transfer*

03 AIR TRANSPORTATION AND SAFETY 22

Includes passenger and cargo air transport operations; and aircraft accidents.

For related information see also *16 Space Transportation* and *85 Urban Technology and Transportation.*

04 AIRCRAFT COMMUNICATIONS AND NAVIGATION 25

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

For related information see also *17 Space Communications, Spacecraft Communications, Command and Tracking* and *32 Communications and Radar.*

05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE 30

Includes aircraft simulation technology.

For related information see also *18 Spacecraft Design, Testing and Performance* and *39 Structural Mechanics.* For land transportation vehicles see *85 Urban Technology and Transportation.*

06 AIRCRAFT INSTRUMENTATION 45

Includes cockpit and cabin display devices; and flight instruments.

For related information see also *19 Spacecraft Instrumentation* and *35 Instrumentation and Photography.*

07 AIRCRAFT PROPULSION AND POWER 57

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and onboard auxiliary power plants for aircraft.

For related information see also *20 Spacecraft Propulsion and Power, 28 Propellants and Fuels,* and *44 Energy Production and Conversion.*

08 AIRCRAFT STABILITY AND CONTROL 72

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

For related information see also *05 Aircraft Design, Testing and Performance.*

09 RESEARCH AND SUPPORT FACILITIES (AIR) 79

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tubes; and aircraft engine test stands.

For related information see also *14 Ground Support Systems and Facilities (Space).*

ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; space communications, spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

For related information see also *Aeronautics*

12 ASTRONAUTICS (GENERAL) N.A.

For extraterrestrial exploration see *91 Lunar and Planetary Exploration.*

13 ASTRODYNAMICS N.A.

Includes powered and free-flight trajectories; and orbital and launching dynamics.

14 GROUND SUPPORT SYSTEMS AND FACILITIES (SPACE) 91

Includes launch complexes, research and production facilities; ground support equipment, e.g., mobile transporters; and simulators.

For related information see also *09 Research and Support Facilities (Air).*

15 LAUNCH VEHICLES AND SPACE VEHICLES 91

Includes boosters; operating problems of launch/space vehicle systems; and reusable vehicles.

For related information see also *20 Spacecraft Propulsion and Power.*

16 SPACE TRANSPORTATION 94

Includes passenger and cargo space transportation, e.g., shuttle operations; and space rescue techniques.

For related information see also *03 Air Transportation and Safety* and *18 Spacecraft Design, Testing and Performance.* For space suits see *54 Man/System Technology and Life Support.*

17 SPACE COMMUNICATIONS, SPACECRAFT COMMUNICATIONS, COMMAND AND TRACKING N.A.

Includes telemetry; space communications networks; astronavigation and guidance; and radio blackout.

For related information see also *04 Aircraft Communications and Navigation* and *32 Communications and Radar.*

18 SPACECRAFT DESIGN, TESTING AND PERFORMANCE 94

Includes satellites; space platforms; space stations; spacecraft systems and components such as thermal and environmental controls; and attitude controls.

For life support systems see *54 Man/System Technology and Life Support.* For related information see also *05 Aircraft Design, Testing and Performance, 39 Structural Mechanics,* and *16 Space Transportation.*

19 SPACECRAFT INSTRUMENTATION N.A.

For related information see also *06 Aircraft Instrumentation* and *35 Instrumentation and Photography.*

20 SPACECRAFT PROPULSION AND POWER 99

Includes main propulsion systems and components, e.g. rocket engines; and spacecraft auxiliary power sources.

For related information see also *07 Aircraft Propulsion and Power, 28 Propellants and Fuels, 44 Energy Production and Conversion,* and *15 Launch Vehicles and Space Vehicles.*

CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; propellants and fuels; and materials processing.

23 CHEMISTRY AND MATERIALS (GENERAL) N.A.

24 COMPOSITE MATERIALS 102

Includes physical, chemical, and mechanical properties of laminates and other composite materials.

For ceramic materials see *27 Nonmetallic Materials.*

25 INORGANIC AND PHYSICAL CHEMISTRY 103

Includes chemical analysis, e.g., chromatography; combustion theory; electrochemistry; and photochemistry.

For related information see also *77 Thermodynamics and Statistical Physics.*

26 METALLIC MATERIALS 110

Includes physical, chemical, and mechanical properties of metals, e.g., corrosion; and metallurgy.

27 NONMETALLIC MATERIALS 112

Includes physical, chemical, and mechanical properties of plastics, elastomers, lubricants, polymers, textiles, adhesives, and ceramic materials.

For composite materials see *24 Composite Materials.*

28 PROPELLANTS AND FUELS 113

Includes rocket propellants, igniters and oxidizers; their storage and handling procedures; and aircraft fuels.

For related information see also *07 Aircraft Propulsion and Power, 20 Spacecraft Propulsion and Power,* and *44 Energy Production and Conversion.*

29 MATERIALS PROCESSING N.A.

Includes space-based development of products and processes for commercial application.

For biological materials see *55 Space Biology.*

ENGINEERING

Includes engineering (general); communications and radar; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

For related information see also *Physics.*

31 ENGINEERING (GENERAL) 117

Includes vacuum technology; control engineering; display engineering; cryogenics; and fire prevention.

32 COMMUNICATIONS AND RADAR 122

Includes radar; land and global communications; communications theory; and optical communications.

For related information see also *04 Aircraft Communications and Navigation* and *17 Space Communications, Spacecraft Communications, Command and Tracking.* For search and rescue see *03 Air Transportation and Safety,* and *16 Space Transportation.*

33 ELECTRONICS AND ELECTRICAL ENGINEERING 153

Includes test equipment and maintainability; components, e.g., tunnel diodes and transistors; microminiaturization; and integrated circuitry.

For related information see also *60 Computer Operations and Hardware* and *76 Solid-State Physics.*

34 FLUID MECHANICS AND HEAT TRANSFER 154

Includes boundary layers; hydrodynamics; fluidics; mass transfer and ablation cooling.

For related information see also *02 Aerodynamics* and *77 Thermodynamics and Statistical Physics.*

35 INSTRUMENTATION AND PHOTOGRAPHY 170

Includes remote sensors; measuring instruments and gages; detectors; cameras and photographic supplies; and holography.

For aerial photography see *43 Earth Resources and Remote Sensing.* For related information see also *06 Aircraft Instrumentation* and *19 Spacecraft Instrumentation.*

36 LASERS AND MASERS 172

Includes parametric amplifiers.

For related information see also *76 Solid-State Physics.*

37 MECHANICAL ENGINEERING 174

Includes auxiliary systems (nonpower); machine elements and processes; and mechanical equipment.

38 QUALITY ASSURANCE AND RELIABILITY 179

Includes product sampling procedures and techniques; and quality control.

39 STRUCTURAL MECHANICS 182

Includes structural element design and weight analysis; fatigue; and thermal stress.

For applications see *05 Aircraft Design, Testing and Performance* and *18 Spacecraft Design, Testing and Performance.*

GEOSCIENCES

Includes geosciences (general); earth resources and remote sensing; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

For related information see also *Space Sciences*.

42 GEOSCIENCES (GENERAL) N.A.

43 EARTH RESOURCES AND REMOTE SENSING 187

Includes remote sensing of earth resources by aircraft and spacecraft; photogrammetry; and aerial photography.

For instrumentation see *35 Instrumentation and Photography*.

44 ENERGY PRODUCTION AND CONVERSION N.A.

Includes specific energy conversion systems, e.g., fuel cells; global sources of energy; geophysical conversion; and windpower.

For related information see also *07 Aircraft Propulsion and Power*, *20 Spacecraft Propulsion and Power*, and *28 Propellants and Fuels*.

45 ENVIRONMENT POLLUTION N.A.

Includes atmospheric, noise, thermal, and water pollution.

46 GEOPHYSICS 187

Includes aeronomy; upper and lower atmosphere studies; ionospheric and magnetospheric physics; and geomagnetism.

For space radiation see *93 Space Radiation*.

47 METEOROLOGY AND CLIMATOLOGY 189

Includes weather forecasting and modification.

48 OCEANOGRAPHY N.A.

Includes biological, dynamic, and physical oceanography; and marine resources.

For related information see also *43 Earth Resources and Remote Sensing*.

LIFE SCIENCES

Includes life sciences (general); aerospace medicine; behavioral sciences; man/system technology and life support; and space biology.

51 LIFE SCIENCES (GENERAL) 190

52 AEROSPACE MEDICINE 190

Includes physiological factors; biological effects of radiation; and effects of weightlessness on man and animals.

53 BEHAVIORAL SCIENCES 207

Includes psychological factors; individual and group behavior; crew training and evaluation; and psychiatric research.

54 MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT 208

Includes human engineering; biotechnology; and space suits and protective clothing.

For related information see also *16 Space Transportation*.

55 SPACE BIOLOGY N.A.

Includes exobiology; planetary biology; and extraterrestrial life.

MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

59 MATHEMATICAL AND COMPUTER SCIENCES (GENERAL) N.A.

60 COMPUTER OPERATIONS AND HARDWARE 221

Includes hardware for computer graphics, firmware, and data processing.

For components see *33 Electronics and Electrical Engineering*.

61 COMPUTER PROGRAMMING AND SOFTWARE 223

Includes computer programs, routines, algorithms, and specific applications, e.g., CAD/CAM.

62 COMPUTER SYSTEMS 232

Includes computer networks and special application computer systems.

63 CYBERNETICS 232

Includes feedback and control theory, artificial intelligence, robotics and expert systems.

For related information see also *54 Man/System Technology and Life Support*.

64 NUMERICAL ANALYSIS 233

Includes iteration, difference equations, and numerical approximation.

65 STATISTICS AND PROBABILITY 234

Includes data sampling and smoothing; Monte Carlo method; and stochastic processes.

66 SYSTEMS ANALYSIS 234

Includes mathematical modeling; network analysis; and operations research.

67 THEORETICAL MATHEMATICS N.A.

Includes topology and number theory.

PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

For related information see also *Engineering*.

70 PHYSICS (GENERAL) N.A.

For precision time and time interval (PTTI) see *35 Instrumentation and Photography*; for geophysics, astrophysics or solar physics see *46 Geophysics*, *90 Astrophysics*, or *92 Solar Physics*.

71 ACOUSTICS 236
Includes sound generation, transmission, and attenuation.
For noise pollution see *45 Environment Pollution.*

72 ATOMIC AND MOLECULAR PHYSICS N.A.
Includes atomic structure, electron properties, and molecular spectra.

73 NUCLEAR AND HIGH-ENERGY PHYSICS N.A.
Includes elementary and nuclear particles; and reactor theory.
For space radiation see *93 Space Radiation.*

74 OPTICS 237
Includes light phenomena and optical devices.
For lasers see *36 Lasers and Masers.*

75 PLASMA PHYSICS 242
Includes magnetohydrodynamics and plasma fusion.
For ionospheric plasmas see *46 Geophysics.* For space plasmas see *90 Astrophysics.*

76 SOLID-STATE PHYSICS N.A.
Includes superconductivity.
For related information see also *33 Electronics and Electrical Engineering* and *36 Lasers and Masers.*

77 THERMODYNAMICS AND STATISTICAL PHYSICS N.A.
Includes quantum mechanics; theoretical physics; and Bose and Fermi statistics.
For related information see also *25 Inorganic and Physical Chemistry* and *34 Fluid Mechanics and Heat Transfer.*

SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law, political science, and space policy; and urban technology and transportation.

80 SOCIAL SCIENCES (GENERAL) N.A.
Includes educational matters.

81 ADMINISTRATION AND MANAGEMENT 243
Includes management planning and research.

82 DOCUMENTATION AND INFORMATION SCIENCE 247
Includes information management; information storage and retrieval technology; technical writing; graphic arts; and micrography.
For computer documentation see *61 Computer Programming and Software*

83 ECONOMICS AND COST ANALYSIS 254
Includes cost effectiveness studies.

84 LAW, POLITICAL SCIENCE AND SPACE POLICY N.A.
Includes NASA appropriation hearings; aviation law; space law and policy; international law; international cooperation; and patent policy.

85 URBAN TECHNOLOGY AND TRANSPORTATION N.A.
Includes applications of space technology to urban problems; technology transfer; technology assessment; and surface and mass transportation.
For related information see *03 Air Transportation and Safety, 16 Space Transportation,* and *44 Energy Production and Conversion.*

SPACE SCIENCES

Includes space sciences (general); astronomy; astrophysics; lunar and planetary exploration; solar physics; and space radiation.
For related information see also *Geosciences.*

88 SPACE SCIENCES (GENERAL) N.A.

89 ASTRONOMY N.A.
Includes radio, gamma-ray, and infrared astronomy; and astrometry.

90 ASTROPHYSICS N.A.
Includes cosmology; celestial mechanics; space plasmas; and interstellar and interplanetary gases and dust.
For related information see also *75 Plasma Physics.*

91 LUNAR AND PLANETARY EXPLORATION N.A.
Includes planetology; and manned and unmanned flights.
For spacecraft design or space stations see *18 Spacecraft Design, Testing and Performance.*

92 SOLAR PHYSICS N.A.
Includes solar activity, solar flares, solar radiation and sunspots.
For related information see *93 Space Radiation.*

93 SPACE RADIATION 255
Includes cosmic radiation; and inner and outer earth's radiation belts.
For biological effects of radiation see *52 Aerospace Medicine.* For theory see *73 Nuclear and High-Energy Physics.*

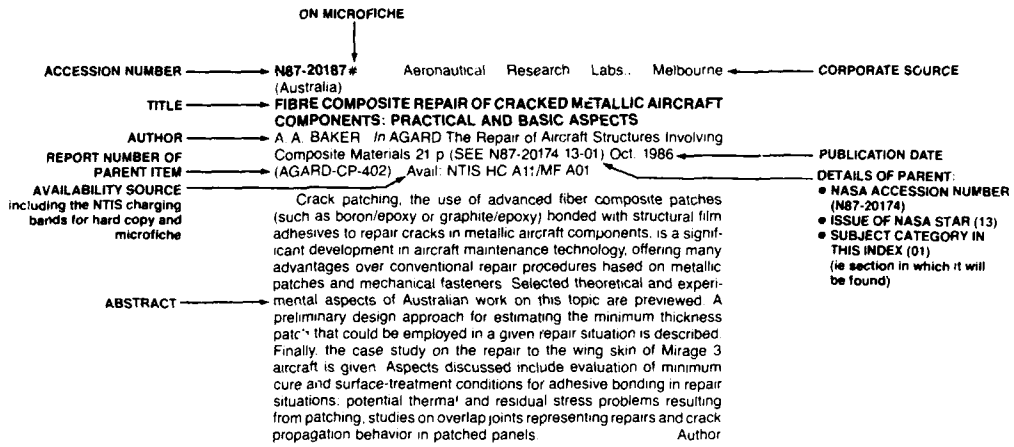
GENERAL

Includes aeronautical, astronautical, and space science related histories, biographies, and pertinent reports too broad for categorization; histories or broad overviews of NASA programs.

99 GENERAL N.A.

Note: N.A. means that no abstracts were assigned to this category for this issue.

TYPICAL CITATION



NB Many AGARD publications, such as Conference Proceedings and Lecture Series, contain a number of individual papers. There is a separate citation in this Index for each such paper, each containing a cross-reference (01 in this instance) to the parent publication in the form shown above. To locate the parent in this Index, refer to the subject category given in the cross-reference. Within each category citations are in numerical order.

AGARD INDEX OF PUBLICATIONS (1986—1988)

ABSTRACT SECTION

01

AERONAUTICS (GENERAL)

N87-20174# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
THE REPAIR OF AIRCRAFT STRUCTURES INVOLVING COMPOSITE MATERIALS
Oct. 1986 240 p In ENGLISH and FRENCH Meeting held in Oslo, Norway, 14-16 Apr. 1986
(AGARD-CP-402; ISBN-92-835-0400-3; AD-A178691) Avail. NTIS HC A11/MF A01

Modern combat aircraft are making increasing use of composite materials in both primary and secondary structures, and the need for repair schemes which involve a mixture of composite and metallic materials is no longer exceptional. At its sixty-second meeting, the Structures and Materials Panel held a conference of Specialists, the aim of which was to share experiences of repairs involving composites and structures now in service. A further aim was to highlight the demand for the development of innovative times and increase repair capabilities under all conditions of service but also make for greater standardization. For individual titles see N87-20175 through N87-20192.

N87-20175# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
REPAIR PROCEDURES FOR COMPOSITE PARTS ON THE ALPHA JET
TH. THIELE *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 7 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

A survey is given of activities to develop repair procedures for the composite parts of the alpha jet. The complete program was divided into two parts: the first part covered the repair and test of specimen; the second part the repair and test of a full scale speed brake. Author

N87-20177# Lockheed-California Co., Burbank.
DEVELOPMENT OF FIELD LEVEL REPAIRS FOR COMPOSITE STRUCTURES
ROBERT H. STONE *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 12 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Bolted and bonded field-level repairs have been developed, fabricated and tested at Lockheed-California Company for several recent contract and independent research programs. Bolted repairs are particularly well adapted to field repair situations. Bolted aluminum repair concepts have been developed and verified under a NASA sponsored program for an L-1011 composite inboard aileron, which is now in flight-service evaluation. Special drilling, machining, fastener installation and sealing procedures were developed for these repairs. Bolted repairs were also developed and validated under a Naval Air Development Center (NADC) sponsored program. These included various configurations of aluminum and titanium patches using blind fasteners, with drilling and installation procedures representative of field conditions including lack of back-side access. Repair specimens were tested in tension and compression, and the patches restored design strength levels to the damaged composite. Bonded field repairs require adhesives with room temperature storability in addition to the other structural/environmental requirements. Screening tests were run on various film and two-part adhesives. A two-part adhesive, developed by NADC and now commercially available, had the best combination of properties for field repairs. Other tests related to bonded field repairs determined that 177 C (350 F) curing film adhesives have several months' storability at room temperature, and verified prebond storability of titanium surface treatments for use in bonded repair kits. Author

N87-20179# Societe Nationale Industrielle Aerospatiale, Marignane (France). Advanced Engineering Dept.
REPAIR OF HELICOPTER COMPOSITE STRUCTURE TECHNIQUES AND SUBSTANTIATIONS
MANUEL TORRES and BERNARD PLISSONNEAU *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 21 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

The advantages of composite materials are now well known and have been widely demonstrated. Lighter weight, lower cost, shorter manufacturing cycles, damage tolerance, etc. are some of the advantages. As a result, composite materials are increasingly used in helicopters. Helicopter designs have made extensive use of composites for over twenty years. Composite rotor blades date from 1970. More recently, major programs have been undertaken to produce the future generation of helicopters with a totally composite fuselage. The increasing number of composite items in the aircraft structure raises the problem of damage and repair. This concern is further justified by the relatively high damage probability of a helicopter that may be operated in severe environmental conditions. The repair philosophy engages the responsibility of the aircraft manufacturer as well as the operator. The manufacturer must develop and substantiate repair methods that are as simple as possible. The operator must be equipped with suitable inspection and repair facilities. These repairs must ensure an adequate safety level for the remaining helicopter's service life. They must be suitable for the nature of the damage and the type of part involved. They must be as easy as possible to implement and require minimal special tools and expertise, and the repair cost must remain well below the price of new replacement parts. Author

N87-20181# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Stress Office.
COMPOSITE REPAIR OF COCURED J-STIFFENED PANELS: DESIGN AND TEST VERIFICATION
GEORG GUENTHER and LUDWIG LEMMER *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 19 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

An increasing percentage of military aircraft fuselage and wing structures are being replaced by cocured integrated carbon fiber composite (CFC) structures. The probability of damage in day-to-day operation is increased, since most of the structure is located on the aircraft surface. The most common field of application for cocured stiffeners are thin panels critical to buckling under shear and/or compression loading and fuselage frames subject to bending. Bonded repair methods for two maintenance levels (depot and field) have been developed and tested using representative components. For the stiffened panels both repair methods (field and depot) fulfilled structural requirements and proved their durability in the fatigue tests. Test results of the stiffened skin elements showed that cocured fuselage structures with complex geometries are repairable without reduction in

NOTICE

The single asterisk following the accession number indicates that the report is NASA sponsored

strength and stiffness tests performed after artificial ageing of the repair structure proved their reliability in the environment.
Author

N87-20182# Royal Aircraft Establishment, Farnborough (England)
EFFECT OF ADHESIVE BONDING VARIABLES ON THE PERFORMANCE OF BONDED CFRP PATCH REPAIRS OF METALLIC STRUCTURES
P. POOLE, M. H. STONE, G. R. SUTTON, and R. N. WILSON *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 21 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

The literature is briefly reviewed and limitations of the existing experimental data on the performance of bonded carbon fiber reinforced plastics (CFRP) patches are indicated. Earlier work from the Royal Aircraft Establishment is summarized, showing the importance of patch size and crack growth conditions prior to patching. Fatigue data for center-cracked, patched aluminum alloy thin sheets (7075-T76) are then presented. These show that: adhesive layer stiffness had only a moderate effect; differential contraction stresses had much less effect than predicted; and neither variations in surface treatment of the aluminum alloy before bonding nor exposure of the patche ' sheet to warm/moist conditions had any substantial effect on crack rates. Bond durability wedge and peel tests did show marked effects of alloy pretreatments. Explanations are advanced for the lack of effect of moisture and al' y pretreatment on the alloy-adhesive bonds of the patched sheets.
Author

N87-20183# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Aeronautical Systems Div.
COMPOSITE REPAIR OF CRACKED ALUMINUM STRUCTURE
LARRY G. KELLY *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 6 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

The use of bonded composite patches for repair of a wide range of typical fatigue cracked and otherwise damaged aluminum structural panels is discussed. Experimental data on stress intensity and crack growth characteristics were obtained to evaluate the advantages of such repairs. A range of metal thickness and patch parameters (thickness, orientation, bonding temperature) were tested. Edge cracked 4 inch by 18 inch 2024T3 aluminum panels were patched and fatigue behavior evaluated under constant amplitude and the Falstaff flight spectrum loading. The results showed panel thickness and fatigue test load spectrum to be important parameters. Present repair procedures for cracked aluminum aircraft structures call for bolted on metal patches. Advanced composite material bonded to such damaged structures offers the advantage of increased fatigue life. To quantify this advantage a test program was conducted with boron/epoxy patches on cracked aluminum panels. The panels were subjected to both constant amplitude and flight spectrum loads. The objective was to establish the reduction in stress intensity and thus reduced crack growth rate achieved through the use of room temperature and 250 F cured adhesive bonded patches. The pertinent parameters evaluated were aluminum thickness, patch area, and ply orientation. Dramatic improvements in fatigue life were achieved up to 20 times extended lifetimes for 1/16 inch repaired aluminum panels having an initial .34 inch induced crack.
Author

N87-20184# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
DAMAGE REPAIR OF IN-SERVICE COMPOSITE STRUCTURES: APPLICATION TO THE MIRAGE 2000 [REPARATION DE DOMMAGES EN SERVICE DES STRUCTURES COMPOSITES. APPLICATION AU MIRAGE 2000]
DANIEL CHAUMETTE and FRANCOISE HENRIOT *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 10 p (SEE N87-20174 13-01) Oct. 1986 In FRENCH; ENGLISH summary
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

A summary is given of the 15 years experience AMD/BA has had in the field of composite structures repair, and the application to the case of the Mirage 2000. AMD/BA has developed repairs using a boron fiber dry fabric impregnated and bonded in situ on aluminum structures. These repairs have been the subject of tests, and of such practical applications as local reinforcements on the Mercure airliner. Since 1978 a large number of carbon fiber ailerons have been put in service on the fighter aircraft Mirage F1 and on the Falcon 50 business jet. Repair procedures have been developed for these elements. These elements have been troublefree up to now.
Author

N87-20185# Societe de Construction des Avions Hurel-Dubois, Paris (France).
COMPOSITE STRUCTURE REPAIRS CARRIED OUT ACCORDING TO AERONAUTICAL TECHNIQUES [REPARATIONS DE STRUCTURES COMPOSITES REALISEES SELON LES TECHNIQUES AERONAUTIQUES]
JEAN-ALAIN JOUAN *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 13 p (SEE N87-20174 13-01) Oct. 1986 In FRENCH
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Advanced composite materials (aramide, carbon, honeycomb) initially utilized in aircraft structures are seeing their domain of application extended to other sectors. The experiences of Hurel-Dubois with two specific composite material applications, frames for the Formula 1 racing car and structures for transoceanic racing catamarans, are discussed with reference to damage repair and the restoration of structural integrity. The various types of in-service damage are outlined and the materials and procedures for repair are described.
Author

N87-20186# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
COMPOSITE REPAIR TECHNIQUES FOR J-STIFFENED COMPOSITE FUSELAGE STRUCTURES
K. LEDWA *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 11 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

The next generation of lightweight military aircraft will feature an essentially increased application of carbon fiber reinforced plastics (CFRP) to primary structure including fuselage side skins. Mainly for cost and weight reasons they will be large size integrally stiffened components cocured in a single shot operation. In order to avoid a costly replacement of the entire side skin in case of damage, adjusted repair techniques are required. Basic repair philosophies for field and depot level repairs using composite materials were defined and proved by two different types of test specimen. Specially designed flat panels with a 50 mm diameter hole penetrating skin and stiffener were followed by single curved side skin elements damaged by a destructive qualification test. Both types were repaired using different methods and finally destructive tested. The test results showed that the restoration of part stiffness and sufficient strength after repair can successfully be realized. Manufacturing problems were recognized concerning material choice and cure cycles at elevated temperatures and regarding the nondestructive inspection of applied repair patches.
Author

N87-20187# Aeronautical Research Labs., Melbourne (Australia).
FIBRE COMPOSITE REPAIR OF CRACKED METALLIC AIRCRAFT COMPONENTS: PRACTICAL AND BASIC ASPECTS
A. A. BAKER *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 21 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Crack patching, the use of advanced fiber composite patches (such as boron/epoxy or graphite/epoxy) bonded with structural film adhesives to repair cracks in metallic aircraft components, is a significant development in aircraft maintenance technology, offering many advantages over conventional repair procedures based on metallic patches and mechanical fasteners. Selected theoretical and experimental aspects of Australian work on this topic are previewed. A preliminary design approach for estimating the minimum thickness patch that could be employed in a given repair situation is described. Finally, the case study on the repair to the wing skin of Mirage 3 aircraft is given. Aspects discussed include evaluation of minimum cure and surface-treatment conditions for adhesive bonding in repair situations; potential thermal and residual stress problems resulting from patching; studies on overlap joints representing repairs and crack propagation behavior in patched panels.
Author

N87-20188# Naval Air Development Center, Warminster, PA.
COMPOSITE REPAIR MATERIAL AND DESIGN DEVELOPMENT EFFORTS
R. C. COCHRAN, T. M. DONNELLAN, E. L. ROSENZWEIG, and R. E. TRABOCCO *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 13 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Recent developments in the area of bonded and bolted composite repair are discussed. An ideal resin or adhesive for field repair would have the following characteristics: ambient storage, low temperature cure, short time cure, elevated temperature and moisture resistance, and vacuum processing. Two approaches were used to achieve resin formulations for repair patches which will meet these requirements. The first method utilizes chemically hindred diamines as curing agents for epoxy resins. The second method involves isolation of the curing agents from the epoxy resin by phase separation. In the area of adhesives for field repair of composites, a two-part paste adhesive has been developed. The adhesive meets all of the program requirements and can be used with various repair materials. The design of bolted repairs for composite structures is discussed. A simplified design has been established which uses standard plate thicknesses, bolt sizes and spacing. Several patch shapes have been tested and found to restore design ultimate strains. Author

N87-20189# McDonnell Aircraft Co., Saint Louis, MO.
BATTLE DAMAGE REPAIR OF COMPOSITE STRUCTURES
THOMAS V. HINKLE, JACK VANES, and CHARLES L. RAMSEY (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.) *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 11 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Concepts and procedures for the rapid repair of battle-damaged composite structures are discussed. The damage consists of elongated or concentrated penetrations of solid wing skins and of honeycomb empennage. The size of the damage, in conjunction with the strength-critical nature of these structures, requires structural repairs in order to restore a strength capability commensurate with the maximum expected flight loads and service temperatures. Guidelines for these repairs are based on the USAF concept of operation for aircraft battle damage repair. Structural tests are being conducted to validate repair designs. Damage simulation, repair design, damage cleanup, repair fabrication, and available test results are reported. Author

N87-20190# Army Materials Technology Lab., Watertown, MA.
UNCONVENTIONAL APPROACHES TO FIELD REPAIR
STANLEY E. WENTWORTH, MICHAEL S. SENNETT, and JOHN W. GIBSON (Southern Research Inst., Birmingham, Ala.) *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 8 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Field repair of composites presents special problems for the Army where the repair might literally be performed in a field or other remote location. In such a situation, access to electric power both for refrigeration to preserve reactive resin systems and for heating to cure the patch, is severely limited. In order to circumvent these problems, we have investigated some novel approaches to the packaging and curing of composite patches. One approach involves a self-contained kit in which all of the patch components including the reinforcement are separate from one another until the patch is needed, at which time they are combined in the proper ratio by means of a simple operation. Shelf-life for such a system, even without refrigeration is thus indefinite. Another approach makes use of optical fibers to carry light energy into the interior of an otherwise opaque graphite fiber-reinforced patch thereby permitting the use of a photochemically curable matrix resin. Initial efforts to implement these approaches, some of the difficulties encountered, and current attempts to circumvent them are discussed. Some new approaches are also outlined. Author

N87-20191# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PATCH REPAIR OF CORRODED AIRCRAFT SKIN AREAS
W. G. J. THART and R. J. H. WANHILL *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 8 p (SEE N87-20174 13-01) Oct. 1986 Sponsored by the Royal Netherlands Air Force
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Environmental conditions in Europe are conducive to corrosion attack of aircraft structures. In military aircraft, corrosion problems occur especially at countersunk fastener holes. The corrosion is generally removed by grinding. A limited amount of material removal is specified by the aircraft manufacturers, but it is sometimes necessary to exceed these limits. When this happens a repair is necessary to allow continued operation. An investigation of the effectiveness of bonded patch repairs was carried out. The patch materials were aluminum alloy sheet and aramid fiber reinforced composite prepreg. A cold curing acrylic based adhesive was used for bonding. Specimens with simulated patch repairs were subjected to both constant amplitude and flight simulation fatigue testing under various environmental conditions. The results indicated that bonded patches are potentially very good repairs for areas weakened by corrosion and its removal. Author

N87-20192# British Airways, Middlesex (England).
BRITISH AIRWAYS EXPERIENCE WITH COMPOSITE REPAIRS
K. B. ARMSTRONG *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 12 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

British Airways experience with composite repairs since 1970 is discussed. The use of composite materials to repair metal structures such as Concorde wing leading edges is discussed. Repair of composite parts from Radomes starting in 1970, through B.747 body fairing and floor panels, to the repair of carbon fiber composite control surfaces and access doors on the B.757 is covered. Most of the repairs have used cold-setting resins (with heat lamp assisted curing) but some hot-setting adhesives and pre-pregs have been used. Effort is being made to develop techniques to facilitate the use of hot-setting adhesives. More information will be sought on diffusion and solubility coefficients of all types of adhesives to aid selection and improve the durability of repairs. Author

N87-22664# Ministry of Defence, London (England).
COST ANALYSIS OF AIRCRAFT PROJECTS
D. FADDY *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 10 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

The effect of advancing technology on the cost of past aircraft and the implications for the future is reviewed. The validity of historical records for forecasting a future dominated by technological change and the consequences of continued escalation are discussed. It is argued that more priority needs to be given to the reduction of support cost and a way of looking at this as a direct contribution to military capability is suggested. The role of operations research is briefly emphasized and a more deliberately evolutionary approach to the production of aircraft is advocated. Author

N88-28857# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
BOUNDARY LAYER SIMULATION AND CONTROL IN WIND TUNNELS
Apr. 1988 462 p
(AGARD-AR-224; ISBN-92-835-0457-7; AD-A198667) Avail: NTIS HC A20/MF A01

The results of a study performed by AGARD Working Group 09 on boundary layer simulation in wind tunnels are presented with emphasis on the transonic speed regime. This report is intended to display the current state-of-the-art in boundary layer simulation where Reynolds number is or cannot be simulated and give attention to wind tunnel effects as well as to document the physical aspects of boundary layer simulation and the research needed. Finally, a simulation methodology is proposed which can serve wind tunnel user and operator as an ordered thinking process for the design of wind tunnel tests where viscous effects are

important. For individual titles, see N88-28858 through N88-28877.

N88-29717# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
THE FLIGHT OF FLEXIBLE AIRCRAFT IN TURBULENCE: STATE-OF-THE-ART IN THE DESCRIPTION AND MODELLING OF ATMOSPHERIC TURBULENCE
Jun. 1988 111 p Meeting held in Cesme, Turkey, 4-9 Oct. 1987
(AGARD-R-734-ADD; ISBN-92-835-0458-5; AD-A198702) Avail: NTIS HC A06/MF A01

The large scale use of flight recorders by commercial airlines, coupled with the enhanced quality of results offered by modern computer based reduction processes makes it possible to broaden knowledge of the phenomenon of atmospheric turbulence. At the same time, new methods for predicting the response of flexible aircraft to turbulence are being proposed, and novel gust alleviation systems are being designed and tested. The presentations made at a workshop held for the discussion of these ideas are given. For individual titles, see N88-29718 through N88-29724.

N88-29725# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
THE FLIGHT OF FLEXIBLE AIRCRAFT IN TURBULENCE: STATE-OF-THE-ART IN THE DESCRIPTION AND MODELLING OF ATMOSPHERIC TURBULENCE
Dec. 1987 187 p Meeting held in Athens, Greece, 28 Sep. - 3 Oct. 1986
(AGARD-R-734; ISBN-92-835-0426-7; AD-A194870) Avail: NTIS HC A09/MF A01

The flight of flexible aircraft in turbulence was studied. Presentations given at the first of two workshops on the subject are provided. Topics covered here are: (1) Measurements of turbulence by specially equipped aircraft, and (2) Data collection and reduction of incremental accelerations observed in commercial flights. For individual titles, see N88-29726 through N88-29734.

N88-29735# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
ADVANCES IN FLYING QUALITIES
May 1988 194 p Lecture held in Delft, Netherlands, 26-27 May 1988, in Rome, Italy, 30-31 May 1988, and in Torrance, Calif., 15-16 Jun. 1988
(AGARD-LS-157; ISBN-92-835-0461-5; AD-A199307) Avail: NTIS HC A09/MF A01

Judging the suitability of an aircraft to safely and effectively perform its mission without undue pilot skill and discomfort is what flying qualities is all about. Central to such judgement, and to the design of suitable aircraft plus flight control systems, is an understanding of what the pilot can do with ease and comfort or conversely what bothers him. The lectures are designed to impart such understanding to both novice and seasoned practioners in flying qualities and flight control and thereby to provide the bridge required to extend flying qualities requirements from simple classic response aircraft, to the responses attending the use of full time active control. Mathematical models of pilot control behavior are explained. The application of various model to flying qualities are discussed; and the influences, regarding the generic likes and dislikes of pilots drawn from such studies are listed. For individual titles, see N88-29736 through N88-29742.

N89-10001# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France) Flight Mechanics Panel.
TECHNICAL EVALUATION REPORT ON THE FLIGHT MECHANICS PANEL SYMPOSIUM ON FLIGHT VEHICLE DEVELOPMENT TIME AND COST REDUCTION
GERALD G KAYTEN (Kayten, Gerald G., Chevy Chase, Md) 1988 16 p Symposium held in Toulouse, France, 11-14 May 1987
(AGARD-AR-244; ISBN-92-835-0473-9; AD-A199742) Avail: NTIS HC A03/MF A01

There is a current perception that time and especially the cost of the new systems are increasing at an ever acceferating rate greater than that for improvement of the capabilities of the machines. The purpose of this symposium was to provide a forum to identify and discuss the elements contributing to the increased time and cost development, and to explore the question of what can be done to arrest and reverse the trend. Another aim of this symposium was to encourage others in the nontechnical area to join with the technical people in attacking these problems resolutely. It is considered that the meeting was successful in focusing attention on this situation, showing what technologies can do to reduce development time and cost growth, and by highlighting key areas that must be addressed to reverse the trend. Author

N89-10831# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
COMPUTING SYSTEMS CONFIGURATION FOR HIGHLY INTEGRATED GUIDANCE AND CONTROL SYSTEMS
Jun. 1988 164 p Lectures held in Bourges, France, 20-21 Jun. 1988, in Neubiberg, West Germany, 23-24 Jun. 1988, and in Seattle, Wash., 6-7 Jul. 1988
(AGARD-LS-158; ISBN-92-835-0464-X; AD-A199308) Avail: NTIS HC A08/MF A01

Modern military air vehicles have to comply with sophisticated performance requirements. As a result, full advantage must be taken of the rapid advances in computer hardware/software and future micro-electronics technologies. New design and development strategies must be implemented in order to obtain the overall performance benefits offered by advanced integrated systems for guidance and control, avionics, weapon delivery and tactical performance management. In a two-day program this Lecture Series addresses issues which have demonstrated notable and outstanding advances in the field of computing system design, design tools and techniques, computers, data buses, and architectures. In particular, the second day's program will show how technological advances have enabled the design of a modern computing system architecture. Future trends and new directions will be subjects for round table discussions. For individual titles, see N89-10832 through N89-10837.

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

N86-27182*# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
TECHNICAL EVALUATION REPORT OF AGARD TECHNICAL EVALUATION MEETING ON UNSTEADY AERODYNAMICS: FUNDAMENTALS AND APPLICATIONS TO AIRCRAFT DYNAMICS
D. G. MABEY (Royal Aircraft Establishment, Bedford, England) and J. R. CHAMBERS (NASA, Langley Research Center, Hampton, VA) Jan. 1986 18 p Meeting held in Goettingen, Fed. Republic of Germany, 6-9 May 1985
(AGARD-AR-222; ISBN-92-835-1515-3; AD-A167592) Avail: NTIS HC A02/MF A01 CSCL 01A

From May 6 to 9, 1985, the Fluid Dynamics Panel and Flight Mechanics Panel of AGARD jointly arranged a Symposium on Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics at the Stadthall, Goettingen, West Germany. This Symposium was organized by an international program committee chaired by Dr K. J. Orlik-Ruckemann of the Fluid Dynamics Panel. The program consisted of five sessions grouped in two parts: (1) Fundamentals of Unsteady Aerodynamics; and (2) Applications to Aircraft Dynamics. The 35 papers presented at the 4 day meeting are published in AGARD CP 386 and listed in the Appendix. As the papers are already available and cover a very wide field, the evaluators have offered brief comments on every paper, followed by an overall evaluation of the meeting, together with some general conclusions and recommendations. Author

N86-27187# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AIRCRAFT DRAG PREDICTION AND REDUCTION. ADDENDUM 1: COMPUTATIONAL DRAG ANALYSES AND MINIMIZATION; MISSION IMPOSSIBLE?
J. W. SLOOFF (National Aerospace Lab., Amsterdam, Netherlands) Apr 1986 33 p Presented at Aircraft Drag Prediction and Reduction, Rhode Saint Genese, Belgium, 20-23 May 1985, and Hampton, Va., 5-8 Aug. 1985; sponsored by the von Karman Inst., AGARD, and NASA Langley Research Center
(AGARD-R-723-ADD-1; ISBN-92-835-1524-2) Avail: NTIS HC A03/MF A01

The Special Course on Aircraft Drag Prediction was sponsored by the AGARD Fluid Dynamics Panel and the von Karman Institute and presented at the von Karman Institute, Rhode-Saint-Genese, Belgium, on 20 to 23 May 1985 and at the NASA Langley Research Center, Hampton, Virginia, USA, 5 to 6 August 1985. The course began with a general review of drag reduction technology. Then the possibility of reduction of skin friction through control of laminar flow and through modification of the structure of the turbulence in the boundary layer were discussed. Methods for predicting and reducing the drag of external stores, of nacelles, of fuselage protuberances, and of fuselage afterbodies were then presented followed by discussion of transonic drag rise. The prediction of viscous and wave drag by a method matching inviscid flow calculations and boundary layer integral calculations, and the reduction of transonic drag through boundary layer control are also discussed. This volume comprises Paper No.9 Computational Drag Analyses and Minimization: Mission Impossible? which was not included in AGARD Report 723 (main volume). Author

N86-32408# Dynetics, Inc., Huntsville, AL. Fluid Dynamics Panel.
AERODYNAMICS OF AIRCRAFT AFTERBODY: REPORT OF THE WORKING GROUP ON AERODYNAMICS OF AIRCRAFT AFTERBODY
1986 348 p
(AGARD-AR-226; AD-A172341) Avail: NTIS HC A15/MF A01

Aircraft afterbody design is still one of the most critical problems for industry, especially in fighter aircraft development. The flow around the rear part of the fuselage is characterized by the simultaneous occurrence of interfering physical phenomena such as thick turbulent boundary layers, viscous flow separation, hot jet interference at the base and the boat tail, and jet plume expansion in three-dimensional transonic and supersonic flow. Even experimental techniques hardly fulfill requirements for correct wind tunnel simulation of all effects. Drag prediction and drag minimization procedures for complex configurations are strongly dependent on the reliability of numerical and experimental flowfield simulation. This publication reports on the progress which has been made by AGARD-FDP Working Croup WG08, established to evaluate the state-of-the-art in experimental and computational techniques for aircraft afterbodies. Author

N87-20199# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
APPLICATIONS OF COMPUTATIONAL FLUID DYNAMICS IN AERONAUTICS
Nov. 1986 428 p In ENGLISH and FRENCH Symposium held in Aix-en-Provence, France, 7-10 Apr. 1986
(AGARD-CP-412; ISBN-92-835-0402-X; AD-A177380) Avail: NTIS HC A19/MF A01

The goal of the symposium was to provide a balanced, if not exhaustive, assessment of the status of computational fluid dynamics in aerodynamic design and analysis, where CFD is making an increasingly major impact. The rapid progress in computer capability, the general availability of large scale computers and parallel achievements in numerical analysis, algorithm development and user experience were evidenced by the presentations. The sessions were divided into subject areas of: grid generation, inviscid flow, viscous-inviscid interactions, and Navier-Stokes solutions. For individual titles see N87-20200 through N87-20231.

N87-20206*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE PREDICTION OF TRANSONIC LOADING ON ADVANCING HELICOPTER ROTORS
R. C. STRAWN and C. TUNG *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 14 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

Two different schemes are presented for including the effect of rotor wakes on the finie-difference prediction of rotor loads. The first formulation includes wake effects by means of a blade-surface inflow specification. This approach is sufficiently simple to permit coupling of a full-potential finite-difference rotor code to a comprehensive integral model for the rotor wake and blade motion. The coupling involves a transfer of appropriate loads and inflow data between the two computer codes. Results are compared with experimental data for two advancing rotor cases. The second rotor-wake modeling scheme is a split potential formulation for computing unsteady blade-vortex interactions. Discrete vortex fields are introduced into a three-dimensional, conservative, full-potential rotor code. Computer predictions are compared with two experimental blade-vortex interaction cases. Author

N87-20207# Canadair Ltd., Montreal (Quebec).
PREDICTION OF WING-BODY-STORE AERODYNAMICS USING A SMALL PERTURBATION METHOD AND A GRID EMBEDDING TECHNIQUE
FASSI KAFYEKE *In* AGARD Applications of Computational Fluid Dynamics in AEronautics 13 p (SEE N87-20199 13-02) Nov. 1986 Sponsored by Department of National Defence of Canada
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A computer program providing accurate and cost effective predictions of transonic flow fields about three dimensional configurations has been developed at Canadair. The computation scheme uses the Small Perturbation Equation and a grid embedding technique. The flow field is solved iteratively, using successive line overrelaxation. The comparisons between computed results and experiment for a wing-body and a generic wing-body-pylon-store configuration show that a good level of accuracy can be obtained with this approach. The program was written with the overall emphasis on lowering the computation time and is considered as a stepping stone towards a full aircraft-store aerodynamic simulation. The potential of the method for analyzing complex three dimensional configurations is discussed, showing that the code is a very practical tool for the design office, for parametric studies or as a lead program for more sophisticated investigations using Euler or Navier-Stokes solvers. Author

N87-20208# National Aerospace Lab., Amsterdam (Netherlands). Information Div.
MATRICS, TRANSONIC POTENTIAL FLOW CALCULATIONS ABOUT TRANSPORT AIRCRAFT
J. VANDERVOOREN, A. J. VANDERWEES, and J. H. MEELKER *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 14 p (SEE N87-20199 13-02) Nov. 1986 Sponsored in part by Netherlands Agency for Aerospace Programs (NIVR)
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

MATRICS is a system under development for the calculation of transonic (potential) flow about transport aircraft. The motivation for this development is discussed, as well as the basic concepts of the system. Details of the full potential flow solver, involving the newly developed Implicit Lower Upper decomposition/Strongly Implicit Procedures (ILU/SIP) relaxation scheme, are given. A discussion on computer power required and some informatics aspects are also presented. Results of computations are presented and discussed. Author

N87-20209# British Aerospace Aircraft Group, Warton (England). Fluid Dynamics Section.
APPLICATIONS AND DEVELOPMENTS OF COMPUTATIONAL METHODS FOR THE AERODYNAMIC PROBLEMS OF COMPLEX CONFIGURATIONS
J. A. H. PETRIE and P. M. SINCLAIR *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 14 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

Problems encountered by the Aerodynamicist at a military design site are characterised by complex geometry and complex flow conditions. Because of the limitations of current Computational Fluid Dynamics (CFD) technology, its use represents a compromise in one or both of these areas. The way in which sensible use of the current generation of CFD codes can generate useful aerodynamic design data is illustrated by three particular examples; wing design, installed store loading and the prediction of store release trajectories. Although these examples will show that data can be generated by such techniques, they are by no means ideal. As an alternative to the methods being widely developed which require a body fitted grid, BAe Brough is developing an integral method which uses a rectangular grid passing through the configuration surface(s). The theory behind this method will be presented together with some results which show the technique to have great promise. Author

N87-20214*# Massachusetts Inst. of Tech., Cambridge. CFD Lab.
APPLICATIONS OF EULER EQUATIONS TO SHARP EDGE DELTA WINGS WITH LEADING EDGE VORTICES
EARLL M. MURMAN and ARTHUR RIZZI (Aeronautical Research Inst. of Sweden, Bromma.) *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 13 p (SEE N87-20199 13-02) Nov. 1986
(Contract NAG1-358)
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

Studies on the solution of discrete Euler equations past swept delta wing configurations with sharp leding edges are presented. Freestream Mach numbers range from zero to supersonic, although the Mach number normal to the leading edge is subsonic for all cases discussed. A few examples are given to show the application of the numerical methods to representative problems. The major dicussion is directed at the application of Computational Fluid Dynamics to the understanding of the fundamental fluid mechanic mechanisms of this class of flows. Author

N87-20215# Avions Marcel Dassault, Saint-Cloud (France). Dept. d'Aerodynamique Theorique.
UTILIZATION OF EULER CODES IN NONLINEAR AERODYNAMICS [UTILISATION DES CODES EULER EN AERODYNAMIQUE NON LINEAIRE]
PIERRE PERRIER *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 8 p (SEE N87-20199 13-02) Nov. 1986 In FRENCH
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

Principal solution techniques for Euler problems are reviewed including the finite difference and finite volume methods, the finite element method, perturbation techniques for potential non-rotational solutions, and methods covering rotational zones. Specific examples of Euler code computations are discussed, namely, air intake, nonstationary, and hypersonic calculations. Finally, the use of Euler codes as approximations of Navier-Stokes codes is examined. M.G.

N87-20217# General Dynamics Corp., Fort Worth, TX.
ANALYSIS OF THE F-16 FLOW FIELD BY A BLOCK GRID EULER APPROACH
STEVE L. KARMAN, JR., JOHN P. STEINBRENNER, and KEITH M. KISIELEWSKI *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 14 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A grid generation procedure was developed to create complex block grid systems, beginning with the generation of block surfaces, up to the generation of the full block volume grids. Parallel to this, a multiple block Euler equation solver was developed using a hybrid flux vector split and split MacCormack scheme, written to allow very general boundary conditions specification. The two codes are utilized herein to generate an inviscid analysis of an entire F-16 transonic flowfield. Preliminary results are presented and are seen to compare well with experimental data. Even better correlation with experimental data is expected once a fully converged solution is obtained. Author

N87-20218# Imperial Coll. of Science and Technology, London (England). Dept. of Mechanical Engineering.
COMPARISON OF FINITE DIFFERENCE CALCULATIONS OF A LARGE REGION OF RECIRCULATING FLOW NEAR AN AIRFOIL TRAILING EDGE
L. REIS and B. E. THOMPSON (Waterloo Univ., Ontario.) *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 21 p (SEE N87-20199 13-02) Nov. 1986 Sponsored by British Ministry of Defense, Institute National de Investigacao Cientifica of Portugal and the National Science and Engineering Council of Canada
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

Calculations are presented for a turbulent boundary layer which separates upstream of a sharp trailing edge and results in a large region of recirculating flow and a curved downstream wake. The solutions obtained from two precedures that solve finite-difference equations formulated with hybrid combinations of upwind-central and bounded skew-upwind-central difference approximations for convective terms, are compared. Numerical error was smaller, and accordingly less false diffusion was apparent, in the bounded-skew calculations although there was no significant improvement in the agreement with experiment. Agreement between measured and calculated values of the lift coefficient was within 3% and required representation of momentum transport and pressure gradient normal to the surface, but the measured drag coefficient was less than 80% of that obtained in both calculations. Deficiencies are attributable, in part, to turbulence-model assumptions which do not represent the effects of stabilizing and destabilizing streamline curvature and the complex interaction of the backflow, pressure-side and curved suction-side boundary layers in the vicinity of the rear stagnation point downstream of the trailing edge. Author

N87-20219# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
ZONAL SOLUTIONS FOR AIRFOILS USING EULER BOUNDARY-LAYER AND NAVIER-STOKES EQUATIONS
M. A. SCHMATZ and E. H. HIRSCHEL *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 13 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A method is presented to simulate steady viscous flows by a zonal concept, where local solutions of the Navier-Stokes equations are coupled with solutions of the Euler and the boundary-layer equations. The basic idea is to solve the Navier-Stokes equations only in those zones of the flowfield where strong interaction occurs. The overall goal is to reduce the computation costs. The governing equations and the coupling procedures are presented for general three dimensional viscous flows. Results are given from two dimensional applications obtained with an alternating coupling scheme. Then a close coupling scheme is introduced. For this purpose a new relaxation approach for the implicit unfactored Euler and Navier-Stokes equations was implemented. The computed results demonstrate good capability for the close approach. Author

N87-20220# Istanbul Univ. (Turkey). Faculty of Aeronautics and Astronautics.
NUMERICAL INVESTIGATION OF THE LAMINAR BOUNDARY LAYER ON A 3-D BODY STARTED IMPULSIVELY FROM REST
U. GULCAT *In* AGARD Applications of Computational Fluid dynamics in Aeronautics 6 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

Unsteady flow of viscous incompressible fluid external to three dimensional bodies is considered. Based on the boundary layer concept the simplified version of the equations of motion are expressed in non-orthogonal coordinates which fits to body surface. The differential form of the equations are discretised with finite differencing to give a solution procedure which does not require any iteration while marching in space and in time. The procedure developed first tested for the flow past a circular cylinder. The

results obtained are compared with the experimental and the results of the previous numerical works available. Finally three dimensional impulsive flow past an oblate spheroid is considered. The metric coefficients and all the necessary geometrical features obtained analytically are used in the governing equations. The numerical solution is carried until the time of flow reversal that occurs at the rear stagnation point of the spheroid. Author

N87-20221# Societe Nationale Industrielle Aerospatiale, Marignane (France). Div. Helicopteres.

THEORETICAL ANALYSIS OF FLOWS AROUND HELICOPTER FUSELAGES: APPLICATION TO DESIGN AND DEVELOPMENT

A. CLER *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 8 p (SEE N87-20199 13-02) Nov. 1986 (AGARD-CP-412) Avail: NTIS HC A19/MF A01

Three dimensional aerodynamic calculations as applied to fuselage design are described. Three levels of complexity may be distinguished in the calculation programs: (1) a singularities method describing the potential flow around a fuselage, (2) an integral three dimensional boundary layer method for predicting three dimensional separations, and (3) a point vortex wake model. The first two methods are routinely used with very short response times, either on complete fuselages or for specific aircraft sections. Close agreement is obtained with the available experimental results. Various examples are given of applications to project or development work. Operational calculations cannot yet be performed with the wake model, as the method is still under development. In the current state of the art, aerodynamic calculations provide undeniable services but can by no means replace wind tunnel tests for determining complete aircraft drag. Author

N87-20224# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.

APPLICATIONS OF RAE VISCOUS FLOW METHODS NEAR SEPARATION BOUNDARIES FOR THREE-DIMENSIONAL WINGS IN TRANSONIC FLOW

M. C. P. FIRMIN *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 14 p (SEE N87-20199 13-02) Nov. 1986 (AGARD-CP-412) Avail: NTIS HC A19/MF A01

Three applications of computational fluid dynamics (CFD) at high subsonic speeds, with transonic flow, are presented. Two of these relate to the prediction of the pressure distribution over swept wings at conditions close to the separation boundary and one to the design of a swept wing for a wind-tunnel model. The methods involved are a potential flow treatment of the inviscid flow coupled with a three dimensional, integral treatment of the turbulent boundary layer. The coupling between the viscous and inviscid flow codes is direct, through a transpiration condition at the wing surface and on a surface downstream of the wing. Author

N87-20225# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.

APPLICATION OF THE NAVIER-STOKES EQUATIONS TO SOLVE AERODYNAMIC PROBLEMS

J. S. SHANG and W. L. HANKEY (Wright State Univ., Dayton, Ohio.) *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 12 p (SEE N87-20199 13-02) Nov. 1986 (AGARD-CP-412) Avail: NTIS HC A19/MF A01

An area presently evolving is Interdisciplinary Computational Fluid Dynamics (ICFD) in which the Navier-Stokes equations are coupled to another set of equations to solve interacting problems. The large computers approaching will permit elaborate solutions to these ICFD problems. Therefore, research on generic systems of equations by the CFD community is required to assist engineers to solve their coupled problems. Already some of the necessary research has been accomplished to solve ICFD problems. Advantage is taken of the present numerical algorithms and grid generation. The conservation form for the governing equations can be utilized and the field data to exploit vector processors can be arranged. However, new technology must be developed to model complex interface boundary conditions and to incorporate a variety of constitutive relationships for the state variables and transport processors. Also, it will become necessary to model many physical processes that are below subgrid scale. Examples of subgrid scale modeling phenomenon are turbulence, evaporation, atomization, devolatization, nucleation, chemical reactions, surface tension and surface roughness. This modeling can only be achieved after a series of numerical computations are combined with validation experiments. It also appears necessary that new numerical damping factors must be developed for ICFD in order to account for the new physics added to the problem with the attendant mathematical stiffness difficulties. Author

N87-20227*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

HIGH SPEED VISCOUS FLOW CALCULATIONS ABOUT COMPLEX CONFIGURATIONS

DENNY S. CHAUSSEE *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 18 p (SEE N87-20199 13-02) Nov. 1986 (AGARD-CP-412) Avail: NTIS HC A19/MF A01 CSCL 01A

A review of past parabolized Navier-Stokes applications is presented. The equations, boundary conditions, the numerical method and the grid generation are all discussed. Results ranging from the low supersonic regime to the hypersonic regime are included. Author

N87-20228*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

TRANSONIC NAVIER-STOKES WING SOLUTION USING A ZONAL APPROACH. PART 1: SOLUTION METHODOLOGY AND CODE VALIDATION

J. FLORES, T. L. HOLST, UNVER KAYNAK (Sterling Software, Palo Alto, Calif.), K. GUNDY, and S. D. THOMAS *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 12 p (SEE N87-20199 13-02) Nov. 1986 Previously announced as N86-29765 (AGARD-CP-412) Avail: NTIS HC A19/MF A01 CSCL 01A

A fast diagonalized Beam-Warming algorithm is coupled with a zonal approach to solve the three dimensional Euler/Navier-Stokes equations. The computer code, called Transonic Navier-Stokes (TNS), uses a total of four zones for wing configurations (or can be extended to complete aircraft configurations by adding zones). In the inner blocks near the wing surface, the thin-layer Navier-Stokes equations are solved, while in the outer two blocks the Euler equations are solved. The diagonal algorithm yields a speedup of as much as a factor of 40 over the original algorithm/zonal method code. The TNS code, in addition, has the capability to model wind tunnel walls. Transonic viscous solutions are obtained on a 150,000-point mesh for a NACA 0012 wing. A three-order-of-magnitude drop in the L2-norm of the residual requires approximately 500 iterations, which takes about 45 min of CPU time on a Cray-XMP processor. Simulations are also conducted for a different geometrical wing called WING C. All cases show good agreement with experimental data. Author

N87-20229*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

TRANSONIC NAVIER-STOKES WING SOLUTIONS USING A ZONAL APPROACH. PART 2: HIGH ANGLE-OF-ATTACK SIMULATION

NEAL M. CHADERJIAN *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 9 p (SEE N87-20199 13-02) Nov. 1986 Previously announced as N86-32392 (AGARD-CP-412) Avail: NTIS HC A19/MF A01 CSCL 01A

A computer code is under development whereby the thin-layer Reynolds-averaged Navier-Stokes equations are to be applied to realistic fighter aircraft configurations. This transonic Navier-Stokes code (TNS) utilizes a zonal approach in order to treat complex geometries and satisfy in-core computer memory constraints. The zonal approach was applied to isolated wing geometries in order to facilitate code development. The TNS finite difference algorithm, zonal methodology, and code validation with experimental data is addressed. Also addressed are some numerical issues such as code robustness, efficiency, and accuracy at high angles of attack. Special free-stream-preserving metrics proved an effective way to treat H-mesh singularities over a large range of severe flow conditions, including strong leading edge flow gradients, massive shock induced separation, and stall. Furthermore, lift and drag coefficients were computed for a wing up through CLmax. Numerical oil flow patterns and particle trajectories are presented both for subcritical and transonic flow. These flow simulations are

rich with complex separated flow physics and demonstrate the efficiency and robustness of the zonal approach. Author

N87-20230# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.

SIMULATION OF THREE-DIMENSIONAL TRANSONIC FLOW WITH SEPARATION PAST A HEMISPHERE CYLINDER CONFIGURATION

W. KORDULLA, H. VOLLMERS, and U. DALLMANN *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 15 p (SEE N87-20199 13-02) Nov. 1986
(Contract DA-183/1-1/2)
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

The numerical simulation of the transonic laminar flow past a hemisphere cylinder at an angle of incidence of 0 deg and 19 deg is presented. In both cases the computations suggest unsteady flow behavior which requires further investigations, in particular because other applications by similar methods in two and three dimensions do allow the simulation of symmetric transonic and steady supersonic flows. One instantaneous flow result for the 19 deg case is used as an example to analyze the topology of a flow with separation. The analysis shows that the numerical simulation yields results consistent with possible topological structures, and can be used further to investigate steady state flows with separation. Author

N87-20231*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.

NUMERICAL SIMULATION OF THE FLOW FIELD AROUND A COMPLETE AIRCRAFT

J. S. SHANG and S. J. SCHERR *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 11 p (SEE N87-20199 13-02) Nov. 1986 Sponsored by NASA
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

The present effort represents a first attempt of numerical simulation of the flow field around a complete aircraft-like, lifting configuration utilizing the Reynolds averaged Navier-Stokes equations. The numerical solution generated for the experimental aircraft concept X24C-10D at a Mach number of 5.95 not only exhibited accurate prediction of detailed flow properties but also of the integrated aerodynamic coefficients. In addition, the present analysis demonstrated that a page structure of data collected into cyclic blocks is an efficient and viable means for processing the Navier-Stokes equations on the CRAY XMP-22 computer with external memory device. Author

N87-24398# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

AEROELASTICITY IN AXIAL-FLOW TURBOMACHINES. VOLUME 1: UNSTEADY TURBOMACHINERY AERODYNAMICS

MAX F. PLATZER, ed. and FRANKLIN O. CARTA, ed. (United Technologies Research Center, East Hartford, Conn.) Mar. 1987 276 p
(AGARD-AG-298-VOL-1; ISBN-92-835-1543-9; AD-A181676)
Avail: NTIS HC A13/MF A01

The field of unsteady turbomachinery aerodynamics is reviewed. Linearized unsteady aerodynamic theory, classical two-dimensional methods, three-dimensional flows, unsteady transonic flow, stall flutter, forced vibration, fan blade flutter, and unsteady aerodynamic measurements on rotors are among the topics discussed. For individual titles, see N87-24399 through N87-24408.

N87-24399 United Technologies Research Center, East Hartford, CT.

LINEARIZED UNSTEADY AERODYNAMIC THEORY

JOSEPH M. VERDON *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 31 p (SEE N87-24398 18-02) Mar. 1987 Sponsored by Naval Air Systems Command and Air Force Office of Scientific Research
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

The importance, complexity and variety of the unsteady flow phenomena occurring in axial flow turbomachines; the major assumptions used in theoretical aerodynamic formulations intended for aeroelastic investigations; and the requirements placed on such formulations were reviewed. Emphases was placed on the description of linearized two-dimensional unsteady aerodynamic theories and on the derivation of a rather general linearization that accounts for the effects of blade geometry, mean blade loading and shocks and their motions on aerodynamic response to prescribed structural and aerodynamic excitations. R.J.F.

N87-24400 Cambridge Univ. (England). Dept. of Engineering.

CLASSICAL TWO-DIMENSIONAL METHODS

D. S. WHITEHEAD *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 30 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

The most important two-dimensional solutions which can be obtained by the superposition of elementary analytical solutions are presented. This has enabled cascades of flat plates to be treated up to Mach numbers at which the axial velocity becomes sonic. Singularity theory valid for incompressible flow through cascades of thick cambered blades is discussed. Author

N87-24401 Kyushu Univ., Fukuoka (Japan). Dept. of Aeronautical Engineering.

THREE-DIMENSIONAL FLOWS

MASANOBU NAMBA *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 30 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

The objective is to outline the available theoretical methods which can predict various three-dimensional effects upon unsteady blade loadings. An attempt is made to describe typical features of three-dimensional effects revealed by those theoretical methods. Author

N87-24402 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

THREE-DIMENSIONAL FLOW

PIERRE SALAUN *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 17 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

A single annular blade row with a finite number of vibrating blades which are rotating at a constant angular velocity in an infinitely long cylindrical duct is considered. The only cases considered are those where the relative velocity is either subsonic or supersonic over all of the blades. R.J.F.

N87-24403 TopExpress Ltd., Cambridge (England).

NUMERICAL METHODS FOR UNSTEADY TRANSONIC FLOW

E. ACTON and S. G. NEWTON (Rolls-Royce Ltd., Derby, England) *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 21 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

Some of the numerical methods used in aeroelastic problems to calculate unsteady transonic flow are reviewed. Blade flutter and force response are studied. Author

N87-24405 Purdue Univ., West Lafayette, IN. Thermal Sciences and Propulsion Center.

UNSTEADY AERODYNAMIC MEASUREMENTS IN FLUTTER RESEARCH

SANFORD FLEETER and ROBERT L. JAY (General Motors Corp., Indianapolis, Ind.) *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 18 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

Various aspects of unsteady aerodynamic flutter experiments were considered. Overall objectives included the validation of analysis, the development of a flutter boundary data bank, and concept investigations. Experimental modeling requirements and the applicability of high speed rotating rigs, stationary annular cascades, and two-dimensional linear cascade facilities were discussed in terms of the overall objectives. Author

N87-24406 General Motors Corp., Indianapolis, IN. Gas Turbine Div.
UNSTEADY AERODYNAMIC MEASUREMENTS IN FORCED VIBRATION RESEARCH
ROBERT L. JAY and SANFORD FLEETER (Purdue Univ., West Lafayette, Ind.) *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 38 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

By defining the operating environment of turbomachinery blading in terms of absolute and relative velocity fields, airfoil dynamic mode shapes, and reduced frequency ranges, the applicability of various flow facilities in establishing critical time varying aeroelastic data needed for the solution of flutter and forced vibration problems was examined. Author

N87-24407 Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
UNDERSTANDING FAN BLADE FLUTTER THROUGH LINEAR CASCADE AEROELASTIC TESTING
EDMOND SZECHENYI *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 16 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

An attempt is made to give some insight into the causes and origins of different flutter regimes. The discussion is based on experimental data obtained in a linear cascade. For subtransonic flutter the validity of the cascade measurements is tested by comparison with actual compressor data. Author

N87-24408 Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Strahlantriebe.
UNSTEADY AERODYNAMIC MEASUREMENTS ON ROTORS
HEINZ E. GALLUS *In* AGARD Aeroelasticity in Axial-Flow Turbomachines. Volume 1: Unsteady Turbomachinery Aerodynamics 18 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

A review is given of the wide variety of fluid and structural measurements used on rotors. Techniques for displacement and vibration measurement of rotor blades, for unsteady flow measurement, for unsteady blade static pressure measurement, and for flow field and rotor wake studies are discussed. Flow visualization employing Schlieren and shadowgraph techniques, gas fluorescence, holographic interferometry, and laser velocimetry are discussed. R.J.F.

N87-24478# Rockwell International Corp., Los Angeles, CA. Aircraft Operations.
UNSTEADY INLET DISTORTION CHARACTERISTICS WITH THE B-1B
C. J. MACMILLER and W. R. HAAGENSON *In* AGARD Engine Response to Distorted Inflow Conditions 17 p (SEE N87-24464 18-07) Mar. 1987
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

An extensive wind tunnel and flight test program was conducted to verify inlet performance and distortion characteristics on the B-1B aircraft. During the course of these investigations, several unsteady, total-pressure disturbances at various discrete frequencies were encountered: (1) inlet duct resonance at low power settings; (2) environmental control system (ECS) precooler duct resonance; and (3) nose gear wake ingestion. This resulted in the need to quantify these effects and assess the impact on engine stability characteristics. As a result, engine control features were modified, and aircraft configuration changes were implemented. Results and findings of these investigations are summarized. Author

N87-24479# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EXPERIMENTAL DETERMINATION OF THE TRANSFER FUNCTION OF AN AXIAL COMPRESSOR TO DISTORTED INLET FLOW [DETERMINATION EXPERIMENTALE DES LOIS DE TRANSFERT DE PERTURBATIONS A LA TRAVERSEE D'UN COMPRESSEUR AXIAL]
JACQUES HUARD *In* AGARD Engine Response to Distorted Inflow Conditions 11 p (SEE N87-24464 18-07) Mar. 1987 In FRENCH; ENGLISH summary Original language document was announced in IAA as A87-21025
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

Transfer equations were identified for disturbances introduced into an axial flow compressor by disturbances to the flow across the inlet. The rotating blade rows are represented as a semi-actuator disk and aerothermodynamic values of the flow upstream and downstream of the disk are related by the transfer equations. The equations were derived from experimental data on the displacement of streamlines and the pressure changes after a distortion screen upstream from a blade row. Upstream flow distortions had a linear quasi-sinusoidal periodicity, while those between rows varied bilinearly. IAA

N87-26881# Leicester Univ. (England). Fluid Dynamics Panel.
THE AERODYNAMICS OF PARACHUTES
D. J. COCKRELL and A. D. YOUNG, ed. Jul. 1987 81 p Sponsored by AGARD, Neuilly-sur-Seine, France
(AGARD-AG-295; ISBN-92-835-0422-4; AD-A184620) Avail: NTIS HC A05/MF A01

This AGARD report discusses the principal aerodynamic characteristics of parachutes and the factors which affect them. It is anticipated that its main readers will be recent engineering graduates entering research establishments, parachute companies or related industries so some appreciation of basic mechanics, the principles of computing and elementary fluid dynamics on the part of the reader has been assumed. Its contents include Steady-State and Unsteady Aerodynamics, Parachute Deployment and Inflation, Experimental Investigations, Methods of analysis, Extraterrestrial Parachute Applications, and some suggestions for future research. Author

N87-28518# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
FUTURE RESEARCH ON TRANSONIC UNSTEADY AERODYNAMICS AND ITS AEROELASTIC APPLICATIONS
Aug. 1987 45 p Meeting held in Athens, Greece, 28 Sep. - 3 Oct. 1986
(AGARD-R-749; ISBN-92-835-0425-9; AD-A184769) Avail: NTIS HC A03/MF A01

The workshop focused on strategies for promoting and developing engineering level transonic flutter prediction techniques. The technology of transonic aerodynamics is currently undergoing rapid development. Significant progress is being made to solve the inherently nonlinear equations describing unsteady motions of wings in transonic flow, while the availability of reliable and efficient computational methods will greatly enhance the ability to predict the aeroelastic behavior of modern aircraft operating under transonic flow conditions. For individual titles, see N87-28519 through N87-28520.

N87-28519*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF COMPUTATIONAL METHODS FOR UNSTEADY AERODYNAMICS AT THE NASA LANGLEY RESEARCH CENTER
E. CARSON YATES, JR. and WOODROW WHITLOW, JR. *In* AGARD, Future Research on Transonic Unsteady Aerodynamics and Its Aeroelastic Applications 20 p (SEE N87-28518 23-02) Aug. 1987 Previously announced as N87-21859
(AGARD-R-749; NAS 1.15:89133) Avail: NTIS HC A03/MF A01 CSCL 01B

The current scope, recent progress, and plans for research and development of computational methods for unsteady aerodynamics at the NASA Langley Research Center are reviewed. Both integral equations and finite difference methods for inviscid and viscous flows are discussed. Although the great bulk of the effort has focused on finite difference solution of the transonic

small perturbation equation, the integral equation program is given primary emphasis here because it is less well known. Author

N87-28520# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).
COMPARISON BETWEEN 2D TRANSONIC FLUTTER CALCULATIONS IN THE TIME AND FREQUENCY DOMAIN
HELMUT ZIMMERMANN and BERND SCHULZE *In* AGARD, Future Research on Transonic Unsteady Aerodynamics and Its Aeroelastic Applications 16 p (SEE N87-28518 23-02) Aug. 1987
(AGARD-R-749) Avail: NTIS HC A03/MF A01

Unsteady airloads in the transonic speed range for the application in flutter calculations can only be predicted by using nonlinear flow equation codes. The MBB-A3 profile is used as theoretical model for the flutter investigations. Flutter calculations are presented using the classical method in the frequency domain as well as a structural aerodynamic coupling procedure in the time domain. The unsteady aerodynamic coefficients which are used for these flutter investigations are calculated for several M-numbers and incidences with the transonic small perturbation (TSP) equation without and with quasiunsteady boundary layer and with the time linearized TSP equation without and with steady boundary layer and for comparison reasons with the Doublet Lattice method. The boundary layer influences essentially the unsteady aerodynamic pressure distributions and coefficients. The flutter results obtained in the frequency and time domain differ less from each other. Nevertheless the time marching flutter simulation takes the nonlinearity effects of the airloads dependent on the vibration amplitude essentially better into account than the classical flutter solution. Author

N88-13219# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AERODYNAMICS OF HYPERSONIC LIFTING VEHICLES
Nov. 1987 560 p *In* ENGLISH and FRENCH Symposium held in Bristol, United Kingdom, 6-9 Apr. 1987
(AGARD-CP-428; ISBN-92-835-0435-6; AD-A198665) Avail: NTIS HC A24/MF A01

The Symposium was conducted at the outset of a new era in hypersonic aerodynamics. The Proceedings therefore present a valuable stock taking of the status of the field after a comparative lull in the last decade. A particular gap exists in the field of experimental facilities. At the same time, developments in computational fluid dynamics and experimental techniques provide possibilities that did not exist 10 years before. The papers presented were grouped in the fields: experimental facilities; experimental techniques and results; computational techniques; design methods; and projects. The most significant results of the symposium was a perspective of the need for special effort in the near future. For individual titles, see N88-13220 through N88-13252.

N88-13224# Complere, Inc., Palo Alto, CA.
TURBULENCE MEASUREMENT IN HYPERSONIC FLOW
F. K. OWEN and W. CALARESE (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.) *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 17 p (SEE N88-13219 05-02) Nov. 1987 Sponsored in part by Hunting Engineering, Ltd., Ampthill, United Kingdom
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

An assessment was made of the potential for hot wire and laser anemometer measurements of turbulent fluctuations in hypersonic flow fields. The results of experiments conducted in the AFWAL M=6 High Reynolds Number Wind Tunnel are reported and comparisons made with previous hot wire turbulence measurements. Author

N88-13225# Technische Univ., Brunswick (Germany, F.R.). Inst. fuer Stroemungsmechanik.
EXPERIMENTAL INVESTIGATIONS ON BLUNT BODIES AND CORNER CONFIGURATIONS IN HYPERSONIC FLOW
DIETRICH HUMMEL *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 16 p (SEE N88-13219 05-02) Nov. 1987
(Contract SCHL-5/82; HU-254/2)
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Within the framework of some theses hypersonic flows were investigated theoretically as well as by experiments in the hypersonic facility gun tunnel of the institute. Some of these activities during the last year are summarized. The first problem to be treated is that of a blunt body of revolution with subsonic blowing in the stagnation point region against the hypersonic main flow. Surface pressure and heat transfer measurements were carried out for two bodies at different free-stream Mach numbers and for various blowing rates. Remarkable agreement was obtained in comparison with a combination of Newtonian and potential theory. The second problem discussed is that of the hypersonic flow in corners formed by intersecting swept wedges. The corner angle and the leading-edge sweep angle were varied systematically. The flow field was analyzed by means of pitot pressure measurements in a characteristic cross section and the flow structure near the wall was determined from oilflow pictures as well as from wall pressure and heat transfer measurements. Strong vortical flows were detected underneath the corner shock system. Starting from a 90 degree corner of unswept wedges, the heat flux in the corner center can be reduced considerably by increasing the corner angle and by sweeping the leading-edges back. Author

N88-13226*# Texas Univ., Austin. Dept. of Aerospace Engineering.
DRIVING MECHANISM OF UNSTEADY SEPARATION SHOCK MOTION IN HYPERSONIC INTERACTIVE FLOW
D. S. DOLLING and J. C. NARLO, II *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 12 p (SEE N88-13219 05-02) Nov. 1987 Sponsored in part by NASA, Washington, D.C. and ONR, Washington, D.C.
(Contract AF-AFOSR-0112-86)
(AGARD-CP-428) Avail: NTIS HC A24/MF A01 CSCL 01A

Wall pressure fluctuations were measured under the steady separation shock waves in Mach 5 turbulent interactions induced by unswept circular cylinders on a flat plate. The wall temperature was adiabatic. A conditional sampling algorithm was developed to examine the statistics of the shock wave motion. The same algorithm was used to examine data taken in earlier studies in the Princeton University Mach 3 blowdown tunnel. In these earlier studies, hemicylindrically blunted fins of different leading-edge diameters were tested in boundary layers which developed on the tunnel floor and on a flat plate. A description of the algorithm, the reasons why it was developed and the sensitivity of the results to the threshold settings, are discussed. The results from the algorithm, together with cross correlations and power spectral density estimates suggests that the shock motion is driven by the low-frequency unsteadiness of the downstream separated, vortical flow. Author

N88-13227# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.
THE EFFECTS OF SWEEP AND BLUNTNESS ON A GLANCING SHOCK WAVE TURBULENT BOUNDARY LAYER INTERACTION
N. R. FOMISON and J. L. STOLLERY *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 18 p (SEE N88-13219 05-02) Nov. 1987 Sponsored in part by Hunting Engineering, Ltd., Ampthill, United Kingdom
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

An experimental investigation was conducted into the effects of leading edge sweep and bluntness on the flow characteristics of a glancing shock wave turbulent boundary layer interaction generated by a fin-on-plate configuration. A series of sharp swept fins (covering angles of sweep from 0 to 75 deg) and a series of blunt unswept fins (ranging in leading edge diameter from 0 to 25.4 mm) were tested at incidences of up to 30 deg at a Mach number of 2.4 and a freestream Reynolds number of 2,600,000/m. Observations of the mean flow were made using oil flow visualization, static pressure measurements, schlieren photography, and vapor screen visualization techniques. In addition, some limited measurements of the unsteady static pressures beneath the interaction were taken. Flow field models are proposed to include the effects of sweep and bluntness and the governing parameters controlling the extent of the disturbed flow and the pressure levels beneath the interaction are examined. Author

N88-13229# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
THE DRAG OF SLENDER AXISYMMETRIC CONES IN RAREFIED HYPERSONIC FLOW
T. J. RHYS-JONES *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 12 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

An experimental study performed in the RAE Low Density Tunnel to determine the aerodynamic characteristics of a range of slender axisymmetric bodies in rarefied hypersonic flow is described. The main purpose of this study was to assess the effects of cone angle, nose bluntness, and Reynolds number on the zero incidence drag of cones. In addition, some measurements of axial force, normal force, and pitching moment at incidence were made. The bodies tested at a nominal Mach number of 10 and at flow conditions which correspond to those in the transitional rarefied flow regime. These data were compared with correlations developed to represent the change in drag coefficient in this flow regime between continuum and free-molecular flow. Author

N88-13230# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Experimental Fluid Mechanics.
LOW REYNOLDS NUMBER INFLUENCE ON AERODYNAMIC PERFORMANCE OF HYPERSONIC LIFTING VEHICLES
GEORG KOPPENWALLNER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 14 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

The aerodynamic performance of lifting reentry vehicles in the high Mach number (Ma is greater than 10) and high altitude (H is greater than 50 km) regime is analyzed. Due to the high flight velocity of chemical reactions, the low density viscous and rarefaction effects are of importance. Free flight data of the U.S. Shuttle and low density wind tunnel data of DFVLR are used. It is found that aerodynamic performance loss and a destabilizing pitching moment change can be explained by viscous-rarefaction effects. Author

N88-13232# Naval Weapons Center, China Lake, CA. Propulsion Research Branch.
COMBUSTION RELATED SHEAR-FLOW DYNAMICS IN ELLIPTIC SUPERSONIC JETS
K. C. SCHADOW, E. GUTMARK, S. KOSHIGOE, and K. J. WILSON *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 13 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

An elliptic jet having an aspect ratio of 3:1 was studied and compared to a circular jet at three Mach numbers: M = 0.15, 1, and 1.3. Hot-wire measurements and schlieren photography were employed. The superior mixing characteristics of an elliptic jet relative to a circular jet, which were found in previous works in subsonic jets, prevail in the sonic jet and are further augmented by the shock structures of the supersonic underexpanded jet. The major and minor axes switch at a distance of 3 diameters from the nozzle, and the spreading rate of the minor axis side is twice that of a subsonic jet. The experimental data are supported by the results of the linear instability analysis of the supersonic elliptic jet which show that the initial vortices are bending at the major axis side in a similar way to the process which occurs in a subsonic elliptic jet. Author

N88-13233*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NUMERICAL ANALYSIS OF FLOW THROUGH SCRAMJET ENGINE INLETS
AJAY KUMAR *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 11 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01 CSCL 01A

A set of computer programs was developed to analyze flow through supersonic combustion ramjet (scramjet) inlets. These programs solve either the two or three dimensional Euler/Navier-Stokes equations in full conservation form by MacCormack's explicit or explicit-implicit method. An algebraic two-layer eddy viscosity model is used for turbulent flow calculations. The programs are operational in Control Data CYBER-200 series vector-processing computer system and were optimized to take maximum advantage of the vector processing capability of the system. Since their development, the programs were extensively verified and used to analyze a number of very complex inlet configurations. Results are presented from two-dimensional, quasi-three-dimensional, and three-dimensional analyses of the inlet flow field to illustrate the use of the program. Author

N88-13234*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL SIMULATION OF THE HYPERSONIC FLOW AROUND LIFTING VEHICLES
YEHIA RIZK (Sterling Federal Systems, Inc., Palo Alto, Calif.), DENNY CHAUSSEE, and JOSEPH STEGER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 11 p (SEE N88-13219 05-02) Nov. 1987 Previously announced as N87-22116
(AGARD-CP-428) Avail: NTIS HC A24/MF A01 CSCL 01A

A method of solving the viscous hypersonic flow field around realistic configurations is presented. The numerical procedure for generating the required finite difference grid and the two-factored implicit flow solver are described. Results are presented for the shuttle orbiter and a generic wing-body configuration at hypersonic Mach numbers. Author

N88-13235# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Aerodynamics Dept.
SOLUTION OF SOME 3-D VISCOUS AND INVISCID SUPERSONIC FLOW PROBLEMS BY FINITE-VOLUME SPACE-MARCHING SCHEMES
H. RIEGER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 17 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

For prediction of steady supersonic flow fields two numerical methods for solution of the three-dimensional Euler and parabolized Navier-Stokes (PNS) equations are considered. Both are based on a Finite-Volume discretization (FVD) of the governing conservation laws and because of the special properties of steady supersonic flows cost-effective space-marching integration techniques can be applied. Both methods are described and results for inviscid and viscous flows are presented. In view of the upcoming European space transportation activities the simulation of hypersonic flows past complex blunted lifting vehicles requires also efficient methods for solution of the full, not-reduced Navier-Stokes equations. These are needed to provide solutions for supersonic and hypersonic flow fields with large subsonic regions and also to get accurate initial conditions for the space marching codes developed. A relaxation procedure for the steady form of the not-reduced Navier-Stokes and the Euler equations is described and some first results are presented. Author

N88-13236# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
HYPERSONIC LAMINAR BOUNDARY LAYER: PARAMETRIC STUDY FOR THE REPRESENTATION OF REAL GAS EFFECTS [COUCHE LIMITE LAMINAIRE HYPERSONIQUE ETUDE PARAMETRIQUE DE LA REPRESENTATION DES EFFETS DE GAZ REEL]
B. AUPOIX, C. ELDEM, and J. COUSTEIX *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 14 p (SEE N88-13219 05-02) Nov. 1987 In FRENCH
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

A sensitivity study of the real gas model was performed in boundary layer computations on an hyperboloid equivalent to the Space Shuttle windward symmetry plane; for the STS 2 reentry. The real gas model is due to Straub and accounts for only five chemical species while assuming thermodynamic equilibrium. The study has brought into evidence the dependence of both wall heat flux and displacement thickness, not only upon the wall catalycity but also upon the selected reaction rates and the wall temperature. The skin friction coefficient is insensitive to the real gas model. Moreover, only a few chemical reactions can be selected and the diffusion model can be simplified to save computational time without drastic changes in the prediction. Author

N88-13237# *Deutsche Forschungs- und Versuchsanstalt fuer* Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.

ON THE NUMERICAL SIMULATION OF THREE-DIMENSIONAL HYPERSONIC FLOW

S. RIEDELBAUCH, W. WETZEL, W. KORDULLA, and H. OERTEL, JR. *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 16 p (SEE N88-13219 05-02) Nov. 1987

(AGARD-CP-428) Avail: NTIS HC A24/MF A01

The first steps towards the numerical simulation of hypersonic flows is presented. Intentionally, the ideal-gas assumption is used to validate the methods by comparing results with experimentally observed or theoretically obtained data in cold hypersonic flows about simple geometries. The approaches cover the continuum as well as the gas-kinetic flow regime. An implicit finite-difference method with bow-shock fitting is employed to integrate the time-dependent Navier-Stokes equations, while the gas-kinetic flow is simulated by approximations to Boltzmann's equation. The direct-simulation Monte Carlo method is preferred to the molecular-dynamics approach because of its larger computational efficiency. Results are compared with experimental data for the laminar flow past a blunted cone at M = 10.6 and past a hemisphere at M = 4.15. The decay of Oseen's vortex at Kn = 0.1, and the gas-kinetic flow past a cylinder at M = 5.48 with Kn = 0.1 and 0.3 were simulated, and results are shown in comparison with theoretical data. As an application to more realistic configurations the three-dimensional laminar flow past the nose of a typical spacecraft and the gas-kinetic flow in the symmetry plane of the flow past the same configuration is being discussed. The next steps will include real-gas modelling. For hot hypersonic flows experimental data are badly needed for comparison purpose. Author

N88-13238# Glasgow Univ. (Scotland). Dept. of Aeronautics and Fluid Mechanics.

NUMERICAL EXPERIMENTS WITH HYPERSONIC FLOWS BENEATH A CONE-DELTA-WING COMBINATION

N. QIN and B. E. RICHARDS *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 14 p (SEE N88-13219 05-02) Nov. 1987

(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Numerical experiments of hypersonic flows beneath a cone-delta-wing combination were carried out by solving the compressible Navier-Stokes equations using an assumption of local conicity. An implicit method is combined with a multigrid scheme in the solution procedure to achieve fast convergence to the steady state. Detailed flow field results provide further insight into the complex flow structures due to interaction between the cone shock and the wing shock and the interaction of the resulting flow with the wing or cone boundary layer. Flow field pictures reveal phenomena of value in the design of hypersonic lifting vehicles, such as the interference surface pressure and the high local wall heating. Comparisons with experimental data and conical Euler solution are also made. Author

N88-13239# Cincinnati Univ., OH. Dept. of Aerospace Engineering and Engineering Mechanics

A SPATIAL MARCHING TECHNIQUE FOR THE INVISCID BLUNT BODY PROBLEM

R. T. DAVIS and FREDERICK G. BLOTTNER (Sandia National Labs., Albuquerque, N. Mex.) *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 11 p (SEE N88-13219 05-02) Nov. 1987 Previously announced as N87-20972

(AGARD-CP-428) Avail: NTIS HC A24/MF A01

A technique was developed for obtaining approximate solutions of the inviscid, hypersonic flow on a blunt body with a spatial marching scheme. The scheme introduces the Vigneron pressure gradient approximation into the momentum equation in the direction along the body surface. The resulting governing equations are hyperbolic. With a specified shock wave these equations are solved at the stagnation streamline with an iteration procedure and are solved in the downstream direction with a marching scheme. The complete Euler equations are solved with the numerical scheme when the flow is supersonic. A global interation procedure is required to obtain the shock wave location. The approximate results from the spatial marching technique are compared with the complete solution of the Euler equations for flow over a sphere. The two results are shown to be in approximate agreement and the spatial marching technique provides useful engineering predictions while requiring considerably less computational time. Author

N88-13240# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Space Systems Group.

A 3-D EULER SOLUTION FOR HYPERSONIC MACH NUMBERS

MICHAEL PFITZNER and CLAUS WEILAND *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 13 p (SEE N88-13219 05-02) Nov. 1987

(AGARD-CP-428) Avail: NTIS HC A24/MF A01

The development of reusable reentry vehicles and hypersonic missiles require the control of aerothermal problems. To that end it is necessary to develop aerothermal prediction methods and to change and extend existing methods, which were developed for subsonic and supersonic flow problems. The integration of three dimensional unsteady and steady Euler equations in the regime of hypersonic flow is discussed. Author

N88-13241# *Imperial Coll. of Science and Technology*, London (England). Dept. of Aeronautics.

COMPUTATION OF FLOW PAST CONICAL HYPERSONIC WINGS USING A SECOND ORDER GODUNOV METHOD

R. HILLIER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 15 p (SEE N88-13219 05-02) Nov. 1987

(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Computations of inviscid hypersonic flow past flat plate delta wings during a second order Godunov-type scheme are presented. The governing equations are written in an unsteady conical form and then time marched to a final conical steady state. The core of the calculation is a generalized Riemann problem which is used to determine the flux transfers at the interfaces between computational cells. Results are presented for wings with shock waves both attached at and detached from the leading edges. The leeward surface flows support embedded shock waves and separated vortex flows and the likely influence of real viscous effects on these is discussed. Author

N88-13242*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

AEROTHERMODYNAMICS RESEARCH AT NASA AMES

GEORGE S. DEIWERT *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 17 p (SEE N88-13219 05-02) Nov. 1987

(AGARD-CP-428) Avail: NTIS HC A24/MF A01 CSCL 01A

Research activity in the aerothermodynamics branch at NASA Ames Research Center is reviewed. Advanced concepts and mission studies relating to the next generation aerospace transportation systems are summarized and directions for continued research identified. Theoretical and computational studies directed at determining flow fields and radiative and convective heating loads in real gases are described. Included are Navier-Stokes codes for equilibrium and thermochemical nonequilibrium air. Experimental studies in the 3.5 foot hypersonic wind tunnel, the ballistic ranges and the electric arc driven shock tube are described. Tested configurations included generic hypersonic aerospace plane configurations, aeroassisted orbital transfer vehicle shapes and Galileo probe models. Author

N88-13243# Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (Germany, F.R.). Unternehmensbereich Transport- und Verkehrsflugzeuge.

VORTEX FORMATION OVER DELTA, DOUBLE-DELTA AND WAVE RIDER CONFIGURATIONS AT SUPERSONIC SPEEDS

UWE GANZER and JOACHIM SZODRUCH *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 32 p (SEE N88-13219 05-02) Nov. 1987

(AGARD-CP-428) Avail: NTIS HC A24/MF A01

The flow field of the thick delta wing at high subsonic and supersonic speeds was the subject of quite a variety of investigations at the Technical University of Berlin. The research work started as early as in the late 60's and is still going on today. It was triggered off by the initiatives of the late Dietrich Kuchemann-aiming at a hypersonic transport and it was taken as a contribution to the Eurohyp activities. The wing configurations investigated were of simple shape: delta wings with straight leading edges and triangular cross sections of different thicknesses. The interest was focussed on the development of the leeside flow with changes in angle of incidence and main stream Mach number.

In addition to that similar delta wings with curved leading edges and also with a jump in leading edge sweep were investigated, as well as two types of wave riders. Besides some theoretical work mainly wind tunnel tests were made applying available test techniques: surface pressure measurements, Pitot measurements in the flow visualization by schlieren, vapor and oilfilm techniques, skin friction determination using oilfilm interferrogram and, finally, laser velocimetry The experimental investigations were particularly challenging, because of the small models of generally not more than 6 cm span. This limitation arose from the small size of the transonic and supersonic wind tunnel. Author

N88-13246# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
HYPERSONIC STATIC AND DYNAMIC STABILITY OF AXISYMMETRIC SHAPES: A COMPARISON OF PREDICTION METHODS AND EXPERIMENT
R. A. EAST and G. R. HUTT *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 15 p (SEE N88-13219 05-02) Nov. 1987 Sponsored in part by Ministry of Defence, United Kingdom
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

The stability of oscillatory motions of vehicles flying at hypersonic Mach numbers is of considerable relevance to their initial design. Methods are needed for quick and accurate predictions of stability and control which are applicable over a wide range of body shapes, angles of attack, and flow conditions, without the need to resort to computationally time consuming numerical flow field calculation methods. Experimental data, obtained over a range of angles of attack, concerning the static and dynamic pitching stability of a wide range of both pointed and blunted axisymmetric shapes including cones and blunted cylinder flares are presented. Although Newtonian theory gives inadequate accuracy of prediction, inviscid embedded Newtonian theory, which accounts for the reduced dynamic pressure and lower flow velocity in the embedded flow downstream of the strong bow shock, is shown to provide surprisingly good agreement with the experimental data over a wide range of conditions. Comparisons with experimental results show that the broad flow features and their effect on static and dynamic stability are well described in regimes not containing flow structural change. However, in some cases discrepancies exist between the predictions and experimental observations and these were attributed to a variety of viscous flow phenomena involving boundary layer transition and flow separation, including complex lee-surface vortical flows.
Author

N88-13249# British Aerospace Public Ltd. Co., Bristol (England). Aerodynamics Research Dept.
EXPERIENCES USING THE MARK IV SUPERSONIC HYPERSONIC ARBITRARY BODY PROGRAM
CARREN M. E. FISHER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 18 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Work done during the last two years in an attempt to gain an understanding of, and to establish a capability for the use of, the Douglas Supersonic/Hypersonic Arbitrary Body Program (S/HABP) is described. This program has a complex structure and offers a large variety of aerodynamic prediction methods to solve many different types of problems. Most of the features of the program were used with success. Aspects of the flowfield routines and viscous options, which could not be utilized correctly, are either under investigation, or updates to the programming are awaited. Some accurate predictions were made using the inviscid pressure methods, which were evaluated for a wide range of configurations, for Mach numbers from 1.7 to 25.0 and from an incidence of -8 to 40 deg. The code was seen to be highly flexible, but the accuracy of the results is user dependent. Relative to computational fluid dynamics codes, S/HABP geometries are easy to prepare and the code is cheap to run. Author

N88-13250# Royal Aircraft Establishment, Bedford (England).
THE RAE EXPERIMENTAL DATA-BASE FOR MISSILES AT HIGH MACH NUMBER AND ITS USE IN ASSESSING CFD METHODS
J. HODGES and L. C. WARD *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 14 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Wind tunnel tests are being performed in order to measure overall and panel forces and moments on cruciform body-control and body-wing missile configurations at M = 2.5, 3.5, and 4.5. When completed, the test results will provide a wide ranging data base suitable for inclusion into semi-empirical prediction methods. Additionally it can be used to help validate and assess the computational fluid dynamics (CFD) methods that are available. A detailed description of all the models and the wind tunnel test conditions, and selected results are presented. Comparisons are shown between the experimental data and results from a space-marching Euler code. An outline is given of the extension of these comparisons to surface pressure. Author

N88-13251# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
GENERAL AERODYNAMIC-AEROTHERMODYNAMIC CONCEPTS FOR HERMES [CONCEPTS GENERAUX AERODYNAMIQUES-AEROTHERMIQUES D'HERMES]
P. PERRIER and PH. CAUPENNE *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 7 p (SEE N88-13219 05-02) Nov. 1987 In FRENCH
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Overall aerodynamic and aerothermal design considerations for the Hermes space vehicle are summarized and a general methodology for the development of Hermes is outlined. Examples of specific design objectives are given which address the problems of longitudinal stability and vehicle aerodynamic heating. M.G.

N88-13252# British Aerospace Public Ltd. Co., Preston (England). HOTOL Study Team.
HYPERSONIC AERODYNAMICS: APPLICATIONS FOR HOTOL
ALISON J. WAKE *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 12 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

HOTOL has emerged from studies between BAe and Rolls-Royce as a totally reusable airframe with a hybrid air-breathing propulsion system. It is aimed at placing payloads into low Earth orbit for 20 percent of the cost of the U.S. Space Shuttle. As part of the current proof-of-concept study an assessment is being made of the aerodynamic characteristics of the vehicle including those in the hypersonic regime. This assessment will also identify areas of high risk and where current methods are deficient. Some of the results obtained, the areas so far identified as requiring further work are detailed and a five year program is proposed to investigate these areas. Author

N88-28860# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Civil Transport Aircraft Div.
DELTA WING CONFIGURATIONS
J. SZODRUCH *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 30-49 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The flow field over a slender delta wing at angle of attack immersed in a supersonic stream can be divided into two characteristic regions. The windward or pressure side faces the oncoming flow and is strongly influenced by the bow shock wave; the leeward or suction side is dominated by the effects of inviscid/viscous interaction. It is mainly the leeward flow which is then affected by Reynolds number changes and especially these effects are discussed in more detail. In the past, for subsonic, transonic, and supersonic free stream Mach numbers the essential issue of design with slender wings, where vortices occur over the wing at virtually every flight condition, is to fix the location of the separation lines so that the vehicle is always controllable. This is why Reynolds number effects in these flow regimes were considered of secondary importance. On the other hand at hypersonic speeds the influence of Reynolds number on peak heating as well as on the development and size of characteristic patterns in the flow field are more important. Here hypersonic viscous interaction is dominating, especially near the wing apex, and the vortices induce high rates of heat transfer along the

attachment line. The discussion is confined to free stream Mach numbers from high subsonic to supersonic. With respect to Reynolds number effects it is of major importance to define the different types of vortical flow in that velocity range and to consider the influence of wing geometry. Author

N88-28869# Potter (J. Leith), Nashville, TN.
MISSILES, FUSELAGES AND SIMILAR BODIES
J. LEITH POTTER *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 191-208 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The flows about elongated bodies are discussed in the context of simulation and scaling. With that as a point of departure, the present discussion is confined to the practice of tripping laminar boundary layers at locations on models selected with the goals of simulating higher Reynolds numbers. Possible flow phenomena and the effects of Reynolds numbers are reviewed. It is suggested that many of the strategies developed mainly in testing airfoils and wing models may also be appropriate when missile and fuselage shapes are involved. B.G.

N88-28870# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle Stroemungsmechanik.
INTRODUCTION AND CRITICAL FLOW PHENOMENA
E. STANEWSKY *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 211-216 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The present scope of work can be expressed as follows: review the physics associated with the simulation of high Reynolds number flow and, in particular, determine viscous and outer inviscid flow parameters that dominate viscous/inviscid interaction crucial to the simulation process; define needed research to improve the understanding of the flow physics associated with boundary layer simulation, including research needed to identify and account for wind tunnel environmental effects on the boundary layer simulation, and define experiments and/or computational fluid dynamics (CFD) exercises needed to establish the sensitivity of relevant flow phenomena or flow developments to viscous effects. Author

N88-28871# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
BOUNDARY LAYER DEVELOPMENT AND TRANSITION
ROGER MICHEL *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 217-249 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The principal critical flow phenomena were defined as being very sensitive to modifications of the properties of the incoming boundary layer. The problem is schematized by considering the transonic flow around some profile; the two main critical flow phenomena are the shock-boundary layer interaction region and the downstream separation and trailing-edge flow region. The properties of the boundary layer are analyzed through the three classical aspects of a laminar boundary layer, boundary layer transition and, at last, a turbulent boundary layer. The essential aspects of the phenomena and weighted factors are examined as well as opportunities which exist in order to predict the initial characteristics of the boundary as regards to the critical phenomena. Author

N88-28874# Technische Hogeschool, Delft (Netherlands). Dept. of Aerospace Engineering.
CLASSICAL SEPARATION, TRAILING-EDGE FLOWS AND BUFFETING
J. L. VANINGEN *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 306-337 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

An overview of those aspects of classical separation, trailing-edge flows, and buffeting which are relevant to the simulation process is given. Viscous flow parameters which should be simulated are defined and some recommendatins for further research are given. Author

N88-28893# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING
MARION L. LASTER (Arnold Engineering Development Center, Arnold Air Force Station, Tenn.) Jul. 1988 13 p Presented at the AGARD Fluid Dynamics Panel Symposium, Naples, Italy, 28 Sep. - 1 Oct. 1987
(AGARD-AR-254; ISBN-92-835-0468-2; AD-A200522) Avail: NTIS HC A03/MF A01

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on Aerodynamic Data Accuracy and Quality; Requirements and Capabilities in Wind Tunnel Testing, held in September 1987 in Naples, Italy. The major issues addressed were: what data accuracy is needed by users; what accuracy is presently achieved; and what can be done to improve the situation. Users have asked that cruise drag be measured to a precision of one drag count for transports and two for military fighters; it was shown that this is possible when reference methods can be used. However, one or two drag count uncertainty is not state-of-the-art for the direct scaling concept and improvement will require a thorough understanding of all these parameters which significantly contribute to wind tunnel uncertainty, including bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag count also appears formidable. Author

N88-29731# National Aeronautical Establishment, Ottawa (Ontario). Unsteady Aerodynamics Lab.
AIRCRAFT DYNAMICS: AERODYNAMIC ASPECTS AND WIND TUNNEL TECHNIQUES
K. J. ORLIK-RUECKEMANN *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 14 p (SEE N88-29725 24-01) Dec 1987 Previously announced as N88-13320
(AGARD-R-734) Avail: NTIS HC A09/MF A01

The dynamic behavior of modern fighter aircraft depends more and more on unsteady aerodynamics. Until recently, the designer concentrated on classical problems such as aeroelasticity and flutter. Dynamic stability parameters were most often determined by low angle of attack calculation methods, without much recourse to experiment. The results obtained from the few dynamic experiments performed were used to confirm the absence of problems rather than as design parameters. New requirements for fighter aircraft performance include the ability to fly at high angles of attack in the presence of extensive regions of separated or vortical flows, relaxed static stability, greatly increased agility, and an interest in unorthodox geometries such as closely coupled canard or tail first configurations. The time lags and unsteady phenomena associated with flow fields resulting from rapid maneuvers and large amplitude motions significantly affect the dynamic behavior of modern fighter aircraft and become as important for aircraft design as the classical static performance criteria. A review is made of the various aerodynamic aspects affecting aircraft dynamic behavior and some experimental techniques. Author

N88-29755# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel
SPECIAL COURSE ON MISSILE AERODYNAMICS
Apr. 1988 429 p Course held in Rhode-Saint-Genese, Belgium, 30 Mar. - 3 Apr. 1987, in Athens, Greece, 18-19 May 1987, and in Ankara, Turkey, 21-22 May 1987
(AGARD-R-754; ISBN-92-835-0452-6; AD-A199172) Avail: NTIS HC A19/MF A01

Topics addressed include: a survey of aerodynamic problems encountered on existing and future missiles and of the most important predictive methods; the criteria that define the required prediction accuracy; nonlinear aerodynamic effects; engineering computation methods used for calculating stability and control for conventional and unconventional missiles; the roles of intake in the propulsion system of turbojet and ramjet powered missiles, internal and external aerodynamic aspects of the induction system, computer aided design; prediction of aerodynamic heating; base flows with and without propulsion; and next generation supersonic and hypersonic missiles. For individual titles, see N88-29756 through N88-29766

N88-29756# McDonnell-Douglas Astronautics Co., Saint Louis, MO.
ACCURACY CRITERIA FOR EVALUATING SUPERSONIC AERODYNAMIC COEFFICIENT PREDICTIONS
J. E. WILLIAMS and R. J. KRIEGER *In* AGARD, Special Course on Missile Aerodynamics 18 p (SEE N88-29755 24-02) Apr. 1988 Sponsored in part by Department of the Air Force, Washington, D.C.
(AGARD-R-754) Avail: NTIS HC A19/MF A01

Aerodynamic prediction methods are traditionally compared with wind tunnel test data. However, the assessment of accuracy is left to an arbitrary interpretation. An accuracy criteria was developed that defines the required prediction accuracy in terms of allowable errors in missile performance and design parameters. Equations were selected that relate these parameters to the aerodynamic drag, stability, and control coefficients. These equations are differentiated with respect to the aerodynamic coefficients and simplified when possible. Allowable errors in the performance or design parameters are estimated, based on preliminary design requirements, and the required aerodynamic coefficient accuracy calculated. The results allow a quantitative evaluation of prediction accuracy. Author

N88-29757# Nielsen Engineering and Research, Inc., Mountain View, CA. Missile and Store Separation Aerodynamics
SURVEY ON NONLINEAR EFFECTS
MARNIX F. E. DILLENIUS and STANLEY C. PERKINS, JR. *In* AGARD, Special Course on Missile Aerodynamics 101 p (SEE N88-29755 24-02) Apr. 1988
(AGARD-R-754) Avail: NTIS HC A19/MF A01

A survey of experimental observations and intermediate level prediction methods aimed at nonlinear aerodynamic characteristics of tactical missiles is described. A description is given of the major differences between missile and aircraft flight and configuration characteristics. The importance of vortical interference and nonlinear compressibility due to shocks is stressed. Nonlinearities associated with deformable fin design, supersonic fin on body interference, wraparound finds, and unsteady flight are discussed. Summarized accounts are provided for the effects of asymmetric body vortex shedding and vortex bursting on overall missile aerodynamic characteristics. Physical examples are given that show vortex structures and shock formations in vapor screen and schlieren pictures. In many instances, the nonlinear aerodynamic effects are illustrated by theoretical results obtained with and without the relevant nonlinearity. Short descriptions are given of intermediate level panel-based missile aerodynamic prediction methods with special attention to the models incorporated to account for vortical and nonlinear compressibility effects. The descriptions include applications to additive force analysis for supersonic inlets and to deformable fins. Additional comparisons with experimental data are provided and the nonlinear effects pointed out. Presently available methods and future needs are summarized in the concluding remarks. Author

N88-29758# PRC Kentron, Inc., Hampton, VA.
SEMI-EMPIRICAL METHODS FOR CONVENTIONAL AND UNCONVENTIONAL MISSILES
MICHAEL J. HEMSCH *In* AGARD, Special Course on Missile Aerodynamics 21 p (SEE N88-29755 24-02) Apr. 1988
(AGARD-R-754) Avail: NTIS HC A19/MF A01

In the development and use of semi-empirical methods for prediction of the aerodynamic characteristics of modern missiles, one fact is exploited more than any other: the slenderness of the airframes and of the flows surrounding them. The first mathematical attempts to use this face were made over thirty years ago and resulted in classical slender-body theory and the universally-known Pitts, Nielsen, and Kaatari method for conventional missiles. It is shown that invoking slenderness for a missile in supersonic high angle-of-attack flow yields similarity forms which correlate data for affine bodies and wings in a particularly useful way. The equivalent angle-of-attack concept which is rooted in classical slender body theory is also presented together with extensions required for flows with high crossflow Mach number, one of the similarity variables. Finally, it is shown that the classical two-term fits to normal-force and center-of-pressure-location data for isolated wings and bodies are inferior to one-term power-law fits to the data in similarity form. Author

N88-29759# Naval Surface Weapons Center, Silver Spring, MD.
SPACE MARCHING EULER SOLVERS
ANDREW B. WARDLAW, JR. *In* AGARD, Special Course on Missile Aerodynamics 32 p (SEE N88-29755 24-02) Apr. 1988
(AGARD-R-754) Avail: NTIS HC A19/MF A01

Space marching Euler solvers for tactical missiles are examined. These solvers are applicable to missiles in supersonic flight provided that the flow field remains supersonic everywhere. The introductory section outlines progress to date and is followed by a discussion of numerical methods which were used to compute the flow about tactical missiles. Four different codes are described which are available for treating missile body shapes. Results from these computational methods are presented for body-alone, body-wing, and body-wing-tail cases. Force coefficients, surface pressures, and flow field predictions are compared to experiment. Reasonable agreement is obtained, illustrating the feasibility of using these methods in the design process. The limitation of the Euler equations are also discussed. Author

N88-29760# MATRA Service Aerodynamique, Velizy-Villacoublay (France).
NUMERICAL METHODS: EULER TIME DEPENDENT SOLVER
J. J. CHATTOT *In* AGARD, Special Course on Missile Aerodynamics 28 p (SEE N88-29755 24-02) Apr. 1988
(AGARD-R-754) Avail: NTIS HC A19/MF A01

The EULER time dependent solver of MATRA is described and the fundamental problem of separated flow simulation with an inviscid model is addressed, in particular separation on a smooth surface. Applications pertinent to missile aerodynamics, ranging from simple configurations to complete missile flow simulations, are examined. Author

N88-29761# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
PREDICTION OF DYNAMIC DERIVATIVES
HEINZ FUCHS and ROLF KAPP *In* AGARD, Special Course on Missile Aerodynamics 41 p (SEE N88-29755 24-02) Apr. 1988
(AGARD-R-754) Avail: NTIS HC A19/MF A01

The dynamic derivatives are introduced by their mathematical definition derived from the general expansion of aerodynamic functions with respect to the relevant independent fluid motion variables. The common classification of the dynamic derivatives is evaluated in accordance with the definitions used at flight mechanical applications. This is shown with the examples of nonstationary motion types creating dynamic derivativa effects. Some basic aspects of a semiempirical method for the calculation of dynamic derivatives of missile configurations or military aircraft are shown. Results of the computer program DYNAM are presented in comparison with experimental results of different test rigs. For higher angles of attack the linear theory for the calculation of the derivatives with respect to q is extended by a cross-flow assumption using the cross-flow drag coefficient. In addition to the semiempirical prediction method of total missile or aircraft configurations there are nonstationary panel methods which are useful for the determination of dynamic derivativa of harmonic oscillating wings or wing-rudder systems. An overview of the different dynamic test rigs is given which are in use at the different aerodynamic test laboratories of FR Germany. Test results of a Dornier standard missile configuration are discussed. An outlook on future activities on the evaluation methods of the dynamic test rigs at the high angle-of-attack region is given. Author

N88-29762# British Aerospace Public Ltd. Co., Bristol (England) Naval and Electronic Systems Div
AIR INTAKE AERODYNAMICS
C. S. JELL *In* AGARD, Special Course on Missile Aerodynamics 62 p (SEE N88-29755 24-02) Apr. 1988
(AGARD-R-754) Avail: NTIS HC A19/MF A01

The effective operation of airbreathing missiles is strongly dependent on the efficiency of the air intake system and its ability to supply the engine with air of adequate quality at all required flight conditions while minimizing any undesirable effects that the intakes may have on the overall aerodynamic characteristics of the missile. The role of the intake in the propulsion system of turbojet and ramjet powered missiles is described and both the internal and external aerodynamic aspect of the induction system are addressed. The features of various types of air intake commonly used for subsonic and supersonic operation are discussed. The

causes and effects of flow instability and flow non-uniformity at engine entry are considered and the operational relationship between the engine and the intake is shown. Finally three major aspects of intake installation are discussed: namely the influence of the missile body flowfields on internal performance; the forces and moments generated by the internal flow; and the effect of the intakes and their associated fairings on the overall aerodynamic characteristics of the missile. Author

N88-29763# McDonnell-Douglas Astronautics Co., Saint Louis, MO.

SEMIEMPIRICAL METHODS FOR AIRBREATHING MISSILES

J. E. WILLIAMS and R. J. KRIEGER *In* AGARD, Special Course on Missile Aerodynamics 12 p (SEE N88-29755 24-02) Apr. 1988

(AGARD-R-754) Avail: NTIS HC A19/MF A01

A computer-aided design procedure is described for use in conceptual design for sizing and shaping supersonic noncircular missiles with turbojet or ramjet propulsion systems. The theoretical basis for the method which uses a sensitivity derivative approach is developed. Avionics, structures, payload, inlet, engine, fuel, aerodynamic and performance models are described. Inlet/engine sizing, external moldline shaping and interactive graphics design processes are presented. The synthesis procedure overcomes many of the major drawbacks of airbreathing missile synthesis. It has features such as: simple initial geometry setup for body, tails, and inlets; modeling of completely arbitrary missile shapes; noncircular subsystem packaging; noncircular and multiple inlet modeling; aerodynamic and performance shaping; low cost, short duration computer sessions; rapic convergence; and accurate aerodynamic predictions. Two example configuration shapings are provided to depict the sizing process. Author

N88-29764# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.)

AERODYNAMIC HEATING OF MISSILES

ROLF KAPP, H. MATHAUER, and H. RIEGER *In* AGARD, Special Course on Missile Aerodynamics 19 p (SEE N88-29755 24-02) Apr. 1988

(AGARD-R-754) Avail: NTIS HC A19/MF A01

The results of investigations of the aerodynamic heatings of missiles are presented. First the applied basic semiempirical methods to determine the flow field about the isolated components of missiles are described and some possibilities to calculate the heat flux in the boundary layer are specified for different pointed or blunted body noses, such as conical, ogival, and hemispherical noses. The methods are valid for laminar and turbulent flow properties and in the transition region between laminar and turbulent. The calculated heat transfer factors or Stanton numbers are compared with experimental results. The agreement between theoretical and measured values is good. A theoretical method for the calculation of the flow field around missile configurations is presented. This method is based on the parabolization of the compressible, stationary Navier-Stokes equations (PNS-eq) and limited to supersonic Mach numbers. The quality of the results is demonstrated by comparison to corresponding tests results of other authors. Finally, a computational method is described to calculate the local time-dependent temperatures at the surface or inside the body. The configuration is divided into a number of volume elements, thus permitting numerical solution of the time varying equation of heat transfer. The resulting temperatures for some special configurations are plotted and when possible compared with experimental results. Author

N88-29765# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

PREDICTION OF BASE-FLOWS

J. DELERY and R. G. LACAU (Societe Nationale Industrielle Aerospatiale, Paris, France) *In* AGARD, Special Course on Missile Aerodynamics 72 p (SEE N88-29755 24-02) Apr. 1988

(AGARD-R-754) Avail: NTIS HC A19/MF A01

The base region of a missile or a launcher is the seat of complex phenomena which can have important repercussions on vehicle performance. The fields they concern are many: afterbody drag, heat transfer, and interaction between external steam and the base. Thus prediction of these phenomena is of great practical interest for missile design. The basic principles underlying most of the methods currently used to compute base-flows are examined. These methods belong essentially to the following categories. In the Inviscid/Viscous Interactive approach, the outer inviscid flow and the viscous regions are computed together and made compatible along a common boundary. In the Multi-Component approach, the flowfield is decomposed into a limited number of regions which are treated by approximate methods and then patched together. This approach has led to the development of a large variety of practical methods which are still routinely used in industry. The last approach consists in solving the time averaged Navier-Stokes equations. Base-flows in the jet-off and jet-on situations are now computed by solving the full Navier-Stokes equations or the thin layer approximation of these equations. Although still costly in computer time and not always in good agreement with experiments because of the difficulty of modeling turbulence in such complex flows, the Navier-Stokes approach is particularly promising. It appears also as the most straightforward way to extend prediction capability to three-dimensional flows. Author

N88-29766# McDonnell-Douglas Astronautics Co. Saint Louis, MO.

NEXT GENERATION MISSILE DESIGN

J. E. WILLIAMS and R. J. KRIEGER *In* AGARD, Special Course on Missile Aerodynamics 12 p (SEE N88-29755 24-02) Apr. 1988

(AGARD-R-754) Avail: NTIS HC A19/MF A01

Traditional long range cruise class missiles fly at low altitudes and subsonic speed. To meet operational requirements, the next generation missiles will fly at relative high altitudes and supersonic or hypersonic speeds. Because of economic constraints, low cost design and development approaches must be used. To illustrate these approaches, the results of the U.S. Air Force sponsored Aerodynamic Configured Missile (ACM) Program and the subsequent Low Cost Aerodynamic Configured Missile Demonstrator Program are summarized with emphasis on the impact of these studies on future missile concepts. The ACM program objective was to exploit the aerodynamic potential of supersonic cruise and maneuvering missiles to achieve significant improvements in performance. During three phases of effort over a 30 month period, configuration development, wind tunnel testing, and performance analyses were performed. The major uses of the program results to date are described. A low cost approach is described which uses existing equipment, standard airframe structural design, the existing ACM data base, trajectory shaping, and aggressive program planning. Two flight test options are then identified. Program plans, costs, and subset experimental programs are identified including growth versions with higher Mach number capability. Author

N89-10006# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

AGARD MANUAL ON AEROELASTICITY IN AXIAL-FLOW TURBOMACHINES. VOLUME 2: STRUCTURAL DYNAMICS AND AEROELASTICITY

MAX F. PLATZER, ed. and FRANKLIN O. CARTA, ed. (United Technologies Research Center, East Hartford, Conn.) Jun. 1988 266 p

(AGARD-AG-298-VOL-2; ISBN-92-835-0467-4; AD-A199697)

Avail: NTIS HC A12/MF A01

An overview of structural dynamics characteristics and analysis methods applicable to single blades and bladed assemblies is presented. The blade fatigue problem and its assessment methods, and life-time predictions are considered. Aeroelastic topics covered include: the problem of blade-disc shroud aeroelastic coupling, formulations and solutions for tuned and mistuned rotors, and instrumentation on test procedures to perform a fan flutter test. The effect of stagnation temperature and pressure on flutter is demonstrated and currentl, available forced vibration and flutter design methodology is reviewed. For individual titles, see N89-10007 through N89-10016.

N89-16760# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
REYNOLDS NUMBER EFFECTS IN TRANSONIC FLOW
A. ELSENAAR, T. W. BINION, JR., E. STANEWSKY, and H. C. HORNUNG, ed. (California Inst. of Tech., Pasadena.) Mar. 1989 92 p
(AGARD-AG-303) Avail: NTIS HC A05/MF A01

Reynolds number effects in transonic flow are critically reviewed. A discussion is presented of the viscous effects observed on realistic configurations. The following geometries are considered: Airfoils and high aspect ratio wings typical of transport aircraft, fighter-type low aspect ratio delta wings, two- and three-dimensional bodies characteristic of missiles and combat aircraft fuselages, and afterbodies. Pseudo-Reynolds number effects are identified which may arise, for instance due to the influence of the Reynolds number on the wind tunnel environment and in turn affect the flow about a model. As an introduction, a brief retrospect of the history of Reynolds number effect is presented. Author

N89-16847*# Army Aviation Systems Command, Moffett Field, CA.
A CRITICAL ASSESSMENT OF WIND TUNNEL RESULTS FOR THE NACA 0012 AIRFOIL
W. J. MCCROSKEY *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 21 p (SEE N89-16846 09-09) Jul. 1988 Previously announced as N88-11636
(AGARD-CP-429) Avail: NTIS HC A22/MF A01 CSCL 01A

A large body of experimental results, obtained in more than 40 wind tunnels on a single, well known two-dimensional configuration, was critically examined and correlated. An assessment of some of the possible sources of error was made for each facility, and data which are suspect were identified. It was found that no single experiment provided a complete set of reliable data, although an investigation stands out as superior in many respects. However, from the aggregate of data the representative properties of the NACA 0012 airfoil can be identified with reasonable confidence over wide range of Mach numbers, Reynolds number, and angles of attack. This synthesized information can now be used to assess and validate existing and future wind tunnel results and to evaluate advanced Computational Fluid Dynamics codes. Author

N89-16849# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
COMPARISON OF THE RESULTS OF TESTS ON A300 AIRCRAFT IN THE RAE 5 METRE AND THE ONERA F1 WIND TUNNELS
C. QUEMARD and P. B. EARNSHAW (Royal Aircraft Establishment, Farnborough, England.) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Studies of the A300 Airbus were carried out in the pressurized low speed wind tunnel at RAE and ONERA. Initially comparison of the results from the same model mounted on an identical three strut support, showed discrepancies which in the case of lift coefficient amounted to about 2.5 pct. A systematic comparison was made of the measurement techniques together with the methods used in the reduction of the resulting data. The production of uncorrected aerodynamic coefficients required the measurement of loads by means of underfloor balances and of the reference pressure. Checks were carried out on the balance calibrations confirming their accuracy after which an attempt was made in both facilities to assess and refine the accuracy of the reference pressure measurement. As a result, corrections were applied to the measurements made in both wind tunnels which reduced but did not eliminate the differences between the two sets of results. The data reduction relies on corrections to be applied for tunnel wall interference as well as that from the strut support system.
Author

N89-16850# Boeing Vertol Co., Philadelphia, PA. Advanced Aircraft Aerodynamics.
ANALYTICAL AND EXPERIMENTAL METHODS USED TO RESOLVE THE AERODYNAMIC RESULTS OF TESTS CONDUCTED IN THREE TEST FACILITIES
ROSS D. CLARK and H. J. ROSENSTEIN *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 15 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The V-22 aerodynamic drag and stability data base developed through extensive wind tunnel testing is examined. Early drag and stability aerodynamic testing showed differences in characteristics when comparing results from different tests facilities. A joint Bell-Boeing/Navy plan involving a thorough understanding/refinement of test techniques, facility calibrations and application of computational methods resolved these issues and permitted validation of the data base. Author

N89-16858# Office National d'Etudes et de Recherches Aerospatiales, Modane (France)
PRECISION IMPROVEMENT OF TRANSPORT AIRCRAFT DRAG MEASUREMENTS [AMELIORATION DE LA PRECISION DE LA MESURE DE LA TRAINEE D'UN AVION DE TRANSPORT]
C. ARMAND and C. PUJOL (Societe Nationale Industrielle Aerospatiale, Toulouse, France.) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 14 p (SEE N89-16846 09-09) Jul. 1988 In FRENCH Previously announced in IAA as A88-22597
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Methods used in the ONERA S1MA and S2MA wind tunnels for attaining the desired absolute precision of 0.0002 in drag measurements of Airbus type transport aircraft are discussed. Factors considered include the quality of the balances, the precision of the incidence measurements, and the effects of friction and extreme temperatures. It is also noted that in order to obtain accurate drag measurements the airfoil geometry and the pressure distribution on the airfoil must be known to a high degree of precision. The results are corrected for the pressure fields in the test section and for the effects of the wall and the sting. E.R.

N89-16866# National Aerospace Lab., Amsterdam (Netherlands).
ON REYNOLDS NUMBER EFFECTS AND SIMULATION
A. ELSENAAR *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 22 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The change in flow development with Reynolds number, commonly referred to as the Reynolds number effect, has both attracted and annoyed the aerodynamic community. A misjudgment of the magnitude of the Reynolds number effect may lead to an over- or underestimation of flight performance resulting in economic loss. In the worst case a costly redesign is required during the period of flight testing. The question of Reynolds number effects is crucial because of its very fundamental nature: a thorough understanding of viscous flow phenomena and their interactions with the inviscid flow field is required to explain the Reynolds number effects. As long as routine wind tunnel testing at the actual flight Reynolds number is not possible, other ways must be found to close the experimental Reynolds number gap. Basically, Reynolds number effects originate from a Reynolds number dependency of a viscous shear layer close to the body surface and its interaction with the outer inviscid flow field. If the boundary layer can be manipulated in the wind tunnel such that its development at flight Reynolds number is closely approximated, the inviscid flow senses the proper boundary condition and the overall flow development will then be very similar. The fundamental aspects of the Reynolds number effects are reviewed. Author

N89-16868# Naples Univ. (Italy). Inst. of Aerodynamics 'Umberto Nobile'.

EXPERIMENTS ON BOUNDARY LAYER TRANSITION TRIPPING AT LOW REYNOLDS NUMBERS

GIUSEPPE P. RUSSO *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 13 p (SEE N89-16846 09-09) Jul. 1988

(AGARD-CP-429) Avail: NTIS HC A22/MF A01

A systematical experimental investigation was undertaken with the aim of obtaining sound results on the effectiveness of distributed roughnesses in tripping transition on a flat plate at low Reynolds numbers. A 2.5 mm band of double stick scotch tape dusted with sparse carborundum grains was used as a tripping element at various speeds, ranging from 11 to 17 m/s. Transition location was detected by streamwise traversing, at a fixed height from the flat plate, both a Pitot tube and a hot-wire probe; also relevant velocity profiles in the boundary layer were measured. When needed surface flow visualization was used to confirm the transition position. A good correlation was found, in terms of the critical roughness Reynolds number needed to fix transition at the roughness, with the results found in the open literature. Author

N89-16869# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).

SOME DIFFICULTIES IN THE WIND TUNNEL PREDICTION OF MODERN CIVIL AIRCRAFT BUFFETING: PROPOSED REMEDIES

R. DESTUYNDER, V. SCHMITT, J. BERGER, and R. BARREAU (Societe Nationale Industrielle Aerospatiale, Toulouse, France) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 14 p (SEE N89-16846 09-09) Jul. 1988 In FRENCH; ENGLISH summary

(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The prediction of transport aircraft buffet response still remains a challenge despite recent progress in understanding of the phenomenon. The prediction is up to now inaccessible to a purely theoretical approach and so is mainly based on wind tunnel investigations. After a review of experimental methods currently used to determine model buffeting and a short description of full scale application techniques, the simulation problems that appear are presented. The next point deals with a number of improvements concerning models and experimental methodology with the final objective to provide more reliable buffeting predictions on large transport aircrafts. Author

N89-16875# MATRA Service Aerodynamique, Velizy-Villacoublay (France).

ACCURACY OF LIFT AND CENTER-OF-THRUST MEASUREMENTS AT MISSILE CONTROL SURFACES

J. PERINELLE and M. RIBADEAU DUMAS *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 17 p (SEE N89-16846 09-09) Jul. 1988 In FRENCH; ENGLISH summary

(AGARD-CP-429) Avail: NTIS HC A22/MF A01

During the study of aerodynamically piloted missiles it is necessary to estimate the forces and moments applied to the control surfaces. These qualities are difficult to evaluate by numerical methods and the study is performed in the wind tunnel experimentally. After a first evaluation of an optimal position of the axis of rotation and of the planform, the efforts, and moments are measured in the whole flight envelope. An accurate knowledge of the moments about the axis (hinge moment) is required for guidance and control studies. The influence of various experimental parameters on the accuracy of such measurements is assessed. Author

N89-16876# Naples Univ. (Italy). Inst. of Aerodynamics 'Umberto Nobile'.

COMPUTERIZED THERMOGRAPHIC TECHNIQUE FOR THE DETECTION OF BOUNDARY LAYER SEPARATION

R. MONTI and G. ZUPPARDI *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 15 p (SEE N89-16846 09-09) Jul. 1988

(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The computerized unsteady thermographic methodology was used as a noninvasive technique to analyze the boundary layer development and to detect the transition lines and the separation regions on airfoil surfaces in the wind tunnel. The method is based on the strong depencence of the heat transfer coefficient upon the flow field condition at the airfoil surface. This noninvasive technique has proved to be very appropriate when studying the boundary layer behavior at very low Reynolds numbers in incompressible flow because at these conditions the boundary layer is very unstable and cannot tolerate any disturbance induced by intrusive techniques. The experimental diagnostic equipment consists of a thermograph (AGA 680), and A/D conversion unit (AVIORRADIO DIGIMEN; and a microcomputer (APPLE IIe). The tests were performed on an elliptic cylinder, on a WORTMANN FX-63-137 and on a Miley MO6-13-128 airfoil. The experimental results compare favorably with those obtained by other authors that ultilized conventional techniques. Author

N89-16614# Royal Aircraft Establishment, Bedford (England).

WIND TUNNEL EXPERIMENTS ON AEROFOIL MODELS FOR THE ASSESSMENT OF COMPUTATIONAL FLOW METHODS

P. R. ASHILL, D. J. WEEKS, and J. L. FULKER *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 14 p (SEE N89-16610 11-34) Dec. 1988

(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Wind tunnel experiments on two airfoil models (unswept and a 25 deg sweep) at high subsonic speeds and for Reynolds numbers up to about 20 x 1,000,000 are described. Both models had detachable trailing edges for studying flows with differing rear pressure distributions and used a method for fixing transition, which gave precise control of the disturbance to the boundary layer. Following a discussion of the measurement and correction procedures, comparisons are presented between the data and CFD methods: these comparisons reveal the importance for the accurate prediction of the flow over advanced airfoils of including effects in the modeling of the shear layers which become significant as separation is approached. Author

N89-16615*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

PARAMETRIC STUDY OF GRID SIZE, TIME STEP AND TURBULENCE MODELING ON NAVIER-STOKES COMPUTATIONS OVER AIRFOILS

CHRISTOPHER L. RUMSEY and W. KYLE ANDERSON *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 19 p (SEE N89-16610 11-34) Dec. 1988

(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01 CSCL 01A

An upwind-biased implicit approximate factorization algorithm is applied to several steady and unsteady turbulent flows. The thin layer form of the compressible Navier-Stokes equation is used. Both the flux vector splitting and flux difference splitting methods are used to determine fluxes, and the results are compared. Flux difference splitting predicts results more accurately than flux vector splitting on a given mesh size, but, in its present implementation, is more severely limited by the maximum CFL number for unsteady time accurate flows. Physical aspects of the computations are also examined. An equilibrium turbulent boundary layer model computes generally better steady and unsteady results than a nonequilibrium model when there is little to no boundary layer separation. Conversely, when a significant region of separation exists, the nonequilibrium model performs in better agreement with experiment. Author

N89-16616*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

ON THE VALIDATION OF A CODE AND A TURBULENCE MODEL APPROPRIATE TO CIRCULAR CONTROL AIRFOILS

J. R. VIEGAS, M. W. RUBESIN, and R. W. MACCORMACK (Stanford Univ., CA.) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 22 p (SEE N89-16610 11-34) Dec. 1988 Previously announced as N88-22864

(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01 CSCL 01A

A computer code for calculating flow about a circulation control airfoil within a wind tunnel test section was developed. This code is being validated for eventual use as an aid to design such airfoils. The concept of code validation being used is explained. The initial stages of the process were accomplished. The present code was

applied to a low subsonic, 2-D flow about a circulation control airfoil for which extensive data exist. Two basic turbulence models and variants thereof were successfully introduced into the algorithm, the Baldwin-Lomax algebraic and the Jones-Launder two equation models of turbulence. The variants include adding a history of the jet development for the algebraic model and adding streamwise curvature effects for both models. Numerical difficulties and difficulties in the validation process are discussed. Turbulence model and code improvements to proceed with the validation process are also discussed. *Author*

N89-18622# *Royal Aircraft Establishment, Bedford (England).*
A THEORETICAL AND EXPERIMENTAL EVALUATION OF A NUMERICAL METHOD FOR CALCULATING SUPERSONIC FLOWS OVER WING-BODY CONFIGURATIONS
J. L. FULKER and P. R. ASHILL *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 11 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A method of solving the Euler equations is described and is applied to the calculation of supersonic flows over two wing-body configurations typical of present day combat aircraft. A multiblock method is used to generate body conforming grids for the complex three dimensional geometries of the configurations and the flow equations are solved by applying time stepping to a finite volume algorithm. An assessment is made of the theoretically predicted flows, by demonstrating the effect on the solution of some of the important features of the CFD method. Results are given for a series of careful wind tunnel tests on models of similar geometry, and comparisons between calculated and measured results are shown. Author

N89-18623# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).
THE DFVLR-F5 WING EXPERIMENT: TOWARDS THE VALIDATION OF THE NUMERICAL SIMULATION OF *TRANSONIC VISCOUS WING FLOWS*
W. KORDULLA, D. SCHWAMBORN, and H. SOBIECZKY *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 18 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A major step towards the rigorous validation of Navier-Stokes codes for the simulation of the transonic flow past transport-type wings is described. The basis for this is the DFVLR-F5 wing experiment which was designed to allow the analytical formulation of a boundary value problem. This requires the determination of flow conditions on the entire surface of the prescribed control volume. The experiment led to the organization of a workshop, selected results of which are presented. These show considerable scatter, the sources of which can not be defined very well because there are too many possible ones, and the salient ingredients are too diverse. Some of the difficulties are illustrated by results of additional computations. Both, experimentalists as well as computational aerodynamicists, have to do more work to achieve a successful validation. *Author*

N89-18628# *Aircraft Research Association Ltd., Bedford (England). GARTEUR Action Group.*
ACCURACY STUDY OF TRANSONIC FLOW COMPUTATIONS FOR THREE DIMENSIONAL WINGS
M. P. CARR *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 17 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

GARTEUR Action Group AD(AG05) has undertaken an investigation of ten flow field methods. Calculations of inviscid flow over the DFVLR F4 wing for two conditions were analyzed. The main results and conclusions are presented. Author

N89-18629# Fokker B.V., Schipol-Oost (Netherlands). Aerodynamics and Aeroelasticity Dept.
CFD APPLICATIONS IN DESIGN AND ANALYSIS OF THE FOKKER 50 AND FOKKER 100
N. VOOGT, W. J. A. MOL, J. STOUT, and D. F. VOLKERS *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 11 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Aerodynamic computational codes were used and validated extensively during the aerodynamic development phases of the Fokker 50 and 100 aircraft projects. Validations were made against wind tunnel tests as well as flight measurements. A description is given of the methods on which the codes are based and applications are discussed in areas of intake aerodynamics, low speed high lift flow and transonic flow. Author

N89-18630*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EXPERIMENTAL PROGRAM FOR REAL GAS FLOW CODE VALIDATION AT NASA AMES RESEARCH CENTER
GEORGE S. DEIWERT, ANTHONY W. STRAWA, SURENDRA P. SHARMA, and CHUL PARK *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 16 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01 CSCL 01A

The experimental program for validating real gas hypersonic flow codes at NASA Ames is described. Ground based test facilities used include ballistic ranges, shock tubes and shock tunnels, arcjet facilities and heated air hypersonic wind tunnels. Also included are large scale computer systems for kinetic theory simulations and benchmark code solutions. Flight tests consist of the Aeroassist Flight Experiment, the Space Shuttle, Project Fire 2, and planetary probes such as Galileo, Pioneer Venus and PAET. Author

N89-18631# Societe Nationale Industrielle Aerospatiale, Paris (France). Div. Engins Tactiques.
THREE-DIMENSIONAL CALCULATIONS OF LATERAL JET INTERACTION WITH AN EXTERNAL SUPERSONIC FLOW [CALCULS TRIDIMENSIONNELS DE L'INTERACTION D'UN JET LATERAL AVEC UN ECOULEMENT SUPERSONIQUE EXTERNE]
M. DORMIEUX and C. MAHE (Office National d'Etudes et de Recherches Aerospatiales, Paris, France) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 16 p (SEE N89-18610 11-34) Dec. 1988 In FRENCH; ENGLISH summary
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

High maneuverability levels and short response time required for some tactical missiles have lead to the development of new concepts for control systems, among which is direct thrust vector control generated by a lateral jet in the vicinity of the center of gravity. Aerospatiale has chosen such a concept for some of its future missiles. However, generation of a transverse jet on a missile raises the problem of the aerodynamic interactions of this jet on the missile. Within the framework of the development of lateral jet control applications, Aerospatiale has been investigating, with the collaboration of ONERA, aerodynamic phenomena connected with lateral jet interactions. Author

N89-18632# Societe Nationale Industrielle Aerospatiale, Paris (France). Div. Engins Tactiques.
NUMERICAL SIMULATION OF SEPARATED SUPERSONIC FLOWS AROUND TACTICAL MISSILE BODIES
PHILIPPE GUILLEN and JEROME LORDON *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 18 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by Direction des Recherches Etudes et Techniques, France
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Beyond 4 or 5 degs of incidence, vortices develop on the leeside of tactical missile fuselages. The validation is presented of a numerical approach to simulate these separated flows. In this approach, the flow is computed by solving the Euler equations and separation is forced by a local treatment (Kutta condition like) on the body of the missile, near the supposed location of

the separation line, which has to be known. This local treatment was implemented in two different Euler solvers. Results are presented for various configurations and different aerodynamic conditions. The influence of several parameters was investigated. Finally some calculations show the interest of the method to evaluate the vortical flow interaction with wings. Author

N89-18641# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
COMPUTATION OF TRANSONIC 3D CASCADE FLOW AND COMPARISON WITH EXPERIMENTS
H.-W. HAPPEL and B. STUBERT *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 11 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by Bundesministerium fuer Forschung und Technologie, Fed. Republic of Germany and Bundesministerium der Verteidigung, Fed. Republic of Germany
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

The inviscid turbomachinery flow within a single stator or rotor blade row is computed by a time marching 3-D Euler code. With respect to rotor blades, the conservation laws are formulated in a rotating frame. The numerical scheme is explicit and first order accurate in time and space. Explicit numerical viscosity terms are added to the Euler equations to achieve a stable solution process. In order to save computer time, local time stepping and a grid refining procedure are used in the calculation. The computational efficiency of the code is demonstrated for realistic blade geometries. The comparison with measurements proves the code to be a useful tool for calculating the 3-D flow through cascades of turbomachinery. Author

N89-18642# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
NUMERICAL AND EXPERIMENTAL INVESTIGATION OF ENGINE INLET FLOW WITH THE DORNIER EM2 SUPERSONIC INLET MODEL
H. BUERS, S. LEICHER, and P. A. MACKRODT (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany, F.R.) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 16 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by the Ministry of Defense, Fed. Republic of Germany
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Numerical and experimental investigations were conducted with the Dornier EM2 supersonic, fixed geometry, side mounted inlet to improve the performance in the supersonic flight regime. A ramp bleed system is described and some representative results from wind tunnel tests are presented to confirm the procedure. The theoretical investigations were executed with a block structured Euler program, which allowed a more accurate modeling of the realistic aircraft geometry. To simulate boundary layer effects at the ramp of the inlet, an outflow velocity perpendicular to the ramp was introduced. The calculated and the experimental data were in good agreement. Author

N89-18644# Carleton Univ., Ottawa (Ontario). Dept. of Mechanical and Aeronautical Engineering.
MEASUREMENTS AND COMPUTATIONS OF SWIRLING FLOW IN A CYLINDRICAL ANNULUS
R. J. KIND, F. M. YOWAKIM, and P. M. REDDY *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 12 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by Natural Sciences and Engineering Research Council, Canada
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Comprehensive measurements were completed for 4 swirling flows in a cylindrical annulus. Nominal swirl angles were 0, 15, 30 and 45 degrees. The data include static and total pressure distributions, axial and tangential wall shear stress components, and profiles of the mean velocity components and of the Reynolds shear and normal stresses. Data was provided for validation of computational methods. Consistency checks indicate that the data are of high quality and suitable for this purpose. Also outlined is a computational method which was used with simple mixing length turbulence models to compute development of the measured flows. The computations have demonstrated that a simple mixing length model gives excellent predictions of the swirling flow near the annulus walls. Author

N89-18645# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
ON THE VALIDATION OF 3-D NUMERICAL SIMULATIONS OF TURBULENT IMPINGING JETS THROUGH A CROSSFLOW
J. M. M. BARATA, D. F. G. DURAO, M. V. HEITOR, and J. J. MCGUIRK (Imperial Coll. of Science and Technology, London, England) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 10 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by RAE, *Farnborough, United Kingdom Prepared in cooperation with Lisbon* Univ. Portugal
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Laser Doppler measurements of the flow field resulting from the impingement of a single axisymmetric jet against a wall after penetrating a confined cross flowing stream are presented and used to validate numerical predictions of the flow. The experiments were carried out for a Reynolds number of 60,000, corresponding to a jet to crossflow velocity ratio of 30 and for a jet exit 5 jet diameters above the opposing wall. A basis is provided for better understanding of several related but more complex practical flow fields. The data is particularly suitable for the evaluation of the accuracy of the turbulence model used in several numerical methods currently under development for the prediction of this type of flow. As an example of this latter use, calculations are presented of the 3-D flow characterized by the measurements (a standard k-epsilon turbulence model is used). The difficulty of assessing turbulence model performance in these complex flows due to the intrusion of numerical diffusion errors is demonstrated by comparing calculations on both coarse and fine meshes and by improving the accuracy of the discretization of the convection terms using the high order QUICK method. Author

N89-18649# Aeritalia S.p.A., Pomigliano D'Arco (Italy). Transport Aircraft Group.
VALIDATION OF A MULTI-BLOCK EULER FLOW SOLVER WITH PROPELLER-SLIPSTREAM FLOWS
A. AMENDOLA, R. TOGNACCINI, J. W. BOERSTOEL, and A. KASSIES (National Aerospace Lab., Amsterdam, Netherlands) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 15 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

A new computer-program system for the numerical simulation of subsonic and transonic flows around complex aircraft configurations is described. This system computes Euler flows on multi-blocked grids. The system consists of four major parts: a block decomposer for the subdivision of flow domains into blocks, a grid generator for blocked flow domains, a flow solver for blocked grids, and a flow visualizer for flows on blocked grids. These parts are interfaced by files with simple formats. Special attention was given to provide this package of software products with: *excellent portability (the system was tested on various front-end* and supercomputers), modularity (with respect to physical and numerical subtasks, and with respect of subdividing total simulation task in loosely coupled subtasks). The system has good growth potential towards a Navier-Stokes simulation environment. The system is being validated with various test cases. Results of one of these test cases (the wing/nacelle/propeller configuration tested in a NASA Langley wind-tunnel, NASA CR 172605) show that the system performs reasonably from the point of view of both accuracy and operational manageability. Author

N89-18650# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.
INVESTIGATION OF THE SURFACE FLOW OF CONICAL BODIES AT HIGH SUBSONIC AND SUPERSONIC SPEEDS
W. J. BANNINK, E. M. HOUTMAN, and S. P. OTTOCHIAN *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 14 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

Turbulent boundary layer calculations have been performed of the flow on the leeward side of two conical bodies at moderate to high angles of attack. A sharp-edged planar 65 deg sweep delta wing at high subsonic speeds up to M (infinity) equals 0.85 and angles of attack up to 15 deg and a 7.5 deg semi-apex angle circular cone at M (infinity) equals 2.95 at 14 deg angle of

attack are used. The boundary layer method, based on a finite difference predictor-corrector algorithm, assumes a conical external flow and applies a local (Blasius) similarity concept in radial direction from the apex. The solution marches in cross-direction from the reattachment line toward produced correct results with respect to the location of separation and the surface flow inclination, experimental pressure distributions are used to generate the inviscid solutions at the edge of the boundary layer. The predicted surface flow on both bodies are in close agreement with the experimental results. In particular the location of the separation lines were very close to those observed in oil flow patterns. That the approximate flow model (conical) produces such good results in the case of the delta wing is due to the relatively large spanwise pressure gradients compared to the chordwise gradients. Author

N89-18653# Boeing Advanced Systems Co., Seattle, WA
SLENDER CONE CFD AND EXPERIMENTAL DATA COMPARISONS IN HYPERSONIC FLOW
J. Y. BALTAR and E. TJONNELAND *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 14 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

A zonal Navier-Stokes Parabolized Navier-Stokes (NS/PNS) computational fluid dynamics (CFD) analysis of the flow field about sharp and slightly blunted cones at Mach 18.7 was made. The results were compared with experimental measurements from the Princeton High Pressure Hypersonic Nitrogen Tunnel. Plots are shown comparing predicted and measured shock locations, surface pressures, surface heat transfer, and several flow field properties. Contour plots of the overall flow field are shown for cones with two nose radii. The agreement between the CFD results and experiment was fair considering that several important aspects of the flow physics in the tunnel were not properly modelled. The most important of these are the axial variation in wind tunnel static pressure and the gas characteristics of the nitrogen in the test section. The experimental data set, including data up to Mach 26.5, has proven to be valuable for improving the understanding of the flow physics on slender cones at hypersonic speeds.
Author

N89-18655# Defence Research Establishment Ottawa, (Ontario).
COMPARISON OF THEORY AND EXPERIMENT FOR FOUR SUPERCRITICAL, LOW DRAG AIRFOILS
D. J. JONES, M. KHALID, and B. EGGLESTON (De Havilland Aircraft Co. of Canada Ltd., Downsview, Ontario) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 16 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

A comparison of a revised Bauer, Garabedian, and Korn (BGK) code, GRUMFOIL, and the DRELA code from MIT (modified by Boeing) is here presented. The results are compared against experimental data for four different airfoils with relative thickness from 10 to 21 percent. Shown here is a comparison of three different two-dimensional transonic airfoil theories and a comparison of them to experimental data obtained in a 1.5 m x 1.5 m blowdown wind tunnel with a 38 cm wide 2-D insert. Four different airfoils of 10, 13, 16 and 21 percent maximum thickness are considered in the study. Author

N89-18657*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DETAILED FLOWFIELD MEASUREMENTS OVER A 75 DEG SWEPT DELTA WING FOR CODE VALIDATION
SCOTT O. KJELGAARD and WILLIAM L. SELLERS, III *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 14 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01 CSCL 01A

Selected results from an experimental investigation documenting the flowfield over 75 deg swept delta wing at an angle-of-attack of 20.5 deg are presented. Results obtained in the investigation include surface flow visualization, off-body flow visualization, and detailed flowfield surveys for various Reynolds numbers. Flowfield surveys at Reynolds numbers of 0.5, 1.0 and 1.5 million were conducted with both a pitot pressure probe and a 5-hole pressure probe; and 3-component laser Doppler velocimeter surveys were conducted at a Reynolds number of 1.0 million. The pitot pressure surveys were obtained at 5 longitudinal stations, the 5-hole probe surveys were obtained at 3 longitudinal stations and the laser Doppler velocimeter surveys were obtained at one station. The accuracy of each instrumentation system is discussed, as well as, discrepancies in the calculation of vorticity using various algorithms. Author

N89-18658*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIMENTS AND CODE VALIDATION FOR JUNCTURE FLOWS
L. R. KUBENDRAN, C.-H. SUNG, and C.-I. YANG (Naval Ship Research and Development Center, Bethesda, MD.) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 11 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01 CSCL 01A

The turbulent flow around a juncture formed by an unswept wing and a flat plate has been experimentally studied, and the effectiveness of modifications near the wing leading edge in controlling the juncture flow field has been evaluated. The results are compared with numerical solutions of the incompressible Reynolds-averaged Navier-Stokes equations. The Baldwin-Lomax turbulence model is used in the computations. The numerical code is very time efficient, and it predicts the flow behavior well, including the detection of leading-edge vortex formation. It tends to over-predict the boundary layer thickness and the location of the vortex. Both the experiment and computations indicate that the leading edge flow separation is eliminated by the use of a leading-edge fillet designed in this study, resulting in drag reduction. Author

N89-18660# Aeronautical Research Inst. of Sweden, Bromma.
LARGE-SCALE VISCOUS SIMULATION OF LAMINAR VORTEX FLOW OVER A DELTA WING
BERNHARD MUELLER and ARTHUR RIZZI (Aeronautical Research Inst. of Sweden, Stockholm.) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 16 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

A numerical method has been developed to solve the Navier-Stokes equations for laminar compressible flow around delta wings. A large-scale solution on a mesh of 129x49x65 points for transonic flow M (*infinity*) *equals 0.85 alpha* equals 10 deg. and Re (infinity), sub C sub R equals 2.38x10 to the 6th around a 65 deg. swept delta wing with round leading edge is presented and discussed. The results reveal the presence of primary, secondary, and even tertiary vortices. Comparison with experiment shows that the interaction between the primary and secondary vortices is obtained correctly and that these results are a more realistic simulation than the one given by the Euler equations. Author

N89-18663*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OVERVIEW OF CFD METHODS AND COMPARISON WITH FLIGHT AEROTHERMAL DATA
KENNETH SUTTON, ERNEST V. ZOBY, and H. HARRIS HAMILTON *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 17 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01 CSCL 01A

An overview of previously published aerothermal investigations which demonstrate the capabilities of detailed computational fluid dynamics and engineering codes to predict the aerothermal environment about an entry vehicle is presented. The overview consists of a brief discussion of the computational methods and experimental data and includes comparisons between the computed results and data. The overview focuses primarily on analyses of flight data since these data provide the unique capability to assess the real-gas chemistry options in the codes. The computed results are based on a series of codes which are employed by the Aerothermodynamics Branch of the Space System Division at the Langley Research Center. The flight data, which were measured on the Reentry F, the Space Shuttle, and the Fire II vehicles, represent a wide range of vehicle configurations and freestream conditions. Also, results of one recent set of ground tests are included since the tests provide data on a model of a

pending flight project. The comparisons of the predicted results and data demonstrate the adequacy of the present computational fluid dynamics capabilities and indicate the potential to predict the aerothermal environment about future flight vehicles. Author

03

AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

N86-30708# Advisory Group for Aerospace Research and Development, Neuilly Sur-Seine (France) Avionics Panel
INTERACTION BETWEEN EMP (ELECTROMAGNETIC PULSE), LIGHTNING AND STATIC ELECTRICITY WITH AIRCRAFT AND MISSILE AVIONICS SYSTEMS
1986 144 p Presented at a Lecture Series, Ankara, Turkey, 29-30 May 1986, Oberpfaffenhofen, West Germany, 2-3 Jun. 1986, and The Hague, The Netherlands, 5-6 Jun. 1986; sponsored by Avionics Panel and the Consultant and Exchange Programme of AGARD
(AGARD-LS-144; ISBN92-835-1528-5; AD-A171298) Avail: NTIS HC A07/MF A01

Interactions between transient electromagnetic waves with aircraft and missile avionics systems are described. Transient electromagnetic waves include electromagnetic pulses (EMP) from nuclear explosions, lightning, and static electricity. Interactions are introduced by coupling of EMP and lightning induced currents and voltages with avionics components. Shielding against these interactions is discussed with respect to induced currents and voltages from EMP and lightning, and induced voltages from static charging effects. Several examples of interactions, coupling, shielding, and measurement techniques are presented. This Lecture Series, sponsored by the Avionics Panel of AGARD, has been implemented by the Consultant and Exchange Program of AGARD. Author

N86-30709# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
CRASHWORTHINESS OF AIRFRAMES
1986 34 p Presented at the 61st Meeting of the Structures and Materials Panel of AGARD in Oberammergau, West Germany, 8-13 Sep. 1985
(AGARD-R-737; ISBN92-835-1525-0; AD-A171305) Avail: NTIS HC A03/MF A01

At its 61st Meeting the AGARD Structures and Materials Panel heard three papers as a preliminary to setting up a Sub-Committee on this topic; this publication contains these papers. They survey a range of theoretical and experimental aspects of crashworthiness relating to metallic structures. For structures made of these materials theoretical methods are becoming useful design tools, but much further development is required before composite structures can be satisfactorily handled. There is a very great need for a data base of reliable experimental information (including accident data bases) on both metallic and composite structures. Author

N89-18421# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
ENERGY ABSORPTION OF AIRCRAFT STRUCTURES AS AN ASPECT OF CRASHWORTHINESS
Dec. 1988 327 p In ENGLISH and FRENCH Meeting held in Luxembourg, 1-6 May 1988
(AGARD-CP-443; ISBN-92-835-0485-2) Avail: NTIS HC A15/MF A01

Considerable effort was hitherto devoted to crash avoidance, but relatively little to crash survivability. In certain regimes the risk of accident remains, e.g., the low-altitude low-speed regime. There is a strong incentive to increase the prospects for occupant survival through improvements in airframe design. Information about structural behavior and characteristics under these conditions is very sparse and an exchange of information between the NATO nations is long overdue. At its sixty-sixth meeting, the Structures and Materials Panel held a conference of specialists, the aim of which was to stimulate an exchange of experience and development results. A further aim was to act as a focus for the discussion of those design philosophies which may be needed to provide the balance between survivability and functions. The document contains the papers presented. For individual titles, see N89-18422 through N89-18442.

N89-18422# Ingenieur a la Direction des Constructions Aeronautiques, Paris (France).
REGULATORY ASPECT OF CRASHWORTHINESS [ASPECT REGLEMENT DU CRASHWORTHINESS]
P. J. RABOURDIN *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 14 p (SEE N89-18421 11-03) Dec. 1988 In FRENCH
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Aircraft crashworthiness is examined from the perspective of safety and regulation. The past and anticipated evolution of crash-related regulations is described. Two main areas of regulatory concern for the future are identified and discussed: acceleration attenuation (including modification of safety standards related passenger seating) and passenger evacuation. Author

N89-18423# Army Aviation Systems Command, Fort Eustis, VA. Safety and Survivability Technical Area.
EVOLVING CRASHWORTHINESS DESIGN CRITERIA
C. HUDSON CARPER and LEROY T. BURROWS *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 8 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Although significant strides were made in recent years toward improving aviation safety, mishaps involving all classes of helicopters presently are and will continue to be a major, expensive U.S. Army problem in terms of casualties, material loss, and reduction in mission effectiveness. Modern day training and tactical employment requirments for the U.S. Army helicopter dictate that a large percentage of operations occur in the low-speed, low-altitude flight regime, which contributes to the problem by reducing critical margins of safety normally associated with higher airspeed and higher altitude operations with accompanying greater time for response in case of an emergency. This increased probability of accident occurrence, coupled with the lack of in-flight egress capability, makes design for crashworthiness essential for Army helicopters. The evolution of crash survival design for rotary-wing aircraft and its application to current and new generation Army helicopters are discussed. Emphasis is given to the need for a total systems' approach in design for crashworthiness and the necessity for considering crashworthiness early in the design phase of an aviation weapons development effort. The actual application of crashworthiness to Army helicopters is presented with statistics that show dramatic reductions in fatalities and injuries with implementation of a crashworthy fuel system. The cost effective aspects of designing helicopters to be more crash survivable are also discussed. Author

N89-18424# Cranfield Inst. of Tech., Bedford (England). Impact Centre.
CRASHWORTHINESS DESIGN METHODS APPLICABLE AT CONCEPT STAGE
M. M. SADEGHI *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 21 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

For the effective incorporation of the secondary safety into structures developed for aircraft and moving vehicles, it is essential to tackle crashworthiness in the early stage of the development. For a set of defined loading conditions (crash or crush) to which the structure must comply, it is of great benefit to specify necessary guidelines for defining collapse zones, as well as structural properties concerning nonlinear behavior of constituent components and joints of the overall structure. A hybrid approach is described which predicts the crash behavior of an impacting structure which is tailored to velocities which do not exceed 30 to 40 miles/h. The method involves using component and joint test data (as data base) in conjunction with coarse finite element idealization to determine the collapse mechanism sequence of

the collapse and collapse speed of an impacting structure.
Author

N89-18425# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
CRASHWORTHINESS ACTIVITITES ON MBB HELICOPTERS
F. OCH *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 22 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Crashworthiness activities at MBB date back to the late sixties, when during BO 105 development crash protection systems such as seats, fuel systems, and landing gears were developed which are integrated in the military versions of the BO 105 for the German Army. In February 1974 a BO 105 was crash tested to show compliance with the Crash Survival Design Guide (TR 71-22) under an impact condition of 15 m/s longitudinal and 8 m/s vertical velocity. Since the mid-seventies theoretical studies were conducted with the aide of the computer program KRASH and nonlinear finite element codes, supported by the German Ministry of Defence, and partly verified by component tests. The experience with the crash behavior of the BO 105 was successfully used for the development of the BK 117 which was shown by a full-scale crash test, conducted in 1985 by Kawasaki, MMB's partner in the BK 117 development. Effective design tools, both in house and at subcontractors and experience with helicopters in service are used at MBB to contribute significantly to fulfill the crash requirements in European helicopter programs and in joint development with foreign partners. Although crash protection techniques and crashworthiness prediction methods are already fairly well established, there still remains a lot of tasks, mainly when using advanced materials and in improving the analytical methods from an economic point of view.
Author

N89-18426# Politecnico di Milano (Italy). Dept. of Aerospace Engineering.
THE DESIGN OF HELICOPTER CRASHWORTHINESS
V. GIAVOTTO, C. CAPRILE, and G. SALA *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 9 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

The extensive use of composite materials in helicopter structures has prompted research activities in crashworthiness in the last decade. A rational design of crashworthy structures requires a great deal of data and experience to be collected and organized; in particular the most efficient mechanisms of energy absorption must be understood and carefully investigated and consequently the best structural concepts and detail design can be identified. With this aim and in cooperation with Agusta Helicopters a research program was undertaken, covering many of the basic aspects of crashworthy design, i.e., dynamic experimentation on subcomponents and subassemblies, hybrid and true finite element modeling, design, and verification procedures. The paper presents some preliminary results, together with the outline of the whole program.
Author

N89-18427# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
DEVELOPMENTS AND PERSPECTIVES AT AMD-BA IN THE FIELD OF IMPACT AND CRASH SIZING [DEVELOPPEMENTS ET PERSPECTIVES DANS LE DOMAINE DU DIMENSIONNEMENT AUX IMPACTS ET AU CRASH AUX AMD-BA]
Y. MARTIN-SIEGFRIED *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 13 p (SEE N89-18421 11-03) Dec. 1988 In FRENCH; ENGLISH summary Original language document was announced in IAA as A89-21407
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Impact and soft crash sizing simulations were performed using a finite-element global ground-aircraft model. Results are presented for the hard landing of a Mercure aircraft and the soft crash of a Falcon 900 aircraft. The data will be used as input in the dynamic and nonlinear modeling of hard crash problems for commuter-type aircraft such as the Falcon 10.
B.G.

N89-18428# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Safety and Survivability Technical Area.
FULL SCALE HELICOPTER CRASH TESTING
HAROLD HOLLAND and KENT F. SMITH *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 7 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Today, analytical math models are becoming more capable of predicting the dynamic behavior of aircraft structures and occupants subjected to crash loads. The engineering community still finds it necessary, however, to periodically perform full-scale crash tests for the purpose of validating math models, exploring crashworthy component design concepts, defining synergistic effects, or a variety of other goals. Aspects of full-scale aircraft crash testing based on almost 30 years experience by the U.S. Army Aviation Applied Technology Directorate (AVSCOM) and its predecessor organizations are addressed. Though each test is unique, certain principles and procedures were found to provide a high degree of assurance of acquiring accurate data.
Author

N89-18429# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
CRUSHING BEHAVIOUR OF HELICOPTER SUBFLOOR STRUCTURES
J. FRESE and D. NITSCHKE *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 23 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Crash loads must be attenuated in the landing gear, the subfloor structure, and the seat to values tolerable for the human body. In addition the remaining loads must not jeopardize a living space for the occupants. A program was undertaken to investigate, both analytically and experimentally, the crushing behavior of helicopter subfloor structures. Stiffened panels and honeycomb sandwich panels in metal were considered under quasistatic and dynamic conditions. The primary intent of the investigations was to design subfloor structures with high efficiency for crash impact and to establish the nonlinear characteristics of subfloor structures as input data for the program KRASH.
Author

N89-18430# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Inst. for Structures and Design.
CRASH INVESTIGATIONS WITH SUB-COMPONENTS OF A COMPOSITE HELICOPTER LOWER AIRPLANE SECTION
CH. KINDERVATER, A. GIETL, and R. MUELLER (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Germany, F.R.) *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 18 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

For the BK 117 helicopter a composite fuselage was designed, manufactured, and will be flight tested at MBB. Within the development program evidence was given to the crashworthy design of the fuselage which was accomplished by a joint activity between MBB and DFLVR Stuttgart. The crash investigations were focused on the lower airframe section under vertical crash loads. The task was performed by design support tests on the specimen level and by subcomponent crush testing. Sandwich panel specimens were statically and dynamically crushed to study various crush initiators at the panel-skin intersections, and to investigate the energy absorption capability. Subcomponent crush tests under quasi-static loading were concentrated on structural node points (intersections of keel beams and bulkheads) and on bulkheads located in the rear of the fuselage. The component's crush characteristics and the energy absorption performance were determined. Various designs with notched corners at the intersections of beams and bulkheads were considered with the aim to reduce the initial peak failure loads. Structural elements supporting the parallel panels of the landing skid frames were used to avoid global buckling and to initiate and stabilize efficient energy absorption crush modes. The generated load-deflection characteristics of the subcomponents are intended to be used as inputs for crash simulation calculations.
Author

N89-18431# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Inst. for Structures and Design.

CRASHWORTHY DESIGN OF AIRCRAFT SUBFLOOR STRUCTURAL COMPONENTS

CH. KINDERVATER, H. GEORGI, and U. KOERBER *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 24 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Subfloor beams and bulkheads in aircraft structures are designed to carry longitudinal and shear loads resulting from fuselage bending and torsion. In crashes, however, the subfloor is highly loaded in compression and shear. Especially the intersections of beams and bulkheads represent stiff vertical hard points, and the resulting high peak failure loads under compression can create life threatening crash pulses to the occupants. For a commuter type aircraft subfloor aluminum as well as composite cruciforms were designed to match the same longitudinal stiffness of the floor beams and the same shear stiffness of the bulkheads. Various designs of the intersections including notched corners, corrugated and tapered edge joints, and less stiff laminate layups were investigated to reduce the initial peak loads, and to trigger efficient energy absorbing crush failure modes. The cruciforms and subelements such as angle stiffeners and angle stiffened plates were statically crush tested in order to gain information about the complex collapse behavior of subfloor construction. Based on the load-deflection curves important energy absorption parameters were determined, and were compared to the aluminum baseline design. For crash simulations with so called hybrid computer codes load deflection curves of structural elements are needed as input data. For the cruciforms and sub-elements, the prediction of load deflection curves are presented and discussed including plastic hinge formation and approximate mean crush load prediction as well as failure load and critical stress evaluations. Author

N89-18432# Centre d'Essais Aeronautique Toulouse (France). Lab. d'Essais de Crash.

METHOD AND MEANS FOR GROUND CRASH TESTING AT THE CENTRE D'ESSAIS AERONAUTIQUE DE TOULOUSE: APPLICATION TO THE SA 341 AND AS 332 HELICOPTERS [METHODE ET MOYENS D'ESSAIS D'ECRASEMENT AU SOL AU CENTRE D'ESSAIS AERONAUTIQUE DE TOULOUSE: APPLICATION AUX HELICOPTERES SA 341 ET AS 332]

RENE GUINOT *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 26 p (SEE N89-18421 11-03) Dec. 1988 In FRENCH
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Test installations and methodologies used for evaluating the general structural response and crashworthiness of helicopters are discussed. In particular, a 20-meter vertical drop tank, a horizontal acceleration stand, a vehicle crash installation, a landing dynamics stand, and a severe crash installation are described. The kinds of results obtained from each test stand are listed. Data acquisition and analysis strategies are also described. Finally, some results obtained for the SA 341 Gazelle and the AS 332 Super Puma are summarized. Author

N89-18433# Institut de Mecanique des Fluides de Lille (France).

NUMERICAL AND EXPERIMENTAL STUDY OF THE CRASH BEHAVIOR OF HELICOPTERS AND AIRCRAFT [ETUDE NUMERIQUE ET EXPERIMENTALE DU COMPORTEMENT AU CRASH DES HELICOPTERES ET DES AVIONS]

F. DUPRIEZ, P. GEOFFROY, J. L. PETITNIOT, and T. VOHY *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 17 p (SEE N89-18421 11-03) Dec. 1988 In FRENCH
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

The crash behavior of helicopters and fixed-wing aircraft was studied numerically by the finite element method and experimentally using representative models. Experimental results obtained with a falling autorotating helicopter compared with full-scale testing results. An experimental study of the landing of a light aircraft on soft ground is discussed. Elastoplastic bending results and data on the crushing of metallic structures were applied to the numerical study of a commercial aircraft structure. M.G.

N89-18434# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.

STUDY OF THE DYNAMIC BEHAVIOUR OF STIFFENED COMPOSITE FUSELAGE SHELL STRUCTURES

J. S. HANSEN and R. C. TENNYSON *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 12 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

An overview of the development of a computer model for analyzing the crash response of stiffened composite fuselage structures is presented together with the experimental validation program. Using a finite element formulation based on Reissner/Mindlin plate theories, the numerical model can treat stiffened laminated shell buckling, large defelections, nonlinear material behavior, and element failure. Numerical results are presented for several test cases, although experimental comparisons are not yet available. Details on the design and construction of the first prototype composite fuselage model are also provided together with a description of the crash test facility. Author

N89-18435# Lockheed Aeronautical Systems Co., Burbank, CA.

TRANSPORT AIRPLANE CRASH SIMULATION, VALIDATION AND APPLICATION TO CRASH DESIGN CRITERIA

G. WITTLIN and C. CAIAFA (Federal Aviation Administration, Atlantic City, NJ.) *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 23 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

A brief description of the evolutionary development of the program KRASH to its most recent release, KRASH85, is presented, and some background is provided to delineate various program features as well as to illustrate the range of aircraft configurations and impact conditions for which the program was validated. The application of program KRASH to analyze the structural crash dynamics behavior of a narrow-body commercial jet transport aircraft used in the FAA/NASA conducted Controlled Impact Demonstration (CID) test is discussed. A description of the modeling along with comparative results between test and analyses is provided. Included in the correlation effort are acceleration time histories, sequence of impact events, fuselage crush distribution, wing and fuselage bending moment distributions, and estimates of moment and shear strength levels. The results of the transport aircraft correlation effort are used in a subsequent parametric study to formulate a crash design velocity envelope. Parametric analyses, section test and full-scale crash test results are utilized and presented in the form of acceleration time histories at the cabin floor. The transport crash design envelope, along with additional data, is used to assess the effect of aircraft size on floor acceleration pulses in a survivable crash environment. The most recent applications of KRASH are discussed. Author

N89-18436# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).

CRASHWORTHINESS OF AIRCRAFT STRUCTURES

W. JARZAB and R. SCHWARZ *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 13 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Modern analytical models and their numerical realizations have become powerful tools in nonlinear crash analysis. Crash simulation has to consider advanced nonlinear constitutive equations and sophisticated formulations of the contact problem. The refinement of discretization and the treatment of geometrical complex structures requires highly developed hardware like the vector processor. Topics discussed are the material modeling of impact loaded composite structures, the main features of an explicit crash code and the results of two calculations simulating the drop test of a B707-section. Finally the possibilities of a specific interface between a crash code based on the finite element method like ANCS and a program like KRASH85 are outlined in detailed. Author

N89-18437# Engineering System International, Eschborn (Germany, F.R.).
CRASH SIMULATION AND VERIFICATION FOR METALLIC, SANDWICH AND LAMINATE STRUCTURES
D. ULRICH, A. K. PICKETT, E. HAUG, and J. BIANCHINI (Engineering System International, Rungis, France) *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 18 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Some of the research for crash simulation of structures using metallic and composite construction recently undertaken at ESI is outlined. Several current areas of interest are reviewed including helicopter stiffened panel construction, automotive structures, and, on a micro level, the compressive failure analysis of Carbon-Epoxy test coupons. In each study a specialized finite element code is used. The dynamic buckling behavior of panels stiffened with Z sections are simulated numerically. The various components are connected using specially developed rivet elements that fail at a prescribed load and are intended to produce a controlled collapse mode. These panels form the lower structure of a helicopter frame which also houses a flexible membrane fuel compartment. The effect of this internal hydrostatic loading is also represented during the crash event. Some preliminary dynamic investigations for failure predictions of honeycomb core panels are also discussed. Verification of these numerical procedures with experimental behavior is an important issue. The automotive industry has well defined experimental test procedures which provide an excellent standard to assess and validate numerical results. The progressive failure analysis of Carbon-Epoxy fiber test coupons loaded in compression and in bending are undertaken using the program PAM-FISS. The material model uses a BI-PHASE concept in which the constituent matrix and fiber materials have independent mechanical and failure criteria. Author

N89-18438# H. W. Structures Ltd., Pitsea (England).
PREDICTING CRASH PERFORMANCE
D. PARSONS and A. BELFIELD *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 13 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

In the past, aircraft were designed with high structural integrity such that crash situations can be avoided, i.e., aircraft were designed for crash avoidance and not crashworthiness. There is considerable effort now being devoted to the study of aircraft crashworthiness. Clearly, it is only in relatively low speed impacts that design considerations may be effective. In this area, H.W. Structures, LTD and the automotive environment in general have built up a wealth of experience. How this experience may be applied to aircraft structures is discussed. Analytical techniques for prediction of the behavior of the structure and its occupants are examined. Author

N89-18439# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Biodynamics and Bioengineering Div.
HUMAN CRASHWORTHINESS AND CRASH LOAD LIMITS
HENNING E. VONGIERKE and JAMES W. BRINKLEY *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 15 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

The assessment of the hazard to a crewmember in a potential aircraft crash requires information about human tolerance to mechanical forces, a method for the identification and evaluation of the contributing factors to potential injury in a crash and a means of estimating the environemental forces on an occupant and the resultant responses of the occupant. Results or research in the U.S. Air Force in these three areas are discussed. Specifically, the rationale for and formulation of a dynamic response six degree-of-freedom whole body impact tolerance specification, a detailed hear-spine structural mechanics and a vehicle occupant gross motion rigid body dynamics model and their areas of applicability in crash analysis; and features of the developed U.S. Air Force Advanced Dynamic Anthropomorphic Manikin (ADAM) are discussed. It is suggested that a comprehensive method for injury risk assessment for any system must consider all three areas. Author

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AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

N87-13275# Strathclyde Univ., Glasgow (Scotland). Dept. of Electronic and Electrical Engineering.
FIBRE OPTIC GYROSCOPES IN INERTIAL NAVIGATION
B. CULSHAW and J. D. NUTTALL (Ferranti Ltd., Edinburgh (Scotland).) *In* AGARD Guided Optical Structures in the Military Environment 6 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The potential application of fiber optic gyroscopes (FOG) in interial navigation (IN) systems is discussed. The requirements for IN are briefly reviewed and compared to the reported performance of experimental FOG's. This leads to the identification of areas in which further work is necessary, in both physical understanding and technological developments. Author

N87-21881# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
EFFICIENT CONDUCT OF INDIVIDUAL FLIGHTS AND AIR TRAFFIC OR OPTIMUM UTILIZATION OF MODERN TECHNOLOGY FOR THE OVERALL BENEFIT OF CIVIL AND MILITARY AIRSPACE USERS
ANDRE BENOIT, ed. Dec. 1986 326 p In ENGLISH and FRENCH Symposium held in Brussels, Belgium, 10-13 Jun. 1986
(AGARD-CP-410; ISBN-92-835-0403-8; AD-A182150) Avail: NTIS HC A15/MF A01

A number of issues related to air traffic control are investigated, with particuliar attention being paid to new technologies. Attention is focused on the use of more powerful data processing technologies, the introduction of satellites for integrated navigation communications and surveillance and the potential role of automatic two-way air/ground data links. The fields covered include advanced surveillance radar, advanced landing systems, the management of air traffic, the potential and limitations of automation, including the possible applications of intelligent knowledge based systems and new onboard equipment that will necessitate a fresh look at the relationship between air traffic control and individual aircraft. For individual titles, see N87-21882 through N87-21904.

N87-21882# Air Navigation Technical Service, Paris (France). Dept. Radiocummincation et Radioguidage.
THE SELECTION OF FUTURE CIVIL AIR NAVIGATION SYSTEMS
OLIVIER CAREL *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 7 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The International Civil Aviation Organization has established a special committee (FANS) responsible for assessing Future Air Navigation Systems. This report describes the creation of this committee and gives a detailed summary of its principle meeting, FANS-2, held in April 1985. Recent work of the committee is also discussed. Automatic dependent surveillance (ADS) and required navigation performance capability (RNPC) concepts are addressed. Finally, the rapid evaluation of aeronautic mobile communications by satellite is discussed. M.G.

N87-21883# Eurocontrol Agency, Brussels (Belgium).
AIR NAVIGATION SERVICES AND AIRCRAFT AROUND THE YEAR 2000
V. VACHIERY *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 16 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The Air Traffic Services (ATS) System for 2000 and beyond shall have to cope with the constantly increasing traffic demand. It shall take wholly into account the methods by which the aircraft

are conducted, and, in particular the ability to adhere accurately to a predefined profile. Since 1980 a working party of the EUROCONTROL Agency has been in charge of the development of a future system concept and the formulation of a corresponding research program. The objectives, the difficulties, the main principles and the characteristics associated with the development and implementation of the future ATS concept are reviewed. The necessity for close consultation between aircraft manufacturers, avionics manufacturers, aircraft operators and the authorities responsible for air traffic management is discussed. Author

N87-21884# Stuttgart Univ. (Germany, F.R.). Inst. for Navigation.

GPS: OVERVIEW AND PRESENT STATUS

PH. HARTL, W. SCHOELLER, and K.-H. THIEL *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 18 p (SEE N87-21881 15-04) Dec. 1986 (AGARD-CP-410) Avail: NTIS HC A15/MF A01

Due to various reasons the interest in the practical use of the Global Positioning System (GPS) has considerably increased during the last two years. The test phase has demonstrated its outstanding performance. With the differential method the relative accuracies achieve values that open its use even for the precision approach of aircraft landing. The development of new techniques also allows 3-dimensional attitude measurement and angular rate determination. Diverse civilian groups will use GPS in the future; in particular motor car drivers, geodesists, civil engineers etc. The present state of development and various practical applications are discussed. Author

N87-21885# Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France). Dept. Aeronautique.

INERTIAL-GPS: A MARRIAGE OF REASON, AN ANALYSIS [INERTIE-GPS: UN MARIAGE DE RAISON - A L'ESSAI]

P. LLORET and B. CAPIT *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 23 p (SEE N87-21881 15-04) Dec. 1986 In FRENCH (AGARD-CP-410) Avail: NTIS HC A15/MF A01

The coupling of inertial navigation methods with the Global Positioning System (GPS) is examined. The characteristics of various types of inertial systems are reviewed and past attempts at inertial/radionavigation hybridizations including those with multi- and VOR-DME (VHF omnidirectional range - distance measuring equipment), Transit, OMEGA, ILS (instrument landing systems), and altitude correlation are discussed. The possible configurations for an inertial/GPS systems, given the type (classical platform and strap-down) and classes of inertial designs and the number of GPS channels utilized, are defined and performance characteristics are outlined for each. Simulation and in-flight studies of prototype systems are discussed. Signal properties and Kalman filtering are addressed. Finally, perspectives on the continuing development of inertial/GPS hybrid systems are offered. M.G.

N87-21886# Aeronautical Radio, Inc., Annapolis, MD. Engineering Dept.

COMMUNICATION, NAVIGATION AND SURVEILLANCE SERVICES FOR THE AVIATION INDUSTRY USING SATELLITE TECHNOLOGY

R. A. PICKENS *In* AGARD Efficient Conduct of Individual Flights and Air Traffice or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 4 p (SEE N87-21881 15-04) Dec. 1986 (AGARD-CP-410) Avail: NTIS HC A15/MF A01

A general historical survey of Communication Navigation, and Surveillance (CNS) services for the aviation industry using satellite technology is given. Aeronautical Radio, Inc's (ARINC) air-ground communications services, which consist of VHF voice and data transfer services, and HF voice communications are discussed. ARINC's implementation of an integrated satellite system and companion integrated avionics to provide air traffic control, company operational control, navigation capability for enroute operations, and support for cooperative operations is discussed. R.J.F.

N87-21887# Eurocontrol Agency, Brussels (Belgium).

POSSIBLE CONTRIBUTIONS FROM THE SSR MODE S DATA LINK TO THE CONDUCT OF EFFICIENT AIRCRAFT OPERATIONS

M. E. COX *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 15 p (SEE N87-21881 15-04) Dec. 1986 (AGARD-CP-410) Avail: NTIS HC A15/MF A01

The paper entitled Data Link - The Key to Improvements in Civil Military Air Traffic Management., presented at the Guidance and Control Panel (GCP) Symposium, Copenhagen, in October 1979, outlined a number of potential applications of a data link, then known as ADSEL/DABS, and referred to a number of feasibility studies that were being conducted in respect of these applications. Since that date the two systems (ADSEL/DABS) have led to the emergence of secondary surveillance radar (SSR) Mode S which is now being standardized for international use. Here, a brief description is given of the Mode S data link characteristics. A number of the applications proposed in 1979 are recalled and the results of studies conducted subsequently on such topics as the controller/pilot interfaces with the link and machine/machine data interchanges and their possible benefits to air traffic control (ATC) are given. Plans are discussed for more extensive data link evaluations. The initial steps that could be taken in progressing from today's situation towards a system of control employing a high level of automation are proposed. Author

N87-21891# Federal Aviation Administration, Atlantic City, NJ. Technical Center.

MICROWAVE LANDING SYSTEM (MLS) AREA NAVIGATION: COMPUTED CENTERLINE EXPERIMENTS AND SYSTEM ACCURACY ANALYSIS IN AN RF ENVIRONMENT

JAMES H. REMER and BARRY R. BILLMANN *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 17 p (SEE N87-21881 15-04) Dec. 1986 (AGARD-CP-410) Avail: NTIS HC A15/MF A01

By definition of the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPS) the Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) will supplant the existing Instrument Landing System (ILS) as the recognized international standard as early as 1995. Among numerous other advantages, the MLS provides the ability to determine the aircraft's position in three dimensional space over a large coverage volume in the airport terminal area. The use of this capability to navigate and execute approaches throughout this volume of coverage results from the application of a technique known as Microwave Landing System Area Navigation (MLS RNAV). Applications of MLS RNAV can be as simple as executing approaches offset from but parallel to the MLS 0 azimuth or as complex as multi-segment and curved path approaches. MLS RNAV is particularly adaptable to helicopter operations. It allows approaches to heliports located away from the main instrumented runway. In order to assess and further develop the potential capabilities of MLS RNAV, the FAA Technical Center has undertaken the task of performing analytical studies, as well as the development of a prototype MLS RNAV system. Applications of this system to helicopter operations are particularly being emphasized. The unique feature of this work is that besides the onboard data acquisition systems, an independent source of position information was, at times, available for comparison. The source was independent position tracking in the form of laser or radar data. The work reviewed here should have immediate application in the development of MLS RNAV Terminal Area Instrument Approach Procedures (TERPS). Author

N87-21892# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helipcopter and Military Aircraft Group.

MLS: ITS TECHNICAL FEATURES AND OPERATIONAL CAPABILITIES

R. SEIFERT *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 10 p (SEE N87-21881 15-04) Dec. 1986 (AGARD-CP-410) Avail: NTIS HC A15/MF A01

Taking into account present developments in guidance and control automation in the airplane cockpit as well as in Air Traffic

Control (ATC) systems, the following aspects of the Instrument Landing System/Microwave Landing System (ILS/MLS) are analyzed and presented: (1) the complexity of MLS approach procedures and function allocation to ATC and aircraft; (2) cockpit automation and presentation of MLS approach information; and (3) aspects of all weather approach and landing with military aircraft. Author

N87-21893*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCED ATC: AN AIRCRAFT PERSPECTIVE
LEONARD CREDEUR, DAVID H. WILLIAMS, WILLIAM E. HOWELL, and CARY R. SPITZER *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 14 p (SEE N87-21881 15-04) Dec. 1986 Previously announced in IAA as A86-49637
(AGARD-CP-410) Avail: NTIS HC A15/MF A01 CSCL 17G

The principal operational improvements desired by commercial aircraft operators in the United States are efficient aircraft operations and delay reductions at the major terminals. Efforts underway within the Advanced Transport Operating Systems Program at the Langley Research Center to provide a technology basis for reducing delay while improving aircraft efficiency are discussed. The principal thrust is the development of time-based traffic control concepts which could be used within the framework of the upgraded National Airspace System and which would allow conventionally equipped aircraft to operate in a manner compatible with advanced aircraft. Author

N87-21894# Consiglio Nazionale delle Ricerche, Rome (Italy). Progetto Finalizzato Trasporti and Istituto di Analisis dei Sistemi ed Informatica.
STRATEGIC CONTROL TO IMPROVE EFFICIENCY OF AIR TRAFFIC MANAGEMENT
LUCIO BIANCO *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 10 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The strategic control concept, intended as a new management *philosophy that can improve efficiency of Air Traffic* Control (ATC) systems, is discussed. After having introduced a classification of the different ATC functions based on a multilevel scheme, strategic control is decomposed in a hierarchy of sub-functions. Subsequently, the on-line strategic control of flights is considered and the mathematical aspects of this problem are illustrated. Then the structure of a real time solution algorithm, proposed in a previous work, and a possible scheme of route-time profile generation are reported. Finally, computational efficiency of the proposed approach is discussed. Author

N87-21895*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A TIME-BASED CONCEPT FOR TERMINAL-AREA TRAFFIC MANAGEMENT
HEINZ ERZBERGER and LEONARD TOBIAS *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 14 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01 CSCL 17G

An automated air-traffic-management concept that has the potential for significantly increasing the efficiency of traffic flows in high-density terminal areas is discussed. The concept's *implementation depends on techniques for controlling* the landing time of all aircraft entering the terminal area, both those that are equipped with on-board four-dimensional (4D) guidance systems as well as those aircraft types that are conventionally equipped. The two major ground-based elements of the system are a scheduler which assigns conflict-free landing times and a profile descent advisor. Landing time provided by the scheduler is uplinked to equipped aircraft and translated into the appropriate 4D trajectory by the-board flight-management system. The controller issues descent advisories to unequipped aircraft to help them achieve the assigned landing times. Air traffic control simulations have established that the concept provides an efficient method for controlling various mixes of 4D-equipped and unequipped, as well as low- and high-performance, aircraft. Piloted simulations of profiles flown with the aid of advisories have verified the ability to meet specified descent times with prescribed accuracy. Author

N87-21896# Federal Aviation Administration, Washington, DC. Systems Engineering Service.
PHILOSOPHY OF APPLYING AUTOMATION TO AIR TRAFFIC CONTROL
LELAND F. PAGE *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 3 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The objectives of the U.S. program for applying automation to air traffic control systems, progress thus far, and plans for the future are discussed. Since the time in 1958 when computers were first used to print flight strips in the United States at a small number of air traffic control (ATC) centers, it has been a continuing objective to capitalize on the rapidly evolving computer technologies to improve the ATC system. Specific objectives have been to apply computers and the associated automation functions to: improve safety of ATC operations; increase the efficiency of traffic management; and increase the productivity of ATC controllers. Author

N87-21897# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugfuehrung.
COMPUTER ASSISTED ARRIVAL SEQUENCING AND SCHEDULING WITH THE COMPAS SYSTEM
U. VOELCKERS *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 11 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The Computer Oriented Metering Planning and Advisory System (COMPAS) developed at the DFVLR-Institute for Flight Guidance was tested and evaluated at the institute's air traffic simulation facility, using traffic scenarios of Frankfurt airport with up to 52 aircraft movements simultaneously. The operational objectives of the COMPAS-system are, with regard to Frankfurt airport, to achieve the best possible usage of the available but limited runway landing capacity, to avoid unnecessary delays and to apply economic approach profiles whenever possible. The planning functions which today are still carried out by human controllers will be transferred to a computer. It generates a comprehensive plan for a best overall arrival sequence and schedule. The execution of this plan, however, intentionally remains the task of the human controllers. They are provided with all data necessary to control the approaching aircraft. The systems concept, the dynamic planning algorithms as well as the operational concept for computer assistance and the man-machine interface are presented. Some preliminary results of the experiments and evaluation are reported. Author

N87-21898# Eurocontrol Agency, Brussels (Belgium).
NEXT GENERATION OF CONTROL TECHNIQUES IN ADVANCED TMA
ANDRE BENOIT, SIP SWIERSTRA, and RENE DEWISPELAERE *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 31 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

It is very likely that any future concept to be used for the safe and efficient conduct of air traffic (in terms of expedition, economy and capacity) will exhibit two essential, closely interrelated components. Firstly, the on-line management of air traffic over a large area - from a Zone of Convergence type to a continental coverage - will generate the landing and departure times for each aircraft entering the area, while at the same time defining the essential characteristics of the relevant flight paths. Secondly, an operational control procedure will be required to conduct each individual flight accurately throughout the area, that is to say, in the case of a Zone of Convergence, from entry to touchdown, in agreement with the air traffic management directives and in line with operational practice (onboard and on the ground). The essential operational features of a control procedure suitable to meet the above constraints while ensuring a 10-second accuracy

for the time of arrival as predicted initially at entry into the zone (and possibly amended subsequently), for current air carriers in present R/T or future D/L communications environments are outlined. Author

N87-21899# Smiths Industries Ltd., Bishops Cleeve (England). Engineering Dept.
EXPLOITING THE CAPABILITIES OF FLIGHT MANAGEMENT SYSTEMS IN SOLVING THE AIRPORT ARRIVAL PROBLEM
J. F. MEREDITH *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 10 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

Increasingly Flight Management Computers are becoming standard fit on present day passenger aircraft (737-300, 757, 767, A310, A300-600). Avionic update programs which incorporate Flight Management Computers are in hand for 747 and MD 80 and new aircraft programs A320, MD 11, 7J7, A330 and A340 are or are likely to include Flight Management Computing as standard fit. As these aircraft come to dominate the traffic entering and leaving major airports *there is potentially a new level of information and* of control available to the air traffic controllers whose task it is to schedule the aircraft flow into and out of the terminal area. This information flow and the consequent control actions should enable the traffic to be handled in a manner to minimize delay, thus enhancing the available traffic handling capacity of an airport. Author

N87-21900# Naval Air Development Center, Warminster, PA.
APPLICATION OF FLIGHT PERFORMANCE ADVISORY SYSTEMS TO US NAVY AIRCRAFT
M. J. FRIEDMAN, L. J. COWLES, and R. C. CARSON, JR. *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 14 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The U.S. Navy, in its Aircraft Energy Conservation Research and Development Program, is currently investigating various methods for improving the fuel efficiency of existing and future Navy aircraft. Fuel saving concepts under development include an aircraft integrated flight performance advisory system, a pre-flight *mission planning program utilizing a desk type computer and an* aircraft performance advisory system using an HP-41 CV hand-held calculator. The integrated flight performance advisory system for the F/A-18, the A-7E, and the S-3 are described in detail by reviewing the displayed outputs to the pilots and describing the required inputs and their sources. Features of each aircraft system are described in accordance with the development status of the program. The preflight mission planning program utilizing an HP-9845 desktop computer is described for the P-3C aircraft. The approach to weather, takeoff and cruise are described by specifying the input and output data. Sample displays are also shown. The hand-held HP-41 CV calculator utilized for flight performance predictions is described for the P-3C. All the calculator functions are described for the takeoff and cruise flight modes of this aircraft. The operational status of these three programs and plans for other Navy aircraft are also specified. Author

N87-21903# Royal Signals and Radar Establishment, Malvern (England).
SEMI-AUTOMATIC CROSS-CHECKING BETWEEN DIFFERENT COPIES OF THE SAME FLIGHT PLAN
S. RATCLIFFE *In* AGARD Efficient Conduct of Individual Flights *and Air Traffic or Optimum Utilization of Modern Technology for* the Overall Benefit of Civil and Military Airspace Users 7 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

A flight-plan usually exists in several different forms in the aircraft flight management system: as hard copy on the flight-deck, in one or more Air Traffic Control/(ATC) data processors, and distributed over flight-progress strips (or their electronic equivalents) in one or more control centers. Any discrepancies between various versions of the plan are potentially hazardous. Given that the flight plan is already stored, for one reason or another, in at least one computer, it is proposed that each computer should also be used to generate a check word which can easily and rapidly be compared with that stored as hard-copy or in some other machine. The check word might consist of four alpha characters which can easily be remembered and passed by voice. Possible algorithms for generating check-words are discussed. The results of some laboratory trials of a prototype system are given. Author

N87-21904# Civil Aviation Authority, London (England).
THE APPLICATION OF INTELLIGENT KNOWLEDGE BASED SYSTEMS TO AIR TRAFFIC CONTROL
W. S. NICOL, G. C. DEAN, A. JACKSON, and W. A. STRETTON (Royal Signals and Radar Establishment, Malvern, England) *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 9 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The need to explore the approach of Intelligent Knowledge Based Systems (IKBS) towards meeting the pressures for change in future air traffic control systems is discussed. The discussion includes the role of automation in air traffic control (ATC) and the *suitability of IKBS within a shared approach between controller* and machine. Areas selected to provide practical experience of IKBS applied to ATC include air traffic flow management and conflict resolution and training. Finally, guideline concepts for the introduction of a new technology to ATC are outlined. Author

N87-23608# *Advisory Group for Aerospace Research and* Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
EFFICIENT CONDUCT OF INDIVIDUAL FLIGHTS AND AIR TRAFFIC OR OPTIMUM UTILIZATION OF MODERN TECHNOLOGY FOR THE OVERALL BENEFIT OF CIVIL AND MILITARY AIRSPACE USERS
BERNARDO FURCOLO 1987 16 p Proceedings of the 42d Symposium of the Guidance and Control Panel of AGARD, Brussels, Belgium, 10-13 Jun. 1986
(AGARD-AR-236; AD-A182145) Avail: NTIS HC A02/MF A01

The AGARD Guidance and Control Panel 42nd Symposium was held in Brussels, Belgium, from 10 to 13 June 1986. The program presented at the symposium is appended to this report, and the Conference Proceedings are published separately. Author

N87-29474# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
ADVANCES IN GUIDANCE AND CONTROL SYSTEMS AND TECHNOLOGY
Jul. 1987 146 p Symposium held in London, England, 7-10 Oct. 1986 Original contains color illustrations
(AGARD-CP-411; ISBN-92-835-0421-6; AD-A191464) Avail: NTIS HC A07/MF A01

Papers were presented under the following headings: target and terrain sensors; aircraft state sensors; force and moment *generators; guidance and control algorithms; and integrated* systems. For individual titles, see N87-29475 through N87-29484.

N87-29477# Army Avionics Research and Development Activity, Fort Monmouth, NJ.
VELOCITY ACCURACY MEASUREMENT OF GPS USER EQUIPMENT
JOSEPH MCGOWAN *In* AGARD, Advances in Guidance and Control Systems and Technology 17 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

A test program conducted by the U.S. Army Avionics Research and Development Activity (AVRADA) to determine the level of velocity accuracy achievable with Global Positioning System (GPS) is described. The precision of the reference instrumentation and the availability of the GPS receiver measurement data were exploited to characterize the errors in GPS observables. An investigation into the performance benefits of GPS and inertial integration is described. Author

N87-29480# Honeywell Advanced Technology Centre, North York (Ontario).
CONFIGURATION DESIGN OF A HELICOPTER INTEGRATED NAVIGATION SYSTEM
S. I. FINGEROTE, D. B. REID, D. F. LIANG, L. VALLOT, C. GREENE, and J. MAHESH (Honeywell Systems and Research Center, Minneapolis, Minn.) *In* AGARD, Advances in Guidance and Control Systems and Technology 9 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

Results are presented from the configuration performance study phase of the Helicopter Integrated Navigation System project. A configuration assessment is presented including processor selection, and a discussion of system architecture and configuration tradeoffs leading to a recommended configuration. Results of the system error analysis and the Kalman filter design are presented demonstrating integrated system performance. Author

N87-29481# Litton Technische Werke, Freiburg (Germany, F.R.).
NAVIGATION SYSTEMS FOR THE NEW GENERATION OF COMBAT AND TRANSPORT HELICOPTERS AND ASSOCIATED FLIGHT TESTS
W. HASSENPFLUG and M. BAEUMKER *In* AGARD, Advances in Guidance and Control Systems and Technology 22 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

An integrated strapdown inertial helicopter navigator which is augmented by a Doppler velocity sensor and a magnetometer is described. A radar altimeter is used to obtain height above ground. Accurate weapon delivery requirements and flight safety aspects while operating the helicopter under adverse weather conditions and at night demand the accurate determination of TAS throughout the entire speed regime. Besides position, velocity, and attitude, the strapdown system provides angular rates for stability augmentation and linear accelerations in bodyframe coordinates, inertial altitude and vertical speed from the Doppler velocity sensor and the baro-inertial loop as well. The system communicates with the other avionics on board the helicopter through a duel MIL-STD 1553B bus and for redundancy purposes through an ARINC 429 interface with the AFCS. Flight tests were performed to demonstrate the navigation capability and performance of a Doppler and flux valve augmented strapdown navigator, a new analytical true air speed system for the low speed regime and the performance of a strapdown magnetometer. The navigation performance was verified in three different helicopters, a BO-105, a CH-53, and a Gazelle. Author

N88-10810# Carleton Univ., Ottawa (Ontario). Dept. of System and Computer Engineering.
AN EXPERT SYSTEM FOR AIRCRAFT CONFLICT RESOLUTION IN DENSE AIRSPACES
B. A. BOWEN *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 13 p (SEE N88-10806 02-08) Aug. 1987 Sponsored by Transport Canada
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

A hybrid, knowledge-based system is described which provides *advice to air traffic controllers on the optimal tactics for resolving* predicted aircraft conflicts. The overall functional architecture is described which has both computational algorithms and rule bases containing the knowledge and experience of controllers in the air traffic environment. The system is designed to replicate the way a controller might react to a predicted conflict. It responds to conflict predictions with resolution advice, which depends on both formal rules and on heuristics obtained from controllers. Author

N88-10815# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugfuehrung.
A RULE-BASED SYSTEM FOR ARRIVAL SEQUENCING AND SCHEDULING IN AIR TRAFFIC CONTROL
U. VOELCKERS *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

A rule based system is presented that is designed to assist human controllers in efficiently merging high density inbound traffic into congested airports. The rationale for the design of a rule based system and the critical requirements for the development of a rule based system for application to air traffic control are discussed. The system uses the OPS5 production system and is programmed in FRANZ LISP with embedded C functions. The system still has limited capabilities. Author

N89-10874# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
THE NAVSTAR GPS SYSTEM
Sep. 1988 141 p Lecture series held in Wessling, West Germany, 19-20 Sep. 1988, in Athens, Greece, 22-23 Sep. 1988, in Ankara, Turkey, 26-27 Sep. 1988, and in Lisbon, Portugal, 29-30 Sep. 1988
(AGARD-LS-161; ISBN-92-835-0477-1; AD-A199829) Avail: NTIS HC A07/MF A01

A comprehensive and up-to-date lecture series on the *NAVSTAR GPS System is presented. Among the subjects covered* are the system concept, navigation principles, system design, user applications, and techniques involved. The lectures are a balanced presentation of theory, application, and measured performance. For individual titles, see N89-10875 through N89-10884.

N89-10875# Aerospace Corp., El Segundo, CA.
THE GPS OVERVIEW AND NAVIGATION SYSTEM CONCEPT
EDWARD LASSITER and MOHAN ANANDA *In* AGARD, The NAVSTAR GPS System 13 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The Global Positioning System (GPS) objective for both military and civil applications and the historical evolutions of the SPS are presented. The GPS concept validation phase, full-scale engineering developments, system test phase and operational system phase are described. The fundamental principles of the GPS concept are briefly reviewed. The GPS radiometric measurements of pseudo-range and accumulated delta range and how these measurements are used in forming the navigation equations to solve for the user position parameters are described. The current program status and future plans for system enhancements are outlined. Author

N89-10876# Aerospace Corp., El Segundo, CA.
THE GLOBAL POSITIONING SYSTEM (GPS) CONSTELLATION AND COVERAGE
MOHAN ANANDA *In* AGARD, The NAVSTAR GPS System 17 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The NAVSTAR Global Positioning System (GPS) is a *space-based system that will be operational in 1990 and will enable* a user to determine position, velocity, and time with greater accuracy on a worldwide basis that it had ever achieved. The GPS is currently undergoing full-scale engineering development and testing. The test constellation and available coverage for *testing the various system segments are reviewed.* Also discussed is the 18-, 21-, and 24-satellite operational constellations. The current baseline constellation consists of 18 satellites with three active spare satellites. The concept of constellation value and various dilution-of-precision parameters due to geometry are discussed, such as geometrical dilution of precision (GDOP) and position dilution of precision (PDOP). The constellation design issues related to minimizing the reduced accuracy regions due to geometry problems are also reviewed. Coverage maps over the globe are presented for the test constellation, as well as for the operational constellations. Author

N89-10877# Aerospace Corp., El Segundo, CA.
THE GLOBAL POSITIONING SYSTEM (GPS) ACCURACY, SYSTEM ERROR BUDGET, SPACE AND CONTROL SEGMENT OVERVIEW
MOHAN ANANDA *In* AGARD, The NAVSTAR GPS System 17 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The NAVSTAR Global Positioning System is a space-based navigation system that will provide continuous, all weather, global navigation capability to properly equipped users with high accuracy. The position, velocity, and time accuracy that can be achieved by a user of the GPS are discussed. The system accuracy will be examined in light of the Geometric Dilution of Precision parameter

and measurement error. Also reviewed is the system error budget for the three subsystem segments: space, control, and user. A discussion of the user range error (URE) and its relationship to three-dimensional position error expressed in spherical error probable (SEP) and horizontal position error expressed in circular error probable (CEP) is presented. The role of the World Geodetic System reference frame in the GPS is discussed. A brief overview of space and control systems is also presented. Author

N89-10878# Naval Materiel Command, Haakonsvern (Norway).
GPS SIGNAL STRUCTURE
PER W. NIEUWEJAAR *In* AGARD, The NAVSTAR GPS System 6 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The characteristics of the Global Positioning System (GPS) signal structure, frequencies, codes, and navigation-message are described. The content of the navigation-message and the user algorithms associated with the navigation-message are described in some detail. Author

N89-10879# Air Force Space Div., Los Angeles, CA. GPS Joint Program Office.
USER EQUIPMENT OVERVIEW
ELIO BOTTARI *In* AGARD, The NAVSTAR GPS System 11 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The Global Positioning System (GPS) includes all the hardware and software needed to determine the user's position, velocity, time data, and other derived parameters, as required. Additionally, the GPS User System can be integrated with other navigation systems to provide accurate navigation under severe dynamics and hostile environmental conditions. During the development phase, various classes of users were defined based on user requirements and characteristics such as desired accuracy, user maneuvering, antijamming capability, and cost. The application of GPS user equipment (UE) in various types of host vehicles, used under a wide variety of operational conditions, has led to the development of three types of UE sets: LD = Low Dynamic (one channel); MD = Medium Dynamic (two channels); and HD = High Dynamic (four or more channels). A brief description of GPS signals is given to better describe the functions and operating concept of user equipment. Author

N89-10880# TAU Corp., Los Gatos, CA.
GPS/INTERNAL NAVIGATION SYSTEM INTEGRATION FOR ENHANCED NAVIGATION PERFORMANCE AND ROBUSTNESS
ROBERT P. DENARO and G. JEFFREY GEIER *In* AGARD, The NAVSTAR GPS System 12 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The emergence of the Global Positioning System (GPS) from the laboratory and the test range into the operational environment, with affordable, high-performance receivers now available, has heralded a widespread study of the integration of GPS with the current standard in precise positioning, inertial navigation systems. Once considered by some to be a potential competitor of inertial navigation, GPS is now recognized by most navigation system developers as having tremendous potential for system performance improvement over either system in isolation by integrating with inertial systems. So powerful is this synergism that deep integration of the two systems often dictates potential major design modifications in the inertial measurement unit (IMU) as well as the GPS receiver. These design modifications are necessary to exploit the performance potential to the maximum, particularly in the military environment, and at the same time to realize substantial cost savings in the system as an additional benefit. Author

N89-10881# Naval Materiel Command, Haakonsvern (Norway).
AIDING AND INTEGRATION OF A GPS RECEIVER
PER W. NIEUWEJAAR *In* AGARD, The NAVSTAR GPS System 10 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The need for receiver aiding due to contingencies such as satellite outages, jamming, and terrain masking is described. Alternative aiding methods are also described, such as: integration of GPS/INS or Attitude Heading Reference System (AHRS); integration of GPS and baro-altimeter; integration of GPS and atomic clock; use of altitude hold or mean sea level information; and integration of GPS/Transit/LORAN-C and/or Omega. Author

N89-10882# Air Force Space Div., Los Angeles, CA.
CIVIL AND MILITARY APPLICATIONS OF GPS
HANS J. KUNZE *In* AGARD, The NAVSTAR GPS System 19 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The objectives are to give an overview of military and civil applications of the NAVSTAR Global Positioning System (GPS), to discuss the resulting benefits for the users, and to present a planned system development that will provide the user community with the GPS information, such as overall system status or satellite data, required for their mission. Author

N89-10883# TAU Corp., Los Gatos, CA.
DIFFERENTIAL OPERATION OF NAVSTAR GPS FOR ENHANCED ACCURACY
ROBERT P. DENARO and RUDOLPH M. KALAFUS *In* AGARD, The NAVSTAR GPS System 18 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The NAVSTAR Global Positioning System has demonstrated impressive absolute accuracy in tests and operational use. Most applications will benefit from the increased accuracy afforded by GPS over conventional systems. However, many applications require even better accuracy than GPS can provide in the stand-alone mode. Differential GPS is a practical solution in many situations. The subject of differential GPS is fundamentally a simple concept, but implementation details can be more complex, and handling of all cases takes special care to achieve continuously reliable results. The concept and objective of differential GPS is covered, and a methodology for implementation presented. Example test results are presented which validate the potential of differential GPS. Author

N89-10884# TAU Corp., Los Gatos, CA.
GPS NAVIGATION PROCESSING AND KALMAN FILTERING
ROBERT P. DENARO and PETER V. W. LOOMIS *In* AGARD, The NAVSTAR GPS System 9 p (SEE N89-10874 02-04) Sep. 1988
(AGARD-LS-161) Avail: NTIS HC A07/MF A01

The processing of Global Positioning System (GPS) signals is a complex process of dealing with two observables, the range and the Doppler of the signal. This provides opportunities for substantial sophistication in processing techniques in the tracking loops, and later in the navigation processing of the Kalman filter or other filter. In total, the combination of techniques is a closely interrelated set of algorithms that provide near-optimum performance. Author

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AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

N86-27276# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
COMBAT LOADS ON MODERN FIGHTERS
Feb. 1986 21 p
(AGARD-R-730; ISBN-92-835-1518-8; AD-A167593) Avail: NTIS HC A02/MF A01

A number of factors which influence the selection of design cases are examined in the light of modern fighter usage and modern technologies that are available, or will soon be available. It was found that pilots fly fighters very differently than was the norm for the period of time when most design criteria specifications were written, largely because the environment created by today's detection systems and weapons is very different than it was then. It was found that as technology advances, such advanced composite construction and fly-by-wire control systems make it

possible to tailor the configuration to achieve a maneuvering capability previously unattainable. It is concluded that the method of selecting design cases need to be updated. Available methods for predicting loads for new, more complex design cases are discussed. No firm recommendations can be made, but a number of suggestions are made which, it is hoped, will contribute to fruitful future consideration of the problems discussed. Author

N86-30726# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel

THE INFLUENCE OF LARGE-SCALE COMPUTING ON AIRCRAFT STRUCTURAL DESIGN

Apr 1986 67 p

(AGARD-R-726; ISBN92-835-1522-6; AD-A171306) Avail: NTIS HC A04/MF A01

An outcome of the AGARD Working Group on Large Scale Computing was the institution by the Structures and Materials Panel of a Sub-Committee to consider this topic in relation to Aircraft Structural design. The publication contains papers on various aspects of the topic heard by the Sub-Committee plus a summary. These cover likely developments in both soft- and hardware, and their applications to the Design process. This Report was sponsored by the Structures and Materials Panel of AGARD. Author

N86-30727# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

STORE SEPARATION FLIGHT TESTING

R. J. ARNOLD, C. S. EPSTEIN, and R. K. BOGUE, ed. Apr. 1986 161 p

(AGARD-AG-300-VOL-5; ISBN92-835-1523-4; AD-A171301)

Avail: NTIS HC A08/MF A01

This volume in the AGARD Flight Test Techniques Series treats stores separation testing from the overall systems standpoint. All aspects of testing are described from the time of identification of a particular aircraft/store requirement through all steps leading to the establishment of a satisfactory employment envelope. Considerable emphasis is placed on the planning and execution of the flight test phase of the stores clearance program, including the definition of a basic structure, and a set of procedures which will maximize the safe and efficient execution of such a program. Author

N87-10067# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

ENGINE-AIRFRAME INTEGRATION FOR ROTORCRAFT

May 1986 154 p Lecture Series held in St. Louis, Mo., 2-3 Jun. 1986, in Rome, Italy, 9-10 Jun. 1986, and in Marseilles, France, 12-13 Jun. 1986

(AGARD-LS-148; ISBN-92-835-1529-3; AD-A171297) Avail: NTIS HC A08/MF A01

Topics addressed include numerous airframe integration aspects relating to rotor wing aircraft. Various areas of engine airframe integration, including the impact of advanced engine design variables to specific propulsion subsystems, will be discussed. Other propulsion system integration aspects such as engine/rotor/drive system torsional stability and transient response will also be discussed. Additional areas considering the specification and qualification requirements of propulsion items will be examined. For individual titles see N87-10068 through N87-10074.

N87-10068# Sikorsky Aircraft, Stratford, CT. Propulsion Systems

ENGINE-AIRFRAME INTEGRATION CONSIDERATIONS FOR PRELIMINARY AIR VEHICLE PERFORMANCE ANALYSIS

R. C. FRAWLEY and H. N. SHOHET *In* AGARD Engine-Airframe Integration for Rotorcraft 21 p (SEE N87-10067 01-05) May 1986

(AGARD-LS-148) Avail: NTIS HC A08/MF A01

Helicopter engine/airframe integration issues are examined from a preliminary design viewpoint with emphasis on those areas where an impact on aircraft power available and/or aerodynamics is involved. The areas of the helicopter propulsion system specifically addressed include: the engine air induction system considering aerodynamic performance, anti-icing, exhaust gas re-ingestion, and inlet particle separation; the engine exhaust system considering aerodynamic performance, engine compartment cooling, and exhaust ejector system; and lastly, engine bleed air extraction as it relates to environmental control systems and the trade studies associated with same. These subsystems are discussed in terms of basic design guidelines, interaction with other helicopter subsystems, system trade studies, and first order analytical design approaches adequate for preliminary design purposes. Author

N87-10069# Pisa Univ. (Italy). Dipt. de Energetica

ENGINE-TRANSMISSION-STRUCTURAL AIRFRAME MEMBERS COMPATIBILITY

D. DINI *In* AGARD Engine-Airframe Integration for Rotorcraft 33 p (SEE N87-10067 01-05) May 1986

(AGARD-LS-148) Avail: NTIS HC A08/MF A01

The sophistication of current turbine-powered helicopters have introduced many new problems involving the compatibility of the major multidegree of freedom systems: rotor, control, airframe, drive train, and powerplant. The solutions to the various problems were obtained from the application of basic engineering principles. Engine installation is described in the helicopter, particularly the A-129, i.e., power plant attachment, oil cooling system, engine control and monitoring, electric starting system, location of components and leading particulars, and anti-vibration devices. The design of the transmission system is dictated by the configuration of the helicopter. An aerodynamic analysis is conducted on the helicopter mission in order to obtain complete spectra of the rotor loads and moments as well as the maneuver loads and transient for maximum transmission reliability. The application of fiber reinforced resin composites to selected areas of the helicopter drive system will produce weight and cost savings as well as improvements in reliability and safety. These improvements which were demonstrated in airframe applications can be transferred to structural components in the drive system, with high weight saving. Author

N87-10070# Rolls-Royce Ltd., Watford (England).

IMPACT OF IPS AND IRS CONFIGURATIONS ON ENGINE INSTALLATION DESIGN

J. R. BALLARD *In* AGARD Engine-Airframe Integration for Rotorcraft 14 p (SEE N87-10067 01-05) May 1986

(AGARD-LS-148) Avail: NTIS HC A08/MF A01

Helicopters operate in a variety of roles many of which pose severe problems to the engine due to ingestion of sand, ice, salt, and other foreign objects. It is possible to design a compromise engine intake which combats all these hazards to a limited degree. Engine design should be coordinated with both engine and airframe mounted separator performance characteristics to ensure that optimized designs can be offered to customers with very different operational requirements. A design method was outlined which would allow the erosion reduction characteristics of engine and airframe Intake Protection System (IPS) designs to be taken into account during engine design. The Infrared Suppression (IRS) designs can be integrated with IPS scavenge requirements to produce a low signature engine installation. B.G.

N87-10071# Army Aviation Systems Command, Saint Louis, MO. Engineering Dept.

ENGINE-AIRFRAME INTEGRATION FOR ROTORCRAFT: COMPONENT SPECIFICATIONS AND QUALIFICATION

J. A. RAY *In* AGARD Engine-Airframe Integration for Rotorcraft 10 p (SEE N87-10067 01-05) May 1986

(AGARD-LS-148) Avail: NTIS HC A08/MF A01

Both past history and current principles associated with engine-airframe integration for rotorcraft are provided as related to component specification requirements and their individual qualification assurance. Component specification and qualification requirements have tended to be generic and standardized without consideration of actual usage, location, and exposure. As such, overall requirements have had problems of being overly restrictive in some cases and not exacting enough in others. The current trend in tailoring for specific applications as well as insuring system performance requirements by conducting early component/bench level tests will be discussed along with lessons learned from past efforts. Components involved in the overall engine-airframe integration effort such as pumps, fans, starter, valves, sensors, infrared suppressors, inlet particle separators, and fuel cells will be discussed Author

N87-10072# *Garrett Turbine Engine Co., Phoenix, AZ.*
INFLUENCE OF ENGINE VARIABLES ON FUTURE HELICOPTER SYSTEMS
M. L. EARLY and P. K. ZEINER *In* AGARD Engine-Airframe Integration for Rotorcraft 24 p (SEE N87-10067 01-05) May 1986
(AGARD-LS-148) Avail: NTIS HC A08/MF A01

A helicopter system defined for the year 2000 must make numerous assumptions about future technology and system requirements. In the case of propulsion system options, the required 5 to 15 year development cycle (from preliminary engine cycle studies through engine development to production) complicates the process of optimizing the engine/rotorcraft system. A well-disciplined approach to engine definiton studies to yield engine candidates that best use emerging technologies is illustrated. An advanced, single-engine helicopter requiring a 2000-shp powerplant was used a a base-line vehicle. Both simple and heat-recovery cycles were evaluated, using trade factors to establish engine effects on helicopter direct operating cost (DOC), the optimization parameter assumed for purposes of illustration. Author

N87-10073# Societe Nationale Industrielle Aerospatiale, Marignane (France). Helicopter Div.
HELICOPTER AIR INTAKE PROTECTION SYSTEMS
X. DELASERVETTE and P. CABRIT *In* AGARD Engine-Airframe Integration for Rotorcraft 20 p (SEE N87-10067 01-05) May 1986
(AGARD-LS-148) Avail: NTIS HC A08/MF A01

The primary function of an engine air intake is to provide air supply with minimum pressure drop and distortion. Static or dynamic air intakes are selected according to both the type of engine air intake and the helicopter missions envisaged. The other function of an engine air intake is to protect the engine against foreign object ingestion, sand erosion, and the various atmospheric agents such as rain, snow, and ice. As a general rule, the air intake protection systems are all the more penalizing as regards performance as they are efficient. The best tradeoff is therefore between both functions. The dimensioning and test criteria for each function of an air intake is examined and then the various development stages are given for the SA 366 G1 Dauphin air intake as an example. Author

N87-10074# Army Aviation Systems Command, Saint Louis, MO. Engineering Dept.
ENGINE-AIRFRAME INTEGRATION FOR ROTORCRAFT: SYSTEM SPECIFICATIONS AND QUALIFICATION
J. A. RAY *In* AGARD Engine-Airframe Integration for Rotorcraft 10 p (SEE N87-10067 01-05) May 1986
(AGARD-LS-148) Avail: NTIS HC A08/MF A01

Both past history and current principles associated with engine-airframe integration for rotorcraft are provided as related to system specification requirements and the resulting qualification assurance. System specification requirements have evolved through periods of few details and lack of definitive requirements to the opposite extreme of exacting details and extremely specific requirements. The current trend of performance related specifications is intended to enhance the freedom of design while meeting the essential mission related requirements. This has required a revised qualification program effort to insure essential requirements are being met throughout the development effort. Lessons learned in this evaluation as well as current methods will be discussed for overall engine-airframe integration system requirement. In particular, system qualification will be addressed for such areas as adverse environment requirements for icing, cold/hot temperatures and sand/dust; mission related requirements for engine response, infrared signature reduction, and crashworthiness; and basic engine integration requirements for torsional stability, vibration, and cooling. Author

N87-15966# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
ROTORCRAFT ICING: PROGRESS AND POTENTIAL
Sep. 1986 140 p
(AGARD-AR-223; ISBN-92-835-1535-8; AD-A173807) Avail: NTIS HC A07/MF A01

Helicopter icing remains a significant operational consideration for military helicopters operating throughout Europe and northern parts of North America. The working group (WG09) considered the following objectives: (1) to examine rotorcraft icing analysis and modeling; (2) to consider new methods of ice protection; (3) to compare operational experience with ice protected rotorcraft with the design and qualification criteria presently established. The findings of an international group are presented including a comparison of icing atmosphere models and forecasting techniques and an assessment of predictive methods and simulation, flight clearance strategies and requirements. Various new methods of icing protection for rotorcraft are considered. Author

N87-16001# *Ferranti Defence Systems Ltd., Edinburgh (Scotland). Electro-Optics Dept.*
THE UNMANNED AIRCRAFT AS A FORCE MULTIPLIER
W. H. MCKENDRICK and MAURICE R. PACK-DAVISON *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 15 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

A principal role for small military remote piloted vehicles (RPVs) now and in the foreseeable future is to enhance the effectiveness of other weapon systems, in particular those capable of delivering munitions against distant targets. The requirement is for a force multiplier which can be used to increase weapon effectiveness and weaken the offensive and defensive capability of the enemy. How the RPV System design and configuration are influenced by a requirement to act as a force multiplier is discussed. The approach adopted is to concentrate initially on the target acquisition role and show how mission requirements impinge on every level of RPV system design. The discussion is then generalized to other weapon support roles and finally to the implication of a multiple-role capability on RPV system equipment and operation. Author

N87-16002# Naval Air Systems Command, Washington, DC.
NAVY TECHNOLOGY REQUIREMENTS FOR UNMANNED AIRBORNE VEHICLES
P. E. MULLOWNEY *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 5 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

Navy technology requirements for unmanned airborne vehicles are most unique in their shipboard launch, recovery, and maintainability. The current and future Remotely Piloted Vehicle (RPV) programs will demand cost and mission effective systems with a high degree of survivability. Cost effectiveness will be emphasized from the shipboard operation end of the problem, starting with storage, launch, remote piloting and data acquisition, through the tradeoff of expendability versus recovery, and shipboard maintenance and Instrument Landing System (ILS) concepts. Until the technology can provide RPVs fully integrated with shipboard operations, Navy applications will remain the same. B.G.

N87-16011# Naval Air Development Center, Warminster, PA. Aero Analysis Div.
HIGH ALTITUDE, LONG ENDURANCE RPV DESIGN TECHNOLOGY STUDY
CAMPBELL HENDERSON, EDWARD MCQUILLEN, and LARRY LEHMAN *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 14 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

The Naval Air Development Center conducted a design technology study of high altitude long endurance Remotely Piloted Vehicles (RPVs) for possible mission applications which might include surveillance, over the horizon communications, and targeting, among others. Phase 1 was to investigate technology levels and potential technology breakthroughs that can provide vehicle endurance of greater than 100 hours at altitudes greater than 60,000 feet, and to incorporate the technologies into conceptual vehicle designs. Thes results are presented. Author

N87-20176# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter Div.

DESIGN FOR REPAIRABILITY OF HELICOPTER COMPOSITE BLADES

M. HAHN *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 15 p (SEE N87-20174 13-01) Oct. 1986 (AGARD-CP-402) Avail: NTIS HC A11/MF A01

First a careful definition is made of the specific kinds of damages where repairability is aimed for. The criteria of repairability are described using the example of the main rotor blade. Then some repair procedures are detailed, starting with the criteria to be used to decide on repair level, showing components in particular and the aspects of design to repairability. Comparison of early and later design is used to demonstrate how improvement with respect to repairability was achieved. The concluding chapter describes service experience with the main and tail rotor blades, gained e.g., out of more than one mio. flight hours of BO 105-fleet. Author

N87-20210# British Aerospace Aircraft Group, Warton (England). Aerodynamics Dept.

THE INTEGRATION OF COMPUTATIONAL FLUID DYNAMICS INTO THE MILITARY AIRCRAFT DESIGN PROCESS

W. R. MARCHBANK *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 13 p (SEE N87-20199 13-02) Nov. 1986 (AGARD-CP-412) Avail: NTIS HC A19/MF A01

The rapid analysis and subsequent iterative refinement of aircraft shape is demonstrated by a number of applications of integrated CFD procedures, aimed at achieving specified supersonic performance. Without any reduction in transonic performance, the following complimentary benefits in the supersonic flight regime were established: (1) 5% reduction in drag through fuselage shaping; (2) 3% reduction in drag by decambering the wing through use of flaps; (3) 6% reduction in drag through a reduction in trim drag; (4) 15% increase in Thrust minus Drag through optimization of the intake flow field. Thus CFD based Project Procedures, used early in configuration design to refine the 3D lines, were used to increase supersonic turn rate by approximately 20%, for a fixed engine thrust, allowing supersonic design requirements to be met without penalizing transonic performance. Author

N87-20216# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Group.

EULER SOLUTION FOR A COMPLETE FIGHTER AIRCRAFT AT SUB- AND SUPERSONIC SPEED

ALBRECHT EBERLE and KENT MISEGADES (Cray Research, Inc., Mendota Heights, Minn.) *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 12 p (SEE N87-20199 13-02) Nov. 1986 (AGARD-CP-412) Avail: NTIS HC A19/MF A01

A survey is given on the construction of a novel high resolution Euler code which is applied for airflow calculations past a fighter type aircraft. The principle feature of the flow solver is a Godunov type averaging procedure based on the eigenvalue analysis of the Euler equations by means of which the fluxes are evaluated at the finite volume faces which separate constant sets of flow variables on either side. The procedure is third order accurate and locally monotonicity preserving thus avoiding the drawbacks of global TVD-schemes. The grid generation for complex configurations is performed from solutions of linear biharmonic equations with only one parameter prescribed by the program user. Vector computer performance of the explicit and implicit program versions are considered. Author

N87-20226# Boeing Military Airplane Development, Seattle, WA.

CALCULATIONS FOR A GENERIC FIGHTER AT SUPERSONIC HIGH-LIFT CONDITIONS

J. C. WAI, G. BLOM, and H. YOSHIHARA *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 8 p (SEE N87-20199 13-02) Nov. 1986 (AGARD-CP-412) Avail: NTIS HC A19/MF A01

The parabolized Navier/Stokes method was used to calculate the flow over a generic fighter configuration with a canard and underwing nacelles at supersonic high lift conditions. The calculated pressure distributions agreed closely with experiments, but the pitot pressure profile predictions for the boundary layer were less satisfactory largely due to an inadequate mesh in the viscous sublayer. Author

N87-21913# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

IDENTIFICATION OF DYNAMIC SYSTEMS - APPLICATIONS TO AIRCRAFT. PART 1: THE OUTPUT ERROR APPROACH

R. E. MAINE and K. W. ILIFF Dec. 1986 187 p (AGARD-AG-300-VOL-3-PT-1; ISBN-92-835-1540-4; AD-A178766) Avail: NTIS HC A09/MF A01

This document examines the practical application of parameter estimation methodology to the problem of estimating aircraft stability and control derivatives from flight test data. The primary purpose of the document is to present a comprehensive and unified picture of the entire parameter estimation process and its integration into the flight test program. The document concentrates on the output-error method to provide a focus for detailed examination and to allow us to give specific examples of situations that have arrisen in our experience. The document first derives the aircraft equations of motion in a form suitable for application to estimation of stability and control derivatives. It then discusses the issues that arise in adapting the equations to the limitations of analysis programs, using a specific program for an example. The document then addresses the roles and issues relating to mass distribution data, preflight predictions, maneuver design, flight scheduling, instrumentation sensors, data acquisition systems, and data processing. Finally, the document discusses evaluation and use of the analysis results. Author

N87-22663# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

IMPROVEMENT OF COMBAT PERFORMANCE FOR EXISTING AND FUTURE AIRCRAFT

Dec. 1986 143 p In ENGLISH and FRENCH Symposium held in Trevisco, Italy, 14-17 Apr. 1986 (AGARD-CP-409; ISBN-92-835-0408-9; AD-A184501) Avail: NTIS HC A07/MF A01

These proceedings contain the unclassified papers presented at the AGARD Flight Mechanics Panel Symposium on The Improvement of Combat Performance for Existing and Future Aircraft, held in Trevisco, Italy from 14 to 18 April 1986. In planning the enhancement of a defence capability to meet a growing threat within increasing financial constraints, it is invariably necessary, and is current practice in all NATO countries, to consider varying options for improvement of existing weapon systems as an alternative to embarking on totally new systems concepts. A wide range of technical options are now available to improve the overall performance of a weapon system. Many of these features are equally applicable for embodiment in new designs or in existing combat aircraft. In considering these varied options, cost and effectiveness remain the common constraints. For individual titles, see N87-22664 through N87-22675.

N87-22665# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).

PERFORMANCE IMPROVEMENT OF AIRBORNE WEAPON SYSTEMS METHODS, SCOPE AND LIMITATIONS

P. EBELING and R. HUBER *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 11 p (SEE N87-22663 16-05) Dec. 1986 (AGARD-CP-409) Avail: NTIS HC A07/MF A01

The performance improvement and the necessity to evaluate the overall and operational system performance improvement by use of systems assessment methods are discussed. These methods are briefly discussed using simple examples of former evaluations Author

N87-22666# Italian Air Staff, Rome.
SOME DEVELOPMENT TRENDS IN LIGHT GROUND ATTACK AIRCRAFT
R. TONINI, G. M. AVAGNINA, E. LOJACONO, and N. BRAGAGNOLO (Aeritalia S.p.A., Caselle Torinese, Italy) *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 16 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

The development of a light bomber attack aircraft, AM-X, is discussed. Specific design requirements and cost effectiveness, a mission effectiveness model, effectiveness tradeoffs, weapon systems and avionics are among the topics surveyed. R.J.F.

N87-22667# French Air Force, Paris. Nouveaux Avions de Combat Div.
WEAPON SYSTEMS POLYVALENCE: AN ECONOMIC AND OPERATIONAL CHALLENGE [POLYVALENCE DES SYSTEMES D'ARMES: UN DEFI ECONOMIQUE ET OPERATIONNEL]
JEAN-JACQUES FLOCH *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 5 p (SEE N87-22663 16-05) Dec. 1986 In FRENCH
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

With the broadening of the concept of the weapons system, air combat missions of the 1990's will include, in the course of a single mission, phases of flight during which air-to-air and air-to-ground capabilities will be alternately or even simultaneously put to the test. The notion of polyvalence is introduced and the importance of the concept to aircraft design and particularly aircraft weapon systems definition is discussed. The primary benefit of polyvalence is that it greatly extends the ability of combat aircraft to adapt to an evolving operational environment. Author

N87-22668# British Aerospace Public Ltd. Co., Kingston-upon-Thames (England). Aerodynamics Dept.
EVOLUTION OF COMBAT PERFORMANCE OF THE HAWK LIGHT COMBAT AIRCRAFT
S. F. STAPLETON and R. S. DABBS *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 11 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

The progressive evolution of the BAe Hawk from its original concept as the advanced flying trainer aircraft for the RAF to the currently planned developments as a light attack aircraft is reviewed. The developments are described in aerodynamics propulsion and systems to give improvement in performance and weapon delivery capability appropriate to effective light attack operational roles. Author

N87-22669# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Airplane Div.
INTEGRATED DESIGN OF STRUCTURES
O. SENSBURG, G. SCHMIDINGER, and K. FUELLHAS *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 20 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

It is shown that for highly sophisticated, naturally unstable airplanes flying supersonically a joint strategy to lay out the flight control system while minimizing design loads must be adopted. The selection of control surface geometry must be performed utilizing all possibilities from overall structural optimization including aeroelastic tailoring for primary carbon fiber structures. In the proposed design philosophy the behavior of the elastic airplane structure must be introduced and optimized in the very early design stage. It is shown that the required control surface hinge moments can be reduced by optimizing mass penalties and efficiencies. Minimizing installed hydraulic power supply has also a beneficial effect on engine performance at low speed, high altitudes. Author

N87-22671# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. X-29 Advanced Development Program Office.
X-29 INTEGRATING ADVANCED TECHNOLOGIES FOR TOMORROW'S AIR COMBAT
THOMAS M. WEEKS and JAMES R. PRUNER *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 13 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

The X-29 Advanced Technology Demonstrator Program is underway and in flight status at NASA Dryden Flight Research Facility. The joint US Air Force, NASA DARPA, Grumman Aerospace Corporation program is demonstrating a set of advanced airframe technologies for consideration by designers of tomorrow's combat aircraft. These technologies are described and preliminary quantitative results are discussed. These technologies are integrated within the X-29 airframe. Tomorrow's combat aircraft will require new, integrated technologies and will benefit from the X-29 integration experience base. The X-29 aircraft is being considered for several potential test bed demonstrations of new equipment and airframe concepts and will serve well in this role to satisfy near term requirements. Author

N87-22672# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SIMULATION OF AN INTEGRATED FLIGHT/FIRE CONTROL SYSTEM DURING AIR-TO-GROUND GUNNERY ATTACK [SIMULATION D'UNE SYSTEME INTEGRE DE COMMANDES DE VOL ET DE CONDUITE DE TIR CANON AIR-SOL]
B. DANG VU and C. LABURTHE *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 5 p (SEE N87-22663 16-05) Dec. 1986 In FRENCH
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

A fixed base simulation study demonstrated that an integrated flight/fire control (IFFC) system decreased pilot workload during an air-to-ground gunnery attack and improved airplane flying qualities in comparison with those of a conventional aircraft. The IFFC system was designed to use only standard on-board instrumentation, excluding sophisticated sensors (e.g., electro-optical). A preliminary investigation of direct side force showed that it does not provide significant improvements in aiming effectiveness. Author

N87-22675# British Aerospace Public Ltd. Co., Lancashire (England). Military Aircraft Div.
THE ASSESSMENT AND EVALUATION OF COMBAT PERFORMANCE IMPROVEMENTS
A. G. BARNES *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 8 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

Aircraft performance improvements, for combat or any other operational role, are becoming increasingly difficult to achieve. The dramatic year-by-year advances of the forties and fifties are long gone. Aerodynamicists have a much better understanding of the physical properties of the atmosphere and the shapes which can best be propelled through it. The relationships between the energy in fuel, and the conversion process into thrust are well developed. Structural engineers understand the mechanical properties of materials needed to build engines and airframes. All these factors have been exploited, and further improvements do not come cheaply. Only in the area of avionics can it be said that large benefits in the weight/cost/performance trade-off can be expected. The use of mathematical models, current simulation capabilities, tradeoff studies, and operational tactics are discussed. Author

N87-23609# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AIRCRAFT DYNAMIC RESPONSE TO DAMAGED AND REPAIRED RUNWAYS
Mar. 1987 45 p Meeting held in Oberammergau, West Germany, 8-13 Sep. 1985
(AGARD-R-739; ISBN-92-835-0409-7; AD-A181678) Avail: NTIS HC A03/MF A01

The dynamic response of aircraft operating from damaged and repaired runways is examined. The response of a simplified

representation of an aircraft to two discrete disturbances is analyzed to see how the second disturbance modifies system behavior caused by the first disturbance. A mathematical model is provided which can be used for calculation of the dynamic response of aircraft structures operating on rough surfaces; a comparison is made between theoretical predictions for a YF16 aircraft and typical measurements from frequency response tests. For individual titles, see N87-23610 through N87-23611.

N87-23610# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Structures and Dynamics Div.

INTERPRETATION IN TERMS OF THE RESPONSE OF A ONE DEGREE-OF-FREEDOM OSCILLATOR TO TWO SUCCESSIVE DISTURBANCES

JAMES J. OLSEN *In* AGARD Aircraft Dynamic Response to Damaged and Repaired Runways 22 p (SEE N87-23609 17-05) Mar. 1987

(AGARD-R-739) Avail: NTIS HC A03/MF A01

The dynamic response of an aircraft that taxies over two arbitrary disturbances, under the assumption that the aircraft can be represented as a linear, one degree-of-freedom system is explained. That analysis produced the concept of the BUMP MULTIPLIER which explicitly and simply determines whether a second discrete disturbance will amplify or attenuate the response from a first disturbance. The BUMP MULTIPLIER also simplifies the understanding and presentation of the results. While the assumptions are very severe, the resulting formulas can be very useful to guide more elaborate nonlinear calculations or to plan test programs. Author

N87-23611# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. of Aeroelasticity.

AN EXPERIMENTAL-ANALYTICAL ROUTINE FOR THE DYNAMIC QUALIFICATION OF AIRCRAFT OPERATING ON ROUGH RUNWAY SURFACES

R. FREYMANN *In* AGARD Aircraft Dynamic Response to Damaged and Repaired Runways 14 p (SEE N87-23609 17-05) Mar. 1987

(AGARD-R-739) Avail: NTIS HC A03/MF A01

A mathematical model to be used as a basis for analytical investigations to predict the dynamic structural response of flexible aircraft operating on rough runway surfaces is presented. It is shown how the structural parameters included in the aircraft generalized equations of motion are determined in a ground vibration test on the real aircraft structure and in additional tests on components of the undercarriage. The validation of the developed mathematical model is achieved by a comparison of typical results from frequency response tests and calculations performed on a YF-16 prototype fighter aircraft. Finally, the way in which the developed mathematical model can be used in combination with various systematic test procedures for the dynamic qualification process of aircraft operation on damages/repaired runways is indicated. Author

N87-24445# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

INTEGRATED DESIGN OF ADVANCED FIGHTERS

May 1987 213 p Lectures held in London, England, 1-2 Jun. 1987; in Lisbon, Portugal; and in Los Angeles, Calif., 23-24 Jun. 1987

(AGARD-LS-153; ISBN-92-835-1552-8; AD-A185224) Avail: NTIS HC A10/MF A01

A general overview of the state of the art in modern fighter design is presented, with an introduction to the innovations of computer aided design evaluation to both preliminary design and the final optimization of the various design compromises. After the introduction reviewing the evolution of the modern fighter aircraft, the various stages of the total design problem is developed. The integration of requirements into the preliminary configuration of the design is followed by discussions of modern design techniques that are currently used to assess and validate the evolving configuration. The overall integrations process as applied to various current design challenges are considered including multi-role aircraft, shipborne operators and VSTOL and STOVL concepts. For individual titles, see N87-24446 through N87-24454.

N87-24446# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).

INTEGRATION OF AERODYNAMIC, PERFORMANCE, STABILITY AND CONTROL REQUIREMENTS INTO THE DESIGN PROCESS OF MODERN UNSTABLE FIGHTER AIRCRAFT CONFIGURATIONS

G. WEDEKIND and P. MANGOLD *In* AGARD Integrated Design of Advanced Fighters (date) 20 p (SEE N87-24445 18-05) May 1987

(AGARD-LS-153) Avail: NTIS HC A10/MF A01

Already in the early design stage of a modern fighter aircraft development with usually unstable basic characteristics in pitch, a well balanced compromise between optimum performance and excellent handling qualities has to be found. This compromise must be based on sufficient margins for stability and control, maneuverability in terms of agility and economic aspects which usually are in contradiction to pure performance requirements as for example sustained/instantaneous turn rates and high specific excess power. Reasonable criteria deducted from flight mechanical and control law design point of view are discussed, which lead straight ahead towards a set of desirable longitudinal and lateral characteristics for the basic unaugmented aircraft. These requirements impose remarkable constraints for the aerodynamic design of a fighter and its elements like wing planform, strakes, vertical fins and horizontal tail size and location. The problems and possibilities to stay within the reasonable flight mechanical limits are demonstrated. Author

N87-24447# Northrop Corp., Hawthorne, CA. Flight Control Engineering.

SIMULATION AS A FIGHTER DESIGN TOOL

J. L. LOCKENOUR *In* AGARD Integrated Design of Advanced Fighters 34 p (SEE N87-24445 18-05) May 1987

(AGARD-LS-153) Avail: NTIS HC A10/MF A01

Simulation has been playing a growing role in the development of fighter aircraft weapon systems. In the 60's and early 70's simulation was almost exclusively the tool of the engineers responsible for the flight control and flying qualities of the airplane. However, in the last 10 to 15 years, simulation has seen an ever increasing usage for tactics, crew workload and mission avionics assessment. The current status of real time, pilot-in-the-loop flight simulation is reviewed. Examples are presented of simulators as is a brief discussion of the components of a flight simulator with emphasis on the features of importance to the user. Fidelity as it relates to the perception of the pilot and his task performance is discussed. Data is given on the motion and visual requirements. Key topics are also presented in experimental design including task selection, pilot factors and data collection. An enumeration of technology improvements already on the horizon which are expected to make a major impact on simulation is also given. Author

N87-24448# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Div.

FLIGHT TESTING OF FIGHTER AIRCRAFT

A. KNAUS and K. H. BURGER *In* AGARD Integrated Design of Advanced Fighters 21 p (SEE N87-24445 18-05) May 1987

(AGARD-LS-153) Avail: NTIS HC A10/MF A01

A realistic overall picture about flight testing of fighter aircraft today and trends for the future is given. It is shown whether, where and to what extent flight testing is and will be necessary. Especially the implications of advanced fighter aircraft concepts on the test program are discussed regarding the high technology standard of the complete weapon system and the operational requirements. It is concluded that best equipped facilities together with a well organized management are mandatory. The introduction of up-to-date scientific computer systems and the development of new software seems to be a permanent requirement to handle the streams of data which confront the flight test engineer. Early plannings and preparations are required to integrate as many tasks as possible per flight in order to save expensive flying time. Finally, an overview of flight test disciplines is given. It is shown that flight test is an universal discipline. Consequently areas of main test effort only and corresponding test methods to be applied are discussed in more detail. Author

N87-24449# Britisn Aerospace Aircraft Group, Kingston-upon-Thames (England).
CARRIAGE OF EXTERNAL STORES
CLIFFORD L. BORE *In* AGARD Integrated Design of Advanced Fighters 23 p (SEE N87-24445 18-05) May 1987
(AGARD-LS-153) Avail: NTIS HC A10/MF A01

The main interactions between the external stores and fighter aircraft as a whole are considered. Since the context is that of fighter design, the understanding of the magnitude of those efforts which can be chosen by designers is concentrated on. The factors affect the overall value of a fighter airforce as a whole, so that the sensitivity of value to these factors can be appreciated. Then the influence of the separate factors is considered: drag and other installed forces, trajectory testing in wind tunnels, stability and flutter, agility, and airframe/store integration. Author

N87-24450# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
DESIGN OPTIMIZATION FOR A FAMILY OF MULTI-ROLE COMBAT AIRCRAFT
JEAN-CLAUDE HIRONDE *In* AGARD Integrated Design of Advanced Fighters 23 p (SEE N87-24445 18-05) May 1987
(AGARD-LS-153) Avail: NTIS HC A10/MF A01

The future multi-role combat aircraft design process is used as an example. At the early stage of the design, requirements of the French Air Force and Navy and other potential customers are studied very closely. Then the main technological improvements, from the existing aircraft, that are needed to meet these requirements are clearly defined. The improvements are achieved by an optimization process carried throughout each and all aircraft design disciplines, involving an intensive use of the very large range of design and tests tools available from the aircraft company and state research establishments. Because of the numerous technical innovations which will be introduced in the future combat aircraft, an in-flight demonstration aircraft was judged necessary. The RAFALE demonstration aircraft, and the evolution into a future family of multi-role specific versions, is presented. Author

N87-24451# McDonnell Aircraft Co., Saint Louis, MO. Aircraft Engineering.
DESIGN OPTIMIZATION OF FIGHTER AIRCRAFT
D. D. SNYDER *In* AGARD Integrated Design of Advanced Fighters 20 p (SEE N87-24445 18-05) May 1987
(AGARD-LS-153) Avail: NTIS HC A10/MF A01

The explosion of digital computation capability over the last 30 years has transformed the military aircraft design process, and provided unprecedented opportunity for true optimization of selected configurations prior to production commitment. To date, this revolution has worked primarily to reduce risk in aircraft development. Today's new aircraft flies as expected, without unforeseen handling quirks or instability, and exploration of most, if not all the flight envelope is possible on the first flight. Digital flight simulation, sophisticated wind tunnel test techniques, and performance, structural and thermal modeling all combine to elevate confidence in a new design to a very high level. Another, as yet unrealized benefit is an enormous potential improvement in productivity and efficiency, and therefore cost, of the aircraft design and manufacturing process. Insight is provided into the modern aircraft development process from the perspective of a designer and builder of high performance military fighter, McDonnell Aircraft Co. Author

N87-24452# British Aerospace Aircraft Group, Kingston-upon-Thames (England).
V/STOL AND STOVL FIGHTER DESIGN
CLIFFORD L. BORE *In* AGARD Integrated Design of Advanced Fighters 20 p (SEE N87-24445 18-05) May 1987
(AGARD-LS-153) Avail: NTIS HC A10/MF A01

A wide range of basing concepts, including dispersed land bases, small and very small ships, ski jump and Skyhook, are reviewed. The design of STOVL fighter aircraft is examined, starting from consideration of the engine and nozzles system, which is the heart of jet powered STOVL fighters. This leads to consideration of the nature of the aerodynamics of vertical landing, such as hot gas ingestion, jet induced suck-down and the ground/jets fountain. Then the special features of air intakes design are considered, followed by the special considerations of lifting-surface design. Finally, the special features of thrust vectoring in forward flight (VIFF), are considered. Author

N87-24453# Societe pour l'Equipment des Vehicules, Gosselies (Belgium).
ADVANCED FIGHTER DESIGN: OPERATIONAL EXPERIENCE AND FUTURE REQUIREMENTS
D. AGNEESSENS *In* AGARD Integrated Design of Advanced Fighters 14 p (SEE N87-24445 18-05) May 1987
(AGARD-LS-153) Avail: NTIS HC A10/MF A01

The possibilities of the F84F, Mirage 5, the F104G and the F-16 are compared. The deficiencies that they show for the mission for which they are employed are examined. Before these aircraft are analyzed, it is necessary to state in what role each they are employed. To do this, the requirements have to be considered. These are mostly imposed by NATO, but national requirements could also be considered. Due to the large variety of missions to be performed, in the air-to-air (A/A) or in the air-to-ground (A/G) roles, it is evident that non specialized aircraft will be used and also low cost aircraft will be chosen more and more often. This analysis is limited to the different aircraft which were or are still in use in European airforces or more generally in the European theater of operations. This theater is very demanding due to different factors such as the threat and the weather. The concept of multi-role aircraft, being considered as the ideal choice by many, is discussed as a response to the variety of requirements in the European theater. Another point that is discussed is pilot training in peace time. The use of simulators is mentioned to show how it is possible to maintain a high level of proficiency for the pilots. Author

N87-24454# Air Force Systems Command, Andrews AFB, MD. Test and Evaluation.
THE INTEGRATION AND OPERATIONAL SUITABILITY OF EMERGING TECHNOLOGIES FOR FUTURE FIGHTER AIRCRAFT: A PILOT'S PERSPECTIVE
JOHN M. HOFFMAN *In* AGARD Integrated Design of Advanced Fighters 9 p (SEE N87-24445 18-05) May 1987
(AGARD-LS-153) Avail: NTIS HC A10/MF A01

The tactical air mission has become extremely challenging and complex due to improvements in ground defenses and sophistication of opposing threat air forces. To fight, survive, and win in this demanding environment, the capabilities must be developed which are needed by the tactical pilots to successfully counter the threat. Technological developments have fostered a host of new capabilities for application to future aircraft. A pilot's perspective on the development, integration, and application of these emerging technologies for the air superiority mission is provided. Of real concern is determining which capabilities will be most useful to the pilot, yet not overload or exceed his capacity to perform. Assessments are based on personal experiences in combat, in flight testing applications in current fighter aircraft, and on plans for incorporation in future fighter aircraft. The pilot/vehicle interface and enhanced pilot performance is the central focus, conditioned by operational suitability. Key factors include information or task saturation, situational awareness, physiological limitations, and cockpit designs. The concept of Fighter Battle Management is introduced. Author

N88-10812# Royal Aircraft Establishment, Farnborough (England).
TOWARDS THE UNMANNED COCKPIT
BRIAN ELLIS *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

Trends in air warfare make the development of autonomous unmanned aircraft necessary. Advances in intelligent knowledge-based systems (IKBS) and in computing technology will make it possible. The case for unmanned aircraft and their probable evolution is made. Some indications are offered of the developments that will be called for in the IKBS themselves and in the computing hardware. Author

N88-11649# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

ROTORCRAFT DESIGN FOR OPERATIONS

Jun. 1987 319 p In ENGLISH and FRENCH Symposium held in Amsterdam, Netherlands, 13-16 Oct. 1986

(AGARD-CP-423; ISBN-92-835-0420-8; AD-A199169) Avail: NTIS HC A14/MF A01

The objective was to explore the impact of operational needs on the evolution of rotorcraft design. The status of rotorcraft design is reviewed and priorities and neglected topics are discussed. For individual titles, see N88-11650 through N88-11672.

N88-11650# Army Aviation Systems Command, Saint Louis, MO.

THE INFLUENCE OF OPERATIONAL REQUIREMENTS ON LHX CONCEPT FORMULATION

ROBERT D. HUBBARD and ROBERT L. TOMAINE *In* AGARD, Rotorcraft Design for Operations 8 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The U.S. Army's Light Helicopter Family (LHX) program which is currently in concept formation is discussed. The activities associated with concept formation including governing regulations, how the process is executed, the scope of the effort involved and innovations included for LHX are discussed. The evolution of the requirements is emphasized and the focus is on how the operational requirements drive the engineering requirements and ultimately the design of the aircraft. Operational requirements are driven by the LHX concept, namely, a family of Scout/Attack (LHX/SCAT) and Utility (LHX-U) aircraft with common dynamic components, core mission equipment and common subsystems. The impacts of the unique LHX-SCAT aircraft on the design of and commonality with the LHX-U are discussed. The operational requirements are categorized into those associated with the Army 21 concept of the future battlefield, the threat, safety and reliability, and availability and maintainability. Each category results in several specific design impacts. Author

N88-11651# KLM Helikopters B.V., Amsterdam (Netherlands).

DESIGN REQUIREMENTS FOR FUTURE COMMERCIAL OPERATIONS

F. F. J. SCHAPER *In* AGARD, Rotorcraft Design for Operations 14 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

Design requirements for helicopters stemming from civil operations are discussed. The offshore oil and gas industry is and will continue to be the main application of civil helicopters. Development of other commercial markets will require major improvements in almost all areas. Some of these areas are highlighted, including: safety, reliability, cockpit ergonomics, and vibration. The current rate of progress is considered to be much too slow and concern is expressed about military and civil requirements drifting too far apart. Designers of new military helicopters should be aware of these civil requirements and take them into account as much as possible. Author

N88-11652# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.

MISSION-ORIENTED FLYING QUALITIES CRITERIA FOR HELICOPTER DESIGN VIA IN-FLIGHT SIMULATION

B. GMELIN, H.-J. PAUSDER, and P. HAMEL *In* AGARD, Rotorcraft Design for Operations 14 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

Some recent activities and results in the fields of rotorcraft in-flight simulation are presented. The following general conclusions were drawn: (1) general purpose in-flight simulators will play a decisive role in the rotorcraft design, evaluation, development, and certification process; (2) the capability of in-flight simulators will support industry to meet the demands for future rotorcraft systems and to reduce the costs and risks of development programs; and (3) for the generation of generic flying qualities, test vehicles providing adequate mission performance and variable characteristics are required. Author

N88-11657# Army Aviation Research and Development Command, Moffett Field, CA.

MODELING XV-15 TILT-ROTOR AIRCRAFT DYNAMICS BY FREQUENCY AND TIME-DOMAIN IDENTIFICATION TECHNIQUES

MARK B. TISCHLER and JUERGEN KALETKA (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick, West Germany) *In* AGARD, Rotorcraft Design for Operations 20 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

Models of the open-loop hover dynamics of the XV-15 Tilt-Rotor Aircraft are extracted from flight data using two approaches: frequency domain and time-domain identification. Both approaches are reviewed and the identification results are presented and compared in detail. The extracted models are compared favorably, with the differences associated mostly with the inherent weighing of each technique. Step responses are used to show that the predictive capability of the models from both techniques is excellent. Based on the results of this study, the relative strengths and weaknesses of the frequency and time-domain techniques are summarized and a proposal for a coordinated parameter identification approach is presented. Author

N88-11658# Royal Aircraft Establishment, Farnborough (England).

OPERATIONAL LOAD MEASUREMENTS ON SERVICE HELICOPTERS

DOROTHY M. HOLFORD *In* AGARD, Rotorcraft Design for Operations 12 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The philosophy of operational load measurement programs as applied to rotary wing aircraft is reviewed. A major aim is to substantiate component fatigue lives in the light of operational usage. The aircraft installation to meet the needs of the programs is described. The analysis techniques, which are designed to provide the operator and engineer with a view of the origins of fatigue damage, are described. Problem areas in comprehensive fatigue monitoring systems are discussed. Author

N88-11663# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).

IMPACTS OF ROTOR HUB DESIGN CRITERIA ON THE OPERATIONAL CAPABILITIES OF ROTORCRAFT SYSTEMS

R. SCHINDLER and E. PFISTERER *In* AGARD, Rotorcraft Design for Operations 23 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

Starting with the description of the different design principles of articulated, see-saw, hingeless and bearingless rotor concepts, a variety of realized constructions is presented and discussed. The flight mechanic aspects such as maneuverability and handling qualities are explained with respect to their operational capabilities. The differences in the flapping hinge offset are discussed. The trend of the flapping hinge offset over three decades of armed and utility helicopters is analyzed. Author

N88-11664# Societe Nationale Industrielle Aerospatiale, Marignane (France). Helicopter Div.

NEW AERODYNAMIC DESIGN OF THE FENESTRON FOR IMPROVED PERFORMANCE

A. VUILLET and F. MORELLI *In* AGARD, Rotorcraft Design for Operations 11 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

A general definition of the fenestron and its advantages for civil and military helicopters are given. A detailed airflow analysis through the fenestron was recently achieved on the tail rotor bench in hover. The experimental technique and the flow measurements are surveyed. Also presented are the correlations made with blade element theory as well as more advanced analysis derived from a radial equilibrium code in use for compressors. Author

N88-11665# Sikorsky Aircraft, Stratford, CT. Research and Advanced Design.

ROTORCRAFT DESIGNS FOR THE YEAR 2000

EVAN A. FRADENBURGH *In* AGARD, Rotorcraft Design for Operations 11 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

Some of the rotorcraft concepts that can offer higher speeds than the pure helicopter, including the compound helicopter, ABC,

tilt-rotor, X-wing, and stowed rotor configurations are discussed. All of these are potentially practical aircraft. Economic considerations will dictate that the pure helicopter is here to stay; higher speed rotorcraft are not as cost effective at short distances. Also examined is the approach to helicopter sizing for heavy-lift applications. It is concluded that a super-large helicopter, sized to carry the heaviest payload needed, is unaffordable. A better solution is to develop a moderately large helicopter that will carry most of the required loads, and to use the twin-lift technique to transport the occasional extra-heavy load. Author

N88-11666# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
HELICOPTER (PERFORMANCE) MANAGEMENT
WINFRIED BENNER and ROLF DUESSMAN *In* AGARD, Rotorcraft Design for Operations 9 p (SEE N88-11649 03-05) Jun. 1987
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The next generation of military helicopters will have to fly under night and adverse weather conditions below tree top level. Dornier System started 15 years ago to develop avionic systems with a performance that would allow pilots to fly the new missions. In the Dornier baseline display cockpit concept the first steps of the Helicopter Management System (HMS) will be realized. Here, the main aspects of the system are discussed. The main parts are the mission planning system on the ground and the HMS onboard the helicopter. Author

N88-11669# Costruzioni Aeronautiche Giovanni Agusta S.p.A., Varese (Italy).
A129 ADVANCED SOLUTIONS FOR MEETING TODAY'S COMBAT HELICOPTER REQUIREMENT
GIUSEPPE VIRTUANI *In* AGARD, Rotorcraft Design for Operations 9 p (SEE N88-11649 03-05) Jun. 1987
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

It is argued that the A129 light attack helicopter represents the answer to modern and severe operational requirements. The main rotar hub and transmission are described as examples of unconventional and advanced technology design. The engine installation represents the case of a configuration where the operative requirement induced a deep physical integration among the subsystems. The large computer structure, the integrated multiplexing system based on the multiplexing and microprocessor technologies, constitutes a major example of functional integration between the helicopter and mission subsystem. Author

N88-11670# McDonnell-Douglas Helicopter Co., Mesa, AZ. Advanced Engineering.
APACHE FOR THE BATTLEFIELD OF TODAY AND THE 21ST CENTURY
JAMES B. RORKE *In* AGARD, Rotorcraft Design for Operations 13 p (SEE N88-11649 03-05) Jun. 1987
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The AH-64A Apache is in service with the U.S. Army. The operational requirements which drove the the design of the Apache and caused this particular combination of attributes are documented. The attributes discussed include performance, survivability, crashworthiness, transportability, deployability, navigation, target acquisition and weapon systems. Author

N88-11672# Agusta S.p.A., Milan (Italy).
THE EH-101 INTEGRATED PROJECT: A NAVAL, UTILITY AND COMMERCIAL HELICOPTER SYSTEM
PIETRO ALLI, RUGGERO BALDASSARRINI, GIOVANNI MARZORATI, GIOVANNI PAGLIARO, and LUCIANO ARMITI *In* AGARD, Rotorcraft Design for Operations 32 p (SEE N88-11649 03-05) Jun. 1987
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The Royal Navy and Marina Militare Italiana tasked EHI to develop a new shipborne helicopter. The two Navies defined a common set of requirements related to the basic common helicopter plus a dedicated different set for each specific mission. Concurrently EHI performed autonomous research on the potential EH 101 civil and utility market. through those analysis EHI came to the conclusion that a common basic helicopter could satisfy all of the requirements even if the roles were sometimes very different. The rationale and the trade off approach which were successfully devised and implemented to produce an aircraft with the best compromise of performance and cost are given. Author

N88-12481# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
DEVELOPMENTAL AIRDROP TESTING TECHNIQUES AND DEVICES
H. J. HUNTER and R. K. BOGUE, ed. Sep. 1987 97 p
(AGARD-AG-300-VOL-6; ISBN-92-835-1559-5; AD-A189621)
Avail: NTIS HC A05/MF A01

The practical aspects of planning, conducting, and reporting on developmental airdrop tests made from cargo transport type aircraft are presented. Typical cargo aircraft aerial delivery systems, parachute extraction systems, and special devices and rigging techniques are described in detail. Typical instrumentation systems for obtaining aircraft and parachute systems force data are also described and piloting techniques for various airdrop methods are briefly discussed. A scenario of a typical parachute tow test is used to demonstrate the application of these techniques and the use of challenge and response checklists among the flight crewmembers. Finally the use of reports is discussed and appendices are included with many useful charts and calculations that are readily applicable in research and development airdrop testing. Author

N88-13244# Lockheed-California Co., Burbank.
THE OFF-DESIGN PERFORMANCE OF HYPERSONIC WAVERIDERS
LYLE N. LONG *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 14 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Waveriders are being considered more and more as potential aerospace vehicles. However there are several questions regarding these configurations that must be answered before they can be considered viable designs. The most significant problems are related to aerothermal heating, propulsion integration, and off-design performance. Off-design performance predictions for two generic waveriders are presented. The results are from a numerical method based upon the nonlinear, inviscid Euler equations. Comparisons to experimental data are also shown. Author

N88-13245*# Maryland Univ., College Park. Dept. of Aerospace Engineering.
NUMERICAL OPTIMIZATION OF CONICAL FLOW WAVERIDERS INCLUDING DETAILED VISCOUS EFFECTS
KEVIN G. BOWCUTT, JOHN D. ANDERSON, JR., and DIEGO CAPRIOTTI *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 23 p (SEE N88-13219 05-02) Nov. 1987 Sponsored in part by NASA Langley Research Office, Hampton, Va. and Army Research Office, Washington, D.C.
(AGARD-CP-428) Avail: NTIS HC A24/MF A01 CSCL 01A

A family of optimized hypersonic waveriders is generated and studied wherein detailed viscous effects are included within the optimization process itself. This is in contrast to previous optimized waverider work, wherein purely inviscid flow is used to obtain the waverider shapes. For the present waveriders, the undersurface is a streamsurface of an inviscid conical flowfield, the upper surface is a streamsurface of the inviscid flow over a tapered cylinder (calculated by the axisymmetric method of characteristics), and the viscous effects are treated by integral solutions of the boundary layer equations. Transition from laminar to turbulent flow is included within the viscous calculations. The optimization is carried out using a nonlinear simplex method. The resulting family of viscous hypersonic waveriders yields predicted high values of lift/drag, high enough to break the L/D barrier based on experience with other hypersonic configurations. Moreover, the numerical optimization process for the viscous waveriders results in distinctly different shapes compared to previous work with inviscid-designed waveriders. Also, the fine details of the viscous solution, such as how the shear stress is distributed over the surface, and the location of transition, are crucial to the details of the resulting wavender geometry. Finally, the moment coefficient variations and heat transfer distributions associated with the viscous optimized waveriders are studied. Author

N88-13248# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Aeromechanics Div.
LIFTING BODIES: AN ATTRACTIVE AERODYNAMIC CONFIGURATION CHOICE FOR HYPERVELOCITY VEHICLES
ALFRED C. DRAPER and MELVIN L. BUCK *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 44 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

A brief chronology is given of the lifting body configurations investigated by the Flight Dynamics Laboratory, along with their aeroperformance capabilities including ASSET, PRIME, the X-24A, and the X-24B. Also included is a brief discussion of lifting body applications at supercircular velocities such as the SORTIE. The impact of basic geometric and component effects on aerodynamic performance parameters is addressed. These results were then translated into an aerodynamic configuration which eliminates the aft vertical fins without degrading the hypersonic lift-to-drag ratio while maintaining directional stability. Additionally, the benefits and applicability are examined. Specifically, the more significant methods such as the Hypersonic Arbitrary Body Program (HABP), PANAIR, Euler, Parabolized Navier-Stokes (PNS), and Navier-Stokes (NS) codes are discussed. Experimental capabilities and needs are discussed and finally, long term goals for future lifting body configurations are assessed. Author

N88-13315# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON FUNDAMENTALS OF FIGHTER AIRCRAFT DESIGN
Oct. 1987 290 p Course held in Rhode-St-Genese, Belgium, 17-21 Feb. 1986, in Athens, Greece, 24-25 Feb. 1986, and in Ankara, Turkey, 27-28 Feb. 1986
(AGARD-R-740; ISBN-92-835-1560-9; AD-A192214) Avail: NTIS HC A13/MF A01

The Special Course on the Fundamentals of Fighter Aircraft was sponsored by the AGARD Fluid Dynamics Panel and the von Karman Institute and presented at the latter in Rhode-Saint-Genese, Belgium, 17 to 21 February 1986, at the Greek Air Force Academy, Athens, Greece, 24 to 25 February 1986, and at the ARGE, Ankara, Turkey, 27 to 28 February 1986. The Course presented a comprehensive review of fundamental procedures used during a fighter pre-development phase concentrating on the following: basic mission requirements and aircraft sizing; aerodynamic design including performance, stability and control; materials, structural optimization and aeroelasticity; aircraft dynamics; engine intake and nozzle integration; and airframe store-compatibility. Experimental and theoretical work has been demonstrated to play complementary roles and, in conclusion, recommendations are given for future development of engineering tools. For individual titles, see N88-13316 through N88-13327.

N88-13316# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Div.
FUNDAMENTALS OF FIGHTER AIRCRAFT DESIGN
P. W. SACHER *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 5 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

Following the technical program of the AGARD Fluid Dynamics Panel (FDP) for the past few years, the aeronautical engineer has found many subjects related to a special technical discipline and directed to industrial applications. But in nearly all cases the analysis of given geometry by experimental or theoretical techniques has overruled the more important engineering task, i.e., the design of a new shape which has desired properties. But in all cases concerning successful flying aircraft the result of engineering work has been a design compromise achieved by the fruitful cooperation of all technically relevant disciplines. Therefore, one of the most important intentions of this course has been to attract people from different aeronautical disciplines, working in industry and research institutes, and to look for links within the different branches of aerodynamics such as Wind Tunnel Test Techniques, Computational Fluid Dynamics, Vortex Dynamics, Unsteady Aerodynamics, Viscous Flow Drag Prediction, and their impact on designing aircraft components. Author

N88-13317# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Design Branch.
MISSION REQUIREMENTS AND AIRCRAFT SIZING
JAMES L. PARKER *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 46 p (SEE N88-13315 05-05) Oct. 1987 Previously announced in IAA as A87-17881
(AGARD-R-740) Avail: NTIS HC A13/MF A01

The development of requirements for new fighter aircraft involves defining threats, targets, and air combat scenarios for the future. Current fighter requirements emphasize the need for close-in combat and beyond-visual-range combat capability to achieve superiority in the air-to-air role. High sortie rates and the ability to perform air-to-surface missions are also primary requirements. Conceptual design and aircraft sizing are used to help define requirements. With conceptual design tools, different fighter designs can be sized for different missions. These configurations allow life cycle cost and effectiveness analysis to be performed, which provide the basis for the definition of the requirement to be constrained to a technologically feasible and economically affordable solution. Author

N88-13318# Boeing Military Airplane Development, Seattle, WA.
DESIGN OF WINGS AND WING/BODY CONFIGURATIONS FOR TRANSONIC AND SUPERSONIC SPEEDS
H. YOSHIHARA *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 19 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

Procedures to design wing/fuselage configurations at transonic and supersonic conditions are described. This is preceded by an introductory section sketching the significant flow features as the shock wave and separation patterns for typical fighter wings which affect the performance, followed by a description of the interference effects due to the fuselage. Author

N88-13320# National Research Council of Canada, Ottawa (Ontario). Unsteady Aerodynamics Lab.
AIRCRAFT DYNAMICS: AERODYNAMIC ASPECTS AND WIND TUNNEL TECHNIQUES
K. J. ORLIK-RUECKEMANN *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 30 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

The dynamic behavior of modern fighter aircraft depends more and more on unsteady aerodynamics. Until recently, the designer concentrated on classical problems such as aeroelasticity and flutter. Dynamic stability parameters were most often determined by low angle-of-attack calculation methods, without much recourse to experiment. The results obtained from the few dynamic experiments performed were used to confirm the absence of problems rather than as design parameters. New requirements for fighter aircraft performance include the ability to fly at high angles of attack in the presence of extensive regions of separated or vortical flows, relaxed static stability, greatly increased agility, and an interest in unorthodox geometries such as closely-coupled-canard or tail-first configurations. The time lags and unsteady phenomena associated with flow fields resulting from rapid maneuvers and large amplitude motions significantly affect the dynamic behavior of modern fighter aircraft and become as important for aircraft design as the classical static performance criteria. A review is made of the various aerodynamic aspects affecting aircraft dynamic behavior, followed by a survey of the most pertinent experimental techniques.

N88-13321# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France). Div. des Etudes Avancees.
TECHNIQUES FOR PERFORMANCE OPTIMISATION IN CRUISE AND MANOEUVERABILITY
PIERRE PERRIER *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 12 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

The design of a combat aircraft cannot be left to trial and error design when a definite performance target is precisely defined. It is obvious that there is a large variation in the possible aerodynamic aircraft shapes having the internal volume required for fuel, engine, equipment and weapon system accommodation. Among all possible shapes, the best aircraft will have definite

advantages over a poor design in terms of performance for a given cost or in terms of cost for given performance. The best aerodynamic definition need no longer be left to the designers in the design office when efficient theoretical-experimental processes of optimization are available in the aircraft industry. Presented is the state of the art of the reflection and application of optimization, i.e., the latter's targets and tools, and some results and perspectives in combat aircraft design are reviewed. Author

N88-13322# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
FUNDAMENTALS OF FIGHTER AIRCRAFT DESIGN: ENGINE INTAKE AND AFTERBODY
J. LEYNAERT *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 39 p (SEE N88-13315 05-05) Oct. 1987 Previously announced in IAA as A87-21014
(AGARD-R-740) Avail: NTIS HC A13/MF A01

Basic conditions, study parameters, and various solutions of fighter intake and afterbody (except VTOL) are reviewed. Airframe integration and intake adaptation to the flight Mach number are discussed. The following topics of intake flow are analyzed: buzz phenomena, internal bleed flow, high incidence, low speed, mean flow, distortion index, and unsteady distortion. The afterbody discussion covers variable geometry, thrust vectoring, and reverse. Wind tunnel test techniques are also described. Author

N88-13323# British Aerospace Public Ltd. Co., Kingston-upon-Thames (England).
AIRFRAME/STORE COMPATIBILITY
C. L. BORE *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 27 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

By considering the various parameters dominating the value of a fighter air force, those terms can be isolated which respond to influences of store release features. It is shown that stores affect the transport capacity of the air force through the lift/drag ratio, the availability factor through the agility term, and the target-killing factor through the delivery accuracy term. The physical effects of store installation are then examined, and ways identified to minimize undesirable effects. Thus, drag prediction and drag reduction are considered in some depth. The effects of drag on the agility of the aircraft are examined and stability and flutter effects are reviewed. Store release conditions are reviewed. Finally, some recent approaches to store/airframe integration are considered. Author

N88-13324# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Group.
AEROELASTICITY AND OPTIMIZATION IN FIGHTER AIRCRAFT DESIGN
H. GOEDEL and H. HOERNLEIN *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 15 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

Constraint functions and their differentiations are given for the most interesting physical disciplines of structural optimization and well-known optimization techniques are mentioned. Because of the growing significances of iterative methods a large space has been conceded to the iterative solution of linear equation systems and its use in various algorithms. It is shown that big computer time saving effects would be achieved if the special characteristics of the physical formulation could be exploited mathematically. Author

N88-13325# British Aerospace Public Ltd. Co., Preston (England).
MATERIALS FOR FIGHTER AIRCRAFT
R. J. SELLARS *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 17 p (SEE N88-13315 05-05) Oct. 1987 Sponsored in part by Ministry of Defence, United Kingdom
(AGARD-R-740) Avail: NTIS HC A13/MF A01

Of the many important decisions to be made during the initial conception and design of advanced fighter aircraft, one of the most critical is that made by the materials engineer. Together with the designer, he will recommend the type of material to be incorporated into the aircraft's structure. Such recommendations, while respecting the criteria of minimum mass and minimum cost, must also ensure that the structure will possess a long life and be simple to service and maintain. Discussed are some of the new materials and production processes available for use on advanced fighter aircraft. Comparisons are made between the advanced light alloys now becoming available (i.e., aluminum-lithium), and the latest intermediate modulus fibers for use in carbon fiber components. Author

N88-13326# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Div.
THE ROLE OF EXPERIMENTAL INVESTIGATION AND COMPUTATIONAL FLUID DYNAMICS DURING FIGHTER AIRCRAFT DESIGN
P. W. SACHER *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 26 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

In a discussion of the role of experimental investigation and computational fluid dynamics in fighter aircraft design the following topics are reviewed: (1) two ways to simulate compressible flowfields, advantages versus disadvantages of numerical and experimental investigations; (2) general trends in time/speed and costs in experiment and computation; (3) state of the art in numerical aerodynamics; (4) model for numerical simulation; and (5) applications and typical results. In a discussion of wind tunnel technology, the following topics are examined: (1) results from wind tunnel/critical review; (2) effect of Reynolds number; (3) wind tunnel effects; (4) the role of CFD during wind tunnel testing; and (5) the role of wind tunnels during configuration development. In conclusion, it is felt that the computer is not about to replace the wind tunnel, the role of computers is a complementary one to save time and costs and to improve the quality of the final product. F.M.R.

N88-13327# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Aerodynamic Dept.
REQUIREMENTS AND RECOMMENDATIONS FOR THE DEVELOPMENT OF THEORETICAL CODES AND EXPERIMENTAL FACILITIES IN THE NEAR FUTURE
B. COSTES *In* AGARD, Special Course on Fundamentals of Fighter Aircraft Design 15 p (SEE N88-13315 05-05) Oct. 1987
(AGARD-R-740) Avail: NTIS HC A13/MF A01

In order to properly use all available tools, the aircraft designer has to be acquainted with both their good qualities and shortcomings. This guides the improvement studies in a context characterized by the following: the general development of the potential of methods and calculation means, wind tunnels and relevant instrumentation; the new requirements for aircraft performance and the ever-growing industrial risks. The incoming developments for various levels of calculation codes, used for an industrial design or for fundamental research are examined. Also, the improvements needed for wind tunnels and testing methods are examined, depending on the character of the studies to be carried out. Examples permit a definition of the present state of the art and an examination of the improvements under study which may be exploitable in the not too distant future. Author

N88-18588# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SOME ASPECTS OF AIRCRAFT DYNAMIC LOADS DUE TO FLOW SEPARATION
D. G. MABEY (Royal Aircraft Establishment, Farnborough, England) Feb. 1988 33 p Presented at the 65th Meeting of the Structures and Materials Panel of AGARD, Cesme, Turkey, 4-9 Oct. 1987
(AGARD-R-750; ISBN-92-835-0445-3; AD-A194170) Avail: NTIS HC A03/MF A01

Various topics associated with the study of Aircraft Dynamic Loads due to Flow Separation are discussed in this AGARD paper. Topics discussed include the need for consistent definitions of buffet and buffeting, the advantages of consistent notation for all the papers, buffeting due to wings and other components, the alleviation of buffeting, the special difficulties of flight tests and the special advantages of buffeting measurements in cryogenic wind tunnels. Author

N88-19449# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

WORKSHOP ON DESIGN LOADS FOR ADVANCED FIGHTERS

Feb. 1988 133 p In ENGLISH and FRENCH Workshop held in Madrid, Spain, 27 Apr. - 1 May 1987

(AGARD-R-746; ISBN-92-835-0442-9; AD-A194869) Avail: NTIS HC A07/MF A01

The design of the modern fighter aircraft is becoming an increasingly complex process, and the establishment of design criteria is an extremely important element in that process. The Structures and Materials Panel of AGARD has noted that the existing design maneuver load regulations in the North Atlantic Treaty Organization (NATO) nations are not uniform in content and generally do not reflect the actual service experience of the aircraft. This workshop focuses on these problems. For individual titles, see N88-19450 through N88-19459.

N88-19450# Bundesamt fuer Wehrtechnik und Beschaffung, Munich (Germany, F.R.).

THE DEVELOPMENT OF MANOEUVRE LOAD CRITERIA FOR AGILE AIRCRAFT

MAX HACKLINGER *In* AGARD. Workshop on Design Loads for Advanced Fighters 9 p (SEE N88-19449 12-05) Feb. 1988

(AGARD-R-746) Avail: NTIS HC A07/MF A01

The maneuver loads part of aircraft design has evolved from a relatively clean cut, predetermined analysis to a long iterative process which gradually utilizes flight test information to expand the flight envelopes. It is a process that is also much more demanding because it involves the reliability of the flight control system (FCS) in proving structural integrity. The conclusions of the study were that: there is no consistent set of airworthiness criteria which fully covers maneuver loads of agile aircraft; attempts to update the existing criteria to embrace the vast possibilities of active control systems (ACT) are only partially successful; proof of airworthiness of aircraft with ACT has become more demanding since the load influencing functions of the FCS are directly safety critical and must be analyzed for failure to the same quantitative criteria as the structure itself; the existing criteria can and should be used for initial design to define the airframe; certification needs to become adaptive to reflect a long period of testing and FCS changes. Author

N88-19451# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.

FIGHTER DESIGN FOR HUMAN LOAD LIMITS

H. E. VONGIERKE and R. E. VANPATTEN *In* AGARD. Workshop on Design Loads for Advanced Fighters Design Loads for Advanced Fighters 7 p (SEE N88-19449 12-05) Feb. 1988

(AGARD-R-746) Avail: NTIS HC A07/MF A01

Recent studies have shown that current first line fighters (F-15, F-16) are being flown at very high levels of sustained acceleration with onset rates sufficiently high to provoke the unique physiological dangers inherent in rapid onset acceleration exposures. The loss of nine aircraft through G-induced loss of consciousness has been acknowledged as a result of this type of acceleration environment. Approximate maneuvering G levels versus engagement duration are shown in graphic form. Author

N88-19452# Aeronautical Systems Div., Wright-Patterson AFB, OH. Loads and Dynamics Branch.

CHANGES IN USAF STRUCTURAL LOADS REQUIREMENTS

DANIEL SHEETS and ROBERT GERAMI *In* AGARD. Workshop on Design Loads for Advanced Fighters 12 p (SEE N88-19449 12-05) Feb. 1988

(AGARD-R-746) Avail: NTIS HC A07/MF A01

The new specification, Mil-A-87221, will allow design requirements to be more closely tailored to the anticipated use of the aircraft. In this way the final product will be more efficient, with less wasted, unneeded, and unused capabilities. This will lead, in turn, to reduce costs of ownership for Air Force weapon systems. This specification has been applied to the definition of requirements for the Advanced Tactical Fighter. Author

N88-19453# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.

STRUCTURAL DESIGN REQUIREMENTS FOR AIRCRAFT INCORPORATING ACTIVE CONTROL TECHNOLOGY

M. J. KILSHAW and A. W. CARDRICK *In* AGARD. Workshop on Design Loads for Advanced Fighters 7 p (SEE N88-19449 12-05) Feb. 1988

(AGARD-R-746) Avail: NTIS HC A07/MF A01

The special structural design and certification requirements that are needed for military aircraft incorporating active control technology (ACT) are considered. United Kingdom requirements are introduced which cover static strength, fatigue performance, aeroelesticity, and the need to assess the influence of modifications to ACT software. The requirements draw attention to the essential role of flight load measurements undertaken during both development and operational flying in the process of structural substantiation. Author

N88-19454# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).

THE RELATIONSHIP BETWEEN OPERATIONAL FLIGHT MANOEUVRE PARAMETERS AND DESIGN PARAMETERS

H. STRUCK and H. BALKE *In* AGARD. Workshop on Design Loads for Advanced Fighters 18 p (SEE N88-19449 12-05) Feb. 1988

(AGARD-R-746) Avail: NTIS HC A07/MF A01

The philosophy of the relevant design requirements and the essential load parameters for the maneuver load conditions, including the determination of the control displacements corresponding to the design requirements, is reviewed. As far as the operational load parameters are concerned, numerous data have been recorded for the normal load factor, but only a few for the other main load parameters, e.g., lateral load factor, roll rate, etc. These data are usually evaluated as cumulative frequency distributions. The envelope of such normal load factor spectra shows a large scatter depending on the aircraft and its usage. For future design work, an approach to the evaluation of operational maneuvers is presented. In this analysis, the maximum values of the main load parameters needed, i.e., normal and lateral load factor, roll rate and bank angle, can be determined. The extreme operational loads on the structural components have been derived by applying a maneuver model and compared with the design values. Author

N88-19455# British Aerospace Public Ltd. Co., Kingston-upon-Thames (England). Flight Mechanics Group.

MANOEUVRES BY DEFAULT, BY DEMAND AND BY DESIGN

E. J. DALLEY and C. D. S. CLARKSON (British Aerospace Public Ltd. Co., Brough, England) *In* AGARD. Workshop on Design Loads for Advanced Fighters 16 p (SEE N88-19449 12-05) Feb 1988

(AGARD-R-746) Avail: NTIS HC A07/MF A01

The use of strain gage bridges for the derivation of aircraft maneuver loads is reviewed in the context of a recent load measuring flight trial on a TMk4a Harrier. Some of the pitfalls encountered in the method used for calibration of the gages and their location are discussed. A comparison is made between the aircraft behavior/load patterns expected at the design stage and the flight results obtained when these maneuvers are flown on the aircraft. The applicability of these statutory aircraft design requirement type maneuvers is explored by comparison with maneuvers flown during Harrier development/operational flying where flap, thrust vectoring and reaction control power have been used to enhance the maneuver envelope. Here emphasis shifts from determining or confirming design load levels to ensuring that the known structure strength boundaries are observed. Conclusions are drawn as to the adequacy of present statutory design requirements. The need for accurate reliable calibrated load measurement in both the aircraft's development and operational stages is demonstrated. Author

05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

N88-19456# Saab-Scania, Linkoping (Sweden).
DESIGN LOADS FOR SWEDISH MILITARY AIRCRAFT IN A TWENTY YEARS' PERSPECTIVE
GOESTA TOERNKVIST and JAN KLOOS *In* AGARD. Workshop on Design Loads for Advanced Fighters 5 p (SEE N88-19449 12-05) Feb. 1988
(AGARD-R-746) Avail: NTIS HC A07/MF A01

The Swedish Viggen aircraft was designed according to Swedish regulations which had matured over a long period of time. The design phase is discussed as well as the need for usage data when the aircraft was in service. When the latest Swedish advanced military aircraft, the JAS39, was planned, it was the intention of the designers to use the US military specifications with minor changes. The experience during the design phase is discussed.
Author

N88-19457# Avions Marcel Dassault, Saint-Cloud (France).
DETERMINATION OF DESIGN LOADS FOR MODERN COMBAT AIRCRAFT [DETERMINATION DES CHARGES DE DIMENSIONNEMENT DES AVIONS DE COMBAT ACTUELS]
C. PETIAU *In* AGARD. Workshop on Design Loads for Advanced Fighters 7 p (SEE N88-19449 12-05) Feb. 1988 In FRENCH
(AGARD-R-746) Avail: NTIS HC A07/MF A01

The simultaneous use of sophisticated servocontrols and electric flight control systems in modern combat aircraft has led to revisions in the classical standards governing the selection of structural design loads. New guidelines for the determination of design loads are suggested and their application is discussed with reference to structural design optimization techniques, flight mechanics, structural weight and aircraft flight characteristics.
Author

N88-19459# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
MANNED SIMULATION: HELPFUL MEANS TO DETERMINE AND IMPROVE STRUCTURAL LOAD CRITERIA
ROLF BEHRMANN *In* AGARD. Workshop on Design Loads for Advanced Fighters 18 p (SEE N88-19449 12-05) Feb. 1988
(AGARD-R-746) Avail: NTIS HC A07/MF A01

The evaluated data show, that a manned simulation in a scenario with its data recording and evaluation can help to optimize the structural design load envelope by recording the occurrence of given parameters in various types of air combat. It is also a means to optimize the structural envelope in relation to the operational envelope under the aspect of carefree handling. After correlation of flight trials with manned simulation, it can provide inputs to update the specifications relevant to future missions.
Author

N88-23129# Tracor Hydronautics, Inc., Laurel, MD.
AN EXPERIMENTAL STUDY TO DETERMINE THE FLOW AND THE SUBSONIC STATIC AND DYNAMIC STABILITY CHARACTERISTICS OF AIRCRAFT OPERATING AT HIGH ANGLES-OF-ATTACK
ALEX GOODMAN and CLINTON E. BROWN *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 28 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

A comprehensive series of experiments was conducted in the Tracor Hydronautics Ship Model Basin (HSMB) to determine the subsonic static and dynamic stability characteristics of a 3.5-foot span, 60-deg delta-high-wing fuselage model operating at high angles-of-attack up to 68 deg. In addition, typical results of flow visualization studies for a range of Reynolds numbers from 0.2 to 1.6 x 10 to the 6th, are presented. Also, the motions, force and moment coefficients resulting from a simulated pitchup maneuver are presented. Described is the HSMB Large Amplitude Horizontal Planar Motion Mechanism System (LAHPMM), 60-deg delta-wing-fuselage model, model-support systems, and the data acquisition and processing system used. The advantages of performing tests in the HSMB using the LAHPMM technique over existing wind tunnel techniques, such as curved flow and combined oscillation, for determination of the dynamic stability derivatives are presented and discussed. Results compare favorably with earlier (1950) tests of a similar configuration at angles of attack up to 32 deg.
Author

N88-26362# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
FLIGHT MECHANICS PANEL SYMPOSIUM ON ROTORCRAFT DESIGN FOR OPERATIONS: TECHNICAL EVALUATION REPORT
F. REINA (Agusta Sistemi S.p.A., Varese, Italy) Mar. 1988 17 p Symposium held in Amsterdam, Netherlands, 13-16 Oct. 1986
(AGARD-AR-243; ISBN-92-835-0450-X; AD-A195893) Avail: NTIS HC A03/MF A01

The expanding roles of the helicopter and the intensified threat perceived by its potential users have led to proposals for future rotorcraft with characteristics significantly different from existing types. The resulting rapid evolution of rotorcraft configurations, in response to user demands, now requires a translation into design criteria to permit the aerospace research and development community to provide appropriate and cost effective responses to these demands. The objective of this symposium is to explore the impact of operational needs on the evolution of rotorcraft design and to identify priorities and neglected topics. Three specific issues are central to this problem: (1) the translation of operational mission requirements into design criteria; (2) the evaluation of techniques to incorporate user defined needs into the design and methods of test and verification; and (3) the identification of design areas where unusual or new user needs are demanding special or radical features. All papers were obtained by invitation. The Conference Proceedings, commissioned by the AGARD Flight Mechanics Panel are published separately as AGARD CP 423. This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.
Author

N88-27185# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
DESIGN MANUAL FOR IMPACT DAMAGE TOLERANT AIRCRAFT STRUCTURE, ADDENDUM
M. J. JACOBSON (Northrop Corp., Hawthorne, Calif.) Mar. 1988 36 p
(AGARD-AG-238-ADD; ISBN-92-835-0443-7; AD-A196775) Avail: NTIS HC A03/MF A01

In 1981 the Structures and Materials Panel of AGARD published a design manual for Impact Damage Tolerant Aircraft Structures (AG 238). Since that date, there have been significant advances in design to resist impact damage. The Panel has therefore considered it appropriate to record this information in an addendum to the AGARDograph. This Addendum has been prepared at the request of the USAF for presentation to the Structures and Materials Panel of AGARD.
Author

N88-27193# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AGARD STANDARD AEROELASTIC CONFIGURATIONS FOR DYNAMIC RESPONSE. 1: WING 445.6
E. CARSON YATES, JR. (National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.) Jul. 1988 82 p Presented at the 61st Meeting of the Structures and Materials Panel at Oberammergau, Fed. Republic of Germany, 8-13 Sep. 1985
(AGARD-R-765; ISBN-92-835-0463-1; AD-A199433) Avail: NTIS HC A05/MF A01 CSCL 01C

This report contains experimental flutter data for the AGARD 3-D swept tapered standard configuration Wing 445.6, along with related descriptive data of the model properties required for comparative flutter calculations. As part of a cooperative AGARD-SMP program, guided by the Sub-Committee on Aeroelasticity, this standard configuration may serve as a common basis for comparison of calculated and measured aeroelastic behavior. These comparisons will promote a better understanding of the assumptions, approximations and limitations underlying the various aerodynamic methods applied, thus pointing the way to further improvements.
Author

N88-28867# Aircraft Research Association Ltd., Bedford (England).
TRANSPORT-TYPE CONFIGURATIONS
A. B. HAINES and A. ELSENAAR (National Aerospace Lab., Amsterdam, Netherlands) *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 139-163 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

Various reasons can be advanced for treating transports as a separate, distinct class of aircraft for the purpose of defining a detailed viscous simulation methodology. The detailed methodology as described was based on past experience and an appreciation of how the advances in computational fluid dynamics can be exploited to place the methodology on a more scientific basis. It is recommended that, to gain experience, the proposed methodology should be applied for a significant period in parallel with whatever is the established practice. Any large differences in the extrapolated results should be assessed to find whether the reasons justify departure from existing practice: in other words, the methodology that was set forth should be better, being on a sound scientific basis, but it will still have to prove itself in the future. Author

N88-28868# Aircraft Research Association Ltd., Bedford (England).
COMBAT AIRCRAFT
A. B. HAINES *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 164-190 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

Devising a viscous simulation methodology for model tests of a combat aircraft design is more difficult than for a subsonic transport. The geometry is more complicated and hence, more difficult to model for a computational fluid dynamics (CFD) calculation; the flow patterns are more complex and can contain various interacting features; there is more interest in the development of the flow beyond the buffet-onset boundary; the ability to manipulate the boundary layer in the model tests is more limited. The emphasis in the methodology rests on the in-depth study of the flow patterns and, in particular, the identification of the scale-sensitive viscous effects in the flow patterns over the model under test. The description of these flow patterns and of how, in principle, to construct a methodology to meet the various possible situations, is based on past experience and on an awareness of the advances in CFD methods. Author

N88-29720# National Aerospace Lab., Emmeloord (Netherlands).
MATCHING P.S.D.: DESIGN LOADS
R. NOBACK *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 12 p (SEE N88-29717 24-01) Jun. 1988 Sponsored by the Netherlands Agency for Aerospace Programs
(AGARD-R-734-ADD) Avail: NTIS HC A06/MF A01

A method to match loads obtained with the Design Envelope criterion of the power spectral density method is presented. Consistent sets of design load conditions can be generated using the correlation coefficients between the loads. Two of these sets are proposed for practical use. Author

N88-29721# Lockheed Aeronautical Systems Co., Burbank, CA. Dynamic Loads Div.
A SUMMARY OF METHODS FOR ESTABLISHING AIRFRAME DESIGN LOADS FROM CONTINUOUS GUST DESIGN CRITERIA
RICHARD N. MOON *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 40 p (SEE N88-29717 24-01) Jun. 1988
(AGARD-R-734-ADD) Avail: NTIS HC A06/MF A01

Continuous gust design criteria for airframe design are specified in FAR 25, JAR 25 and various U.S. military specs. Two forms of criterion, the design envelope approach and the mission analysis, are usually referenced as an acceptable means of compliance. However, these criteria do not provide methods of applying the statistical results of the airframe manufacturer, subject to approval of the certifying agency. Some of the methods that are currently used by U.S. airframe manufacturers are summarized. Continuous gust design requirements from various certifying agencies are reviewed. A brief discussion is also provided on the methods employed to include the effect of the L-1011 Tristar active controls wing load alleviation system on the loads due to corrective roll control in turbulence. Author

N88-29722# Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (Germany, F.R.). Civil and Transport Aircraft Div.
COMPARISON OF THE INFLUENCE OF DIFFERENT GUST MODELS ON STRUCTURAL DESIGN
MANFRED MOLZOW *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 17 p (SEE N88-29717 24-01) Jun. 1988
(AGARD-R-734-ADD) Avail: NTIS HC A06/MF A01

Depending on the country of certification, different gust models and means of compliance of the airworthiness requirements have to be covered in structural design of civil transport aircraft. The influence on aircraft design from gust models, aircraft modeling, and control systems and laws is demonstrated on example of a short to medium range transport aircraft. Recommendations for future harmonized approaches in gust methods and modeling are given. Author

N88-29738# National Aerospace Lab., Amsterdam (Netherlands).
LOW-SPEED LONGITUDINAL FLYING QUALITIES OF MODERN *TRANSPORT AIRCRAFT*
H. A. MOOIJ *In* AGARD, Advances in Flying Qualities 16 p (SEE N88-29735 24-01) May 1988
(AGARD-LS-157) Avail: NTIS HC A09/MF A01

The suitability of an aircraft with respect to human control is determined by its handling qualities. In modern transport aircraft the handling qualities are determined to a high degree by the flight control system. An introduction to the following aspects of closed loop flight control systems for modern transport aircraft is given: stabilization and maneuvering functions, candidate implementation forms, manipulators for flight control, and mathematical representations of the airframe/flight control system combination required for prediction and evaluation purposes. Regarding criteria for good handling qualities of transport aircraft, the terminal flight phase (takeoff, initial climb, final approach and landing) are of prime interest. A treatise on a number of promising quantitative criteria for transport aircraft equipped with advanced flight control systems is given. Two groups of criteria are distinguished: criteria based on the dynamic characteristics of the aircraft alone and criteria based on the dynamic characteristics of the pilot/aircraft closed loop system. In the latter case, a quasi-linear describing function for the human controller behavior is used. Author

N88-29739# Systems Technology, Inc., Hawthorne, CA.
ADVANCES IN FLYING QUALITIES: CONCEPTS AND CRITERIA FOR A MISSION ORIENTED FLYING QUALITIES SPECIFICATION
ROGER H. HOH *In* AGARD, Advances in Flying Qualities 28 p (SEE N88-29735 24-01) May 1988
(AGARD-LS-157) Avail: NTIS HC A09/MF A01

There has been considerable activity over the past 8 years to upgrade the military flying qualities specifications for conventional aircraft, as well as for V/STOLs and helicopters. The primary objectives of these upgrades has been to account for the use of high gain, high authority augmentation, and to more directly reflect the requirements of the intended missions into the specifications. The methodologies developed to accomplish the latter objective are summarized. A brief overview of the Lower Order Equivalent Systems and Bandwidth criteria follows. Problems with the specification of control sensitivity, and potential solutions are then discussed, followed by a brief presentation of the use of time vs frequency domain criteria. An empirical method to combine the Cooper-Harper Handling Qualities Ratings (HQRs) from each axis of control into an overall rating is then presented. Finally, a proposed specification for precision flare and landing is given, followed by an example application of the method. Author

05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

N88-29740# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
A SECOND LOOK AT MIL PRIME FLYING QUALITIES REQUIREMENTS
ROBERT J. WOODCOCK *In* AGARD, Advances in Flying Qualities 15 p (SEE N88-29735 24-01) May 1988
(AGARD-LS-157) Avail: NTIS HC A09/MF A01

Current and projected applications of flying qualities criteria are addressed. The current state of the art, its deficiencies, and needs for further work are addressed. The rationale for the new U.S. Military Standard and Handbook on flying qualities is briefly discussed. With advanced vehicles, the scope of flying qualities is expanding, opening new areas to investigate and creating new problems. With relaxed static stability now commonly used, control margin is a prime safety consideration: control must be available for stabilization, maneuvering and recovery from any possible attitude, as well as for trim. Flying qualities aspects of agility include the need for nonlinear flying qualities metrics, and control systems that provide both rapid maneuvering and good damping for tight tracking. For all aspect engagement, the pilot needs to be thoroughly integrated with displays, automatic flight control modes and other systems. For dynamic longitudinal flying qualities, MIL-STD 1797 presents the Control Anticipation Parameter of an equivalent classical system as a primary criterion, but gives several alternatives in recognition of other problems. Author

N89-10056# Societe Nationale Industrielle Aerospatiale, Paris (France). Tactical Missile Div.
SIMULATION WITH REAL ELEMENTS OF EXOCET ANTI-SHIP MISSILES [SIMULATION AVEC ELEMENTS REELS DES MISSILES ANTI-NAVIRES EXOCET]
CHRISTIANE RENON, GUY LEGALLO, and GERARD SELINCE *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 9 p (SEE N89-10048 01-08) Jul. 1988 In FRENCH
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

Simulation results gained on the first 1500 production anti-ship missiles of the EXOCET family (MM 38, MM 40, AM 39, SM 39) are presented. After describing the simulation facilities of the tactical missile division of Aerospatiale and in particular Subdray facility located near Bourges in France, the role of simulation is shown from the beginning of the project, through development up to the production of the missiles. The advantage of such simulation during the production phase is emphasized. It is used to improve the quality of missiles, to gain knowledge useful for the development of new versions and as a quality insurance method during production. Author

N89-10057# Rockwell International Corp., Columbus, OH.
HELLFIRE SYSTEM MODEL VALIDATION
R. V. HUPP *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 13 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

The hybrid simulation facilities, system modeling, and validation process for a U.S. Army missile development program are discussed. Two fundamental problems in missile system design and development require an accurate, valid, proven computer simulation; analysis of errors and performance verification. The classical approach to error analysis is by Monte Carlo simulation. System performance over the entire spectrum of operating conditions cannot be verified by field tests alone due to economic constraints; it must be verified by simulation. Verification of total system performance was a major analytical effort in the development program. A complete hybrid computing facility was procured and dedicated to this end. Two independent system simulations were developed; a hybrid simulation and an all digital simulation. The development program was very successful. The computer simulation equipment procured for this effort was found to be quite adequate for the task and cost effective. Author

N89-12564# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GUIDANCE AND CONTROL/FLIGHT MECHANICS PANELS JOINT SYMPOSIUM ON THE MAN-MACHINE INTERFACE IN TACTICAL AIRCRAFT DESIGN AND COMBAT AUTOMATION Technical Evaluation Report
RUDIGER SEIFERT (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, West Germany) 1988 21 p Symposium held in Stuttgart, Federal Republic of Germany, 28 Sep. - 1 Oct. 1987
(AGARD-AR-249) Avail: NTIS HC A03/MF A01

A Keynote address and thirty-one papers were presented at the Joint Guidance Control Panel/Flight Mechanics Panel Symposium, held in Stuttgart, Germany from 28 September to 1 October 1987, under the following headings: Combat scenarios and mission segment requirements; Human capabilities and limitations; Technological capabilities and limitations of combat automation; Crew station implementation; System integration. The Keynote Address and twenty-five papers are published in CP-425 (one paper was not available at time of printing) and the four remaining classified papers are included in CP-425(Supplement). Author

N89-17691# Saab-Scania, Linkoping (Sweden)
AN ANALYSIS METHOD FOR BOLTED JOINTS IN PRIMARY COMPOSITE AIRCRAFT STRUCTURE
INGVAR ERIKSSON *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 19 p (SEE N89-17685 10-31) Mar. 1988 Prepared in cooperation with Royal Inst. of Tech., Stockholm (Sweden).
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

The analysis of bolted joints in composite structure requires, like structural analysis in general, methods for determining the stress distributions and relevant failure criteria. The stress analysis procedure discussed here starts by addressing the joints as an integrated part of the overall structure. The stresses in the vicinity of the hole boundary are obtained through a series of finite element analyses, which starts with an overall load distribution analysis and ends with a two-dimensional detailed contact stress analysis of the most highly stressed region in the joint. Strength is predicted for two basic failure modes occurring in a joint, net-tension and bearing failure. The failure hypotheses for these failure modes are described. Both the stress analysis and failure hypotheses are performed and established, respectively under certain idealizations. The conditions in a real joint in an aircraft may differ from these idealizations. Hence, further work is required and is also proposed here. The analysis procedure described here is based on today's powerful computer facilities and offer great advantages compared with more empirical procedures. The procedure is presently used at Saab Aircraft Division. Author

N89-17693# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Technology Programs.
TYPICAL JOINTS IN A WING STRUCTURE
DIETER ROSE, MANFRED ROTHER, and HELMUT SCHELLING (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart, Germany, F.R.) *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 14 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

For the development of the Alpha-Jet carbon fiber reinforced plastic (CFRP) wing, typical connections between different components were examined both theoretically and experimentally. Environmental conditions - component humidity and temperature were considered mainly within the experimental work which was performed by the DFVLR-Stuttgart. Covered here are typical joints such as: (1) single-shear connection between skins and spars with low load transfer; (2) joints between skins and ribs due to interior tank pressure; and (3) multibolt joint between the CFRP skins and the fuselage attachment fittings with reference to bolt strength distribution and bearing stresses. Author

N89-18652# Royal Aircraft Establishment, Farnborough (England).
THE DESIGN OF THE GARTEUR LOW ASPECT-RATIO WING FOR USE IN THE VALIDATION OF SHEAR LAYER AND OVERALL FLOW PREDICTION METHODS
M. C. P. FIRMIN and M. A. MCDONALD *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 17 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

A low aspect-ratio wing has been designed for use in the critical analysis of computational methods for three-dimensional shear layers, following the guidelines agreed by GARTEUR Action Group AD(AG07). The aim here is to give details of the design processes used and to indicate the flow conditions which will be explored in the detailed shear-layer tests to be made in the NLR LST (3.0 x 2.25 m) and ONERA (1.8 x 1.4 m) low-speed wind tunnels, as part of the GARTEUR program. Calculations have been made, using a selection of boundary layer methods which indicate that the design should provide very challenging tests for methods. Pilot model tests have suggested that the wing has been designed successfully and these have encouraged the Action Group to proceed with the main test program. Author

N89-18654# Defence Research Establishment Valcartier (Quebec). Ballistics Group.
VALIDATION OF A USER-FRIENDLY CFD CODE FOR PREDICTION OF THE AERODYNAMIC CHARACTERISTICS OF FLIGHT VEHICLES
MICHEL FORTIER *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 19 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

A computational fluid dynamics code based on the development of small perturbation theory for the solution of inviscid irrotational compressible fluid flow around flight vehicle configurations is described. The user-friendly feature of the code is illustrated by a guided weapon canard configuration for which are displayed computed pressure distributions on selected components. Five test cases including a simple wing shape and more complex guided weapon and aircraft configurations are presented to demonstrate the capabilities and limitations of the code. Theoretical pressure, force and moment coefficients are compared to wind tunnel data obtained from various facilities. The results of the comparison show the capabilities of the code in the subsonic and supersonic speed regimes for simple and complex configurations at low incidences, and its limitations at transonic speeds and at high angles of attack. Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

N86-29816# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
ANALOGUE SIGNAL CONDITIONING FOR FLIGHT TEST INSTRUMENTATION
D. W. VEATCH and R. BOGUE Apr. 1986 179 p
(AGARD-AG-160-VOL-17; ISBN-92-835-1520-X; AD-A171303)
Avail: NTIS HC A09/MF A01

The application of analog signal conditioning to flight-test data-acquisition systems is discussed. Emphasis is placed on practical applications of signal conditioning for the most common flight-test data-acquisition systems. A limited amount of theoretical discussion is included to assist the reader in a more complete understanding of the subject matter. Nonspecific signal conditioning, such as amplification, filtering, and multiplexing, is discussed. Signal conditioning for various specific transducers and data terminal devices is also discussed to illustrate signal conditioning that is unique to particular types of transducers. The purpose is to delineate for the reader the various signal-conditioning technique options, together with tradeoff considerations, for commonly encountered flight-test situations. Author

N87-21902# Royal Aircraft Establishment, Bedford (England). Flight Systems Div.
SOME EXPERIENCES IN INTEGRATING AVIONIC SYSTEMS ON THE CIVIL FLIGHT DECK
P. ENGLAND, R. HARLOW, and N. COOKE *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 17 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

Some of the work carried out in the Civil Avionics Research program at the Royal Aircraft Establishment, Bedford is described. After a discussion of some of the factors that are leading to a future Air Traffic Management system, the activities in navigation, flight management, displays and novel human input techniques are reviewed. The progress made and some of the lessons learned are also described. A view of how a future air traffic management system might operate is given. Author

N87-21920# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
MICROPROCESSOR APPLICATIONS IN AIRBORNE FLIGHT TEST INSTRUMENTATION
M. J. PRICKETT Feb. 1987 66 p
(AGARD-AG-160-VOL-18; ISBN-92-835-1542-0; AD-A178983)
Avail: NTIS HC A04/MF A01

This volume in the AGARD Flight Tests Instrumentation Series addresses flight test engineers and flight test instrumentation engineers interested in the design of microprocessors into new airborne flight test equipment. It describes general microprocessor based, system design principles and architectures suitable for flight test and flight test instrumentation applications. In preparing this volume the author has met with several engineers actively participating in aircraft and electronic flight testing at various organizations. Each of these organizations has developed microprocessor based instrumentation to solve their unique requirements and these are described in this text as case studies of current microprocessor applications. Author

N87-22673# Army Avionics Research and Development Activity, Fort Monmouth, NJ.
THE IMPACT OF FUTURE AVIONICS TECHNOLOGY ON THE CONDUCT OF AIR WARFARE
JOSEPH A. DASARO *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 9 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

A synopsis is given of the conclusions reached by the Systems Subpanel of the NATO AGARD workshop on the potential impact of development in electronic technology on the future conduct of air warfare. Avionic system integration technology, system architecture, data processing, data communication paths, computer programs, fault detection and isolation, and system design methodology are among the topics discussed. Author

N87-24949# Naval Air Development Center, Warminster, PA.
NEW TECHNOLOGY IMPACTS ON FUTURE AVIONICS ARCHITECTURES
RICHARD S. MEJZAK *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 7 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

An interpretation of avionics architecture is provided with respect to system components, organization, and design factors. Initially, general avionics architecture characteristics are addressed followed by discussions on emerging technologies and their impact on advanced systems. Information handling requirements are projected for future tactical aircraft. In addition, advanced avionics architecture design consideration and technical issues are addressed relative to achieving improved performance, reliability, survivability, flexibility, and low life cycle cost. Author

06 AIRCRAFT INSTRUMENTATION

N87-29503# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
INFORMATION MANAGEMENT AND DECISION MAKING IN ADVANCED AIRBORNE WEAPON SYSTEMS
Feb. 1987 323 p In ENGLISH and FRENCH Symposium held in Toronto, Ontario, 15-18 Apr. 1986
(AGARD-CP-414; ISBN-92-835-0411-9; AD-A184044) Avail: NTIS HC A14/MF A01

These conference proceedings focus on the significant human factors issues posed by the development of advanced aircrew stations incorporating new technologies such as adaptive and supervisory systems and multipurpose displays and computer graphics. Complimentary papers by members of the Avionics Panel focusing on the role of voice interactive systems and a summary of the findings of the Guidance and Control Panel's Working Group on Automation at the Man Machine Interface were also presented at the symposium. For individual titles, see N87-29504 through N87-29529.

N87-29519# Army Avionics Research and Development Activity, Fort Monmouth, NJ.
INTEGRATING AVIONICS SENSOR SIGNALS FOR TACTICAL AIRCRAFT
BARBARA A. BERNABE and JOHN J. WARD (Smiths Industries Ltd., Bishops Cleeve, England) *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 10 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Current tactical aircraft must be prepared to operate in more severe threat environments than ever before. Stealth relies on conducting missions at night, at low levels, and at high speeds. Despite these adverse mission constraints, successful pilotage requires the aviator to continuously and accurately assess his own aircraft position in relation to surrounding landform configurations for navigation, for obstacle avoidance, and for masking, cover, and concealment. To assist the aviator in managing mission specific information, tactical aircraft are increasingly being equipped with sophisticated data gathering, storage, and processing systems. Data generated by these systems can be of two forms. One is that of video or digital spacially formatted images generated by an onboard sensor or processor. Typically the image represents the environmental situation surrounding the aircraft or at some remote location and is usually presented via a CRT. The other is that of alphanumeric codes which represent coordinates, elevations, ranges, or description of critical tactical locations. Typically this information is presented to the aviator via a control display unit (CDU). Conventionally, the aviator integrates and interprets the raw data output from these systems, for pilotage, tactical assessment, and decision making. Author

N87-29527# Royal Aircraft Establishment, Bedford (England).
THE FLIGHT EVALUATION OF A SPEECH RECOGNITION AND A SPEECH OUTPUT SYSTEM IN AN ADVANCED COCKPIT DISPLAY AND FLIGHT MANAGEMENT SYSTEM FOR HELICOPTERS
R. LITTLE *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 12 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

A Wessex helicopter at RAE Bedford was used to develop and evaluate a set of electronic cockpit displays and a comprehensive suite of avionics which were integrated to form an advanced display and flight management system for both military and civil applications. Two important features of the system were automatic speech recognition and synthetic speech output. Flight trials were conducted to determine the ground rules and principles pertinent to the successful integration of these devices with other advanced avionics. The trial has shown that the combination of speech recognition and synthetic voice systems offers an element of redundancy and if correctly integrated into the cockpit will be capable of improving the man machine interface to a far greater degree than is achievable by hand or voice alone. Author

N88-11659# Royal Aircraft Establishment, Bedford (England). Flight Systems Div.
THE FLIGHT EVALUATION OF AN ADVANCED ENGINE DISPLAY AND MONITORING SYSTEM
L. ADAMS *In* AGARD, Rotorcraft Design for Operations 10 p (SEE N88-11649 03-05) Jun. 1987
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

A Wessex helicopter was used to develop and evaluate a suite of advanced, integrated avionics. An important area of study was concerned with the display of engine and transmission data, and with a system monitor which gives audio and visual warning of any problems. The system demonstrated that the suppression of engine and transmission data at all times except when the pilot asks for it to be displayed or the system detects a problem is an acceptable technique. Author

N88-11671# Societe Nationale Industrielle Aerospatiale, Marignane (France). Div. Helicoptere.
SYSTEM FOR SAR MISSIONS [SYSTEME DE MISSION SAR]
S. RIOCHE *In* AGARD, Rotorcraft Design for Operations 10 p (SEE N88-11649 03-05) Jun. 1987 In FRENCH
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The helicopter division of Aerospatiale developed a specially adapted system for search and rescue (SAR) missions at sea. The system allows entirely automatic piloting and guidance, particularly during the execution of search patterns and the descent to hovering flight in the proximity of the target. An electronic flight instrument system (EFIS) panel includes cathode screen displays for attitude, horizontal situation parameters, and search radar data. The horizontal situation parameters are selected as a function of the phase of flight from four modes: horizontal situation indicator, sector with or without superimposed radar data, search pattern, and hover. M.G.

N88-13331# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
WORKSHOP ON AVIONICS CORROSION CONTROL
Sep. 1987 80 p Workshop held in Hovik, Norway, 16-17 Apr. 1986 Original contains color illustrations
(AGARD-R-733; ISBN-92-835-0428-3; AD-A194868) Avail: NTIS HC A05/MF A01

This document contains the keynote and other presentations made at a Workshop held by the Structures and Materials Panel on Avionics Corrosion. The discussion covered the problem's extent, the state of the corrosion-prevention art, the prospects for innovative corrosion avoidance techniques, including the substitution of nonmetallic for metallic materials and preventive maintenance techniques. For individual titles, see N88-13332 through N88-13336.

N88-13332# Naval Air Development Center, Warminster, PA.
AVIONIC CORROSION
IRVING S. SHAFFER *In* AGARD Workshop on Avionics Corrosion Control 10 p (SEE N88-13331 05-06) Sep. 1987
(AGARD-R-733) Avail: NTIS HC A05/MF A01

The paper discusses the major causes of corrosion in the Navy's avionic equipment and provides specific examples of corrosion failures. Maintenance and readiness data summaries are included to denote further the corrosion problem severity. Corrective measures in design, testing, and maintenance are reviewed. Author

N88-13333# Air Force Materials Lab., Wright-Patterson AFB, OH. Electronic Failure Analysis Group.
CORROSION OF ELECTRONIC COMPONENTS
BILL DOBBS *In* AGARD Workshop on Avionics Corrosion Control 26 p (SEE N88-13331 05-06) Sep. 1987 Original document contains color illustrations
(AGARD-R-733) Avail: NTIS HC A05/MF A01

The Materials Laboratory Electronic Failure Analysis Group supports U.S. Air Force electronic systems in the areas of materials and manufacturing processes. A large majority of electronic failures is caused by materials and manufacturing process defects. It has been found that corrosion of electronic components is the cause of failure in about 20 percent of items submitted for testing. Airframe corrosion prevention requirements are well documented. It would be beneficial to the Air Force if corrosion prevention in electronic

systems were as well documented. Existing documents, such as T.O. 1-1-689 and NAVAIR 16-1-540, are a step in the right direction. However, compulsory MIL specifications should be applied, since corrosion in Air Force electronic systems contributes significantly to system failure. Failure analysis investigations have been conducted for aircraft circuit breakers, antennas, printed wiring boards, fuses, linear steering position transducers, stepper motors, accelerometers, disk recorder heads, and electrical connectors. The cause of failure is identified and means of preventing future occurrence are presented. Author

N88-13334# Commanders Naval Air Forces US Atlantic and Pacific Fleets, Norfolk, VA. Material Advisor.
US NAVAL AIR FORCE AVIONIC AND ELECTRICAL SYSTEM CORROSION PREVENTION AND CONTROL MAINTENANCE
G. T. BROWNE *In* AGARD Workshop on Avionics Corrosion Control 20 p (SEE N88-13331 05-06) Sep. 1987
(AGARD-R-733) Avail: NTIS HC A05/MF A01

A study of premature failures of installed avionics, electrical equipment, and systems experienced in U.S. Fleet operational aircraft in the 1960s and 1970s has been reported. These failures were caused by corrosion, water intrusion, and other contaminating agents. To reverse this trend the Commanders Naval Air Forces U.S. Atlantic and Pacific Fleets (COMNAVAIRLANT) (COMNAVAIRPAC) requested that Commander Naval Air System Command (COMNAVAIRSYSCOM) develop a corrosion prevention and control program for avionics, electrical and installed systems used in naval aircraft. COMNAVAIRSYSCOM directed the Naval Air Development Center (NAVAIRDEVCEN) to develop the program together with a technical manual. A conference of interested parties was held in 1976 and action initiated to develop the program and technical manual for use by the fleet technicians. Author

N88-13335# Industrial Marine Products Group Ltd., Dartmouth (Nova Scotia). Aerospace Engineering Div.
CORROSION IN AVIONICS AND ASSOCIATED EQUIPMENT; CAUSE, EFFECT AND PREVENTION
R. G. BARTLETT and E. G. EDGAR *In* AGARD Workshop on Avionics Corrosion Control 9 p (SEE N88-13331 05-06) Sep. 1987
(AGARD-R-733) Avail: NTIS HC A05/MF A01

Addressed, with examples, are the cause, effect, and prevention of corrosion as it relates to Canadian Forces aircraft. It deals particularly with aircraft operated in a marine environment and is based on the experience of the authors during previous service with the Department of National Defence and in their present employment in industry. The Canadian Forces corrosion prevention treatment program is also mentioned and discussed briefly.
Author

N88-13336# Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France).
AVIONICS AND CORROSION
ALAIN POINTET and CHRISTOPHE TURPIN-INVERNON *In* AGARD Workshop on Avionics Corrosion Control 6 p (SEE N88-13331 05-06) Sep. 1987
(AGARD-R-733) Avail: NTIS HC A05/MF A01

Avionic manufacturing and environmental conditions are responsible for corrosion and/or make easier the action of corrosion in the various parts of an avionics system. A brief survey is made of environmental conditions affecting avionics, how to reproduce them in accordance with norms and which associated problems might occur. All parts of an avionic system are examined, i.e., housings, printed circuit boards, hybrid and integrated circuits. For each component, examples and solutions are given. Author

N88-23767# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
THE DESIGN, DEVELOPMENT AND TESTING OF COMPLEX AVIONICS SYSTEMS
Dec. 1987 408 p In ENGLISH and FRENCH Symposium held in Las Vegas, Nev., 27 Apr. - 1 May 1987
(AGARD-CP-417; ISBN-92-835-0437-2; AD-A198666) Avail: NTIS HC A18/MF A01

The design, development and testing of complex avionics systems are discussed. Design aspects for future avionics systems, managing the future system design process, and system design tools and integration are among the topics covered. For individual titles, see N88-23768 through N88-23804

N88-23768*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TECHNOLOGY DEVELOPMENT PROGRAM FOR TWENTY-FIRST CENTURY AEROSPACE VECHICLES
WILLIAM T. SUIT and DOUGLAS B. PRICE *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 6 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01 CSCL 01D

A program to meet the avionics technology needs for the design of future space transportation systems is presented. The program is designed to meet as many technology goals as possible by 1996 so decisions can be made as to which vehicles are feasible and which should be constructed. Author

N88-23769# Naval Air Development Center, Warminster, PA.
SYSTEMS FOR THE 21ST CENTURY
RICHARD G. DESIPIO *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 7 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

An avionic system index is proposed which allows for the definition of each function of the avionics system. The results of two demonstrations relative to the exploitation of on-board avionics built-in-test and diagnostics are presented. Author

N88-23770# Thomson-CSF, Malakoff (France).
ARCHITECTURE AND ROLE OF THE SENSOR SUBSYSTEM IN FUTURE AIRCRAFT WEAPON SYSTEMS
J. A. SALMON, C. J. C. RAVAT, and F. J. LORK *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 6 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Today, in military aircraft systems, each external sensor (radar, ESM, electro-optical equipment, radio communications) is almost independent and reports to the central computer. Taking into account the evolution of operational context in which the aircraft is involved and the dramatic progress in processing capabilities, it appears necessary and possible to spread the intelligence aspect of the weapon system in order to optimize the global cost efficiency. This distribution enables each specialist to concentrate his efforts in order to take advantage of the ever increasing scope of knowledge associated with each discipline. Here, the sensor subsystem is dealt with, its architecture is defined and its function in the aircraft system is described. Author

N88-23771# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Sistemi Avionici ed Equipaggiamenti.
RAPID PROTOTYPING OF COMPLEX AVIONIC SYSTEM ARCHITECTURES
L. BERARDI, N. GIORGI, W. MELLANO, A. VALENTE, and E. ZUCCO *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 13 p (SEE N88-23767 17-06) Dec. 1987 Sponsored in part by Unisys, Italy
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

A design tool called Expert Consultant for Avionics system Transformation Exploration (ECATE) is described. ECATE, rapidly prototyping different alternatives, helps the designer in establishing the information flow architecture of the avionics system, that is, the organization of the internal data handling. The tool provides the user with an interface to assist him in describing the avionics from the point of view of the data handling and presents the results in a suitable format. It performs consistency checks and advises the user on possible architectural problems by means of expert system techniques. Author

N88-23772# British Aerospace Public Ltd. Co., Woodford (England). Civil Aircraft Div.
THE SPECIFICATION AND DESIGN OF A FUTURE MARITIME RECONNAISSANCE AIRCRAFT
J. SHEPARD *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 11 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The problems of providing specifications for system components of the highly integrated avionic systems of the future are discussed

in the context of the avionics systems of a Future Maritime Reconnaissance Aircraft (FMRA). The need and extent of the integration of the avionic systems are discussed, as are the consequences for system definition and specification. Potential techniques for addressing these problems are reviewed. These are brought together to describe an approach which could provide the tools required. The implication of this approach for vendors and integrators is addressed. Author

N88-23773# British Aerospace Aircraft Group, Preston (England). *Military Aircraft Div.*

A STRUCTURED APPROACH TO WEAPON SYSTEM DESIGN

H. M. MALLEY, N. T. JEWELL, and R. A. C. SMITH *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 12 p (SEE N88-23767 17-06) Dec. 1987 Sponsored in part by the Ministry of Defence, United Kingdom

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

A structured approach to the design of highly integrated weapon systems of the future is described. The approach was used in the design of the avionics system for the UK Experimental Aircraft Program (EAP) demonstrator aircraft. Brief descriptions are given of the EAP systems, the main systems design tools used, the activities carried out during the systems design process and the management and control procedures adopted. A series of observations highlighting some of the findings of the project and providing pointers to the design of future weapon systems is given. Author

N88-23774# International Business Machines Corp., Owego, NY. Federal Systems Div.

DEVELOPMENT OF A GENERIC ARCHITECTURE

CHRISTINA BERGGREN *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 5 p (SEE N88-23767 17-06) Dec. 1987

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

A new generation systems architecture is designed to bridge the gap between today's 1553-based systems and fault-tolerant, totally integrated systems of tomorrow. Described here is a novel approach to system functional area partitioning and the design of this generic distributed real time architecture. The architecture incorporates new military standards in development. Author

N88-23775# Agusta Sistemi S.p.A., Varese (Italy).

TEST PHILOSOPHY OF THE EH101 INTEGRATED AVIONIC

E. GALLI *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 5 p (SEE N88-23767 17-06) Dec. 1987

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The philosophy employed during the development and testing of the EH101 integrated avionic Navel helicopter is outlined. The avionics architecture is given in graphic form. Overall avionic integration, the aircraft management computer test, the sensor interface units test, and the aircraft management system test are described. Author

N88-23776# International Business Machines Corp., Owego, NY. Federal Systems Div.

SYSTEMS ENGINEERING TECHNIQUE

LEONARD KARAS and DONNA RHODES *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 9 p (SEE N88-23767 17-06) Dec. 1987

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

An overview is given of the Systems Engineering Technique (SET). SET was developed to effect an improvement in quality and productivity aspects in the development of avionics systems. The methodology synthesizes the best features of existing development methodologies into a single core procedure which is equally applicable throughout the systems development phases of complex systems. Six key areas emphasized by SET are discussed, and the concept of systems engineering measurements is introduced as the means to evaluate system quality and productivity. SET is being applied to the development of avionics systems at IBM Owego and has been effective in improving specification quality. Author

N88-23777# Avions Marcel Dassault, Saint-Cloud (France).

MODELING OF FUNCTIONAL SPECIFICATIONS FOR ONBOARD SOFTWARE: EXPERIENCE WITH THE RAFALE AVIONICS SYSTEM [MAQUETTAGE DES SPECIFICATIONS FONCTIONNELLES DU LOGICIEL EMBARQUE EXPERIENCE DU SYSTEME AVIONIQUE RAFALE]

PATRICK SCHIRLE *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 12 p (SEE N88-23767 17-06) Dec. 1987 In FRENCH

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The avionics system of the Rafale aircraft entailed innovations such as the integration of aircraft systems and the acquisition of control information. These new functions resulted in a notable increase in, and qualitative evolution of, onboard computer software. For the improvement of quality and response characteristics of software, development was supported by an integral methodology for modeling software functional specifications. The model was constructed around a SEL computer supporting a FORTRAN listing of 3500 pages of system functional specifications. The model allows the direct validation of each individual specification and the whole ensemble of specifications. The model was used to support the analysis of the system failures, provide a base for the assessment of modifications, generate acceptance rules, and prepare a functional reference for integration. Author

N88-23778# International Business Machines Corp., Owego, NY.

THE AVIONICS SOFTWARE ARCHITECTURE IMPACT ON SYSTEM ARCHITECTURE

C. DOUGLASS LOCKE *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 5 p (SEE N88-23767 17-06) Dec. 1987

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Technology developments that led to the problem of system vulnerability to software errors resulting from increased avionic system complexity and the impact of these developments on the functionality and design of new systems are considered. The current sequence for performing the physical and software architectural design, including a definition of the software architecture is discussed. The likely consequences of using these methods for designing new avionics systems are also discussed. Author

N88-23779# Litton Technische Werke, Freiburg (Germany, F.R.).

A COMPARISON OF INTEGRATED AND SEPARATE SYSTEMS FOR FLIGHT CONTROL AND NAVIGATION

H. BUITKAMP *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 10 p (SEE N88-23767 17-06) Dec. 1987

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Two steps for the integration of flight control sensors, the Altitude and Heading Reference System (AHRS) and the Inertial Navigation System (INS) are discussed. It has been shown that the use of the same sensors for flight control and AHRS functions, as for example in the Aircraft Motion Sensor Unit (AMSU) system, yield excellent results. The AMSU system has demonstrated its performance capability in the Experimental Aircraft Program (EAP) inherently unstable aircraft. These aircraft, as opposed to conventional aircraft, require inertial sensor data with an extremely high bandwidth and very small data latency for flight control purposes. Author

N88-23780# Textron Bell Helicopter, Fort Worth, TX. Advanced Human Factors System Design.

DEVELOPMENT AND TESTING OF A PREDICTIVE METHODOLOGY FOR OPTIMIZATION OF MAN-MACHINE INTERFACE IN FUTURE AVIONICS SYSTEMS

ROGER E. PARKS *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 9 p (SEE N88-23767 17-06) Dec. 1987

(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The trend toward increasing complexity and cost in emerging avionics systems, driven by requirements for increased functional capability, has created a need for a predictive analytical methodology which accurately forecasts system performance early in the design process, and treats the human operator and the equipment as a fully integrated man-machine system. A

methodology that meets these needs has been developed and validated by Bell Helicopter Textron. The process is being used to provide early, accurate avionics system characterization, thereby reducing design costs. Author

N88-23781# Boeing Military Airplane Development, Wichita, KS.
CREWSTATION INFORMATION AND DEVELOPMENT SYSTEM (CIDS)
M. E. ROWLAND and W. R. WAGONER *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 11 p (SEE N88-23767 17-06) *Dec. 1987*
(AGARD-CP-417) *Avail: NTIS HC A18/MF A01*

The process by which requirements for an avionics system are translated into an integrated crewstation design is discussed. The Crewstation Information Development System (CIDS) was divided into three phases of activity. In Phase 1, methodology development, a comprehensive set of requirements, resource allocation, and an information utilization assessment is derived. Phase 2, crewstation development, focuses on deriving the most effective methods of utilizing required crewstation information, taking into consideration the impact of the operational environment. The final phase, design application, concerns the details of crewstation design and the development of a crewstation information manager. Author

N88-23782# Naval Air Development Center, Warminster, PA.
A CHANGE IN SYSTEM DESIGN EMPHASIS: FROM MACHINE TO MAN
M. L. METERSKY and J. L. RYDER (Pacer Systems, Inc., Horsham, Pa.) *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 9 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Even though software has increased in importance and percentage of cost in system development, it is still philosophically considered as a means to facilitate hardware performance. This thinking has had an adverse effect on system performance by relegating decision requirements to a minor or nonexistent role in the system design process. It is the premise here that system design should be dictated by decision requirements, since decisions humans make determine how well and to what degree a weapon system's inherent capabilities will be utilized. A system design approach based on an emphasis of the human's role as a decision *maker is presented.* Author

N88-23783# Northrop Corp., Hawthorne, CA. ASET Development.
MANAGING ADVANCED AVIONIC SYSTEM DESIGN
PHILIP H. SIMONS *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 8 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The critical requirements of advanced avionic system design are overall system requirements, configuration item requirements, interface requirements, and design process management requirements. These requirements can be met through the design process of abstract requirements definition, requirements/functional decomposition, functional recomposition, and detailed interface definition. This process can be greatly aided by computer automation, resulting in the design of more complex avionics systems in far less time than would be possible using older tools. Author

N88-23784# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France). Lab. Central de Biologie Aerospatiale.
PSYCHOSENSORY COCKPIT ERGONOMICS, ADVANTAGES OF INTELLIGENT INFORMATION SYSTEMS [ERGONOMIE PSYCHOSENSORIELLE DES COCKPITS, INTERET DES SYSTEMES INFORMATIQUES INTELLIGENTS]
R. AMALBERTI, F. DEBLON, and J. P. MENU *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 12 p (SEE N88-23767 17-06) Dec. 1987 In FRENCH; ENGLISH summary
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Psychosensory cockpit ergonomics consists of a pluridisciplinary approach focused on global consideration of man-machine interface issues. Knowledge supplied by each research field (sensory physiology, cognitive psychology, design of intelligent systems) is used in every concrete approach, taking into consideration aviation requirements and technological advances. Requirements that must be met to build such systems and computer system goals are discussed. Author

N88-23785# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
ADVANCED DEVELOPMENT OF A COCKPIT AUTOMATION DESIGN SUPPORT SYSTEM
PHILIP V. KULWICKI, JOE W. MCDANIEL, and LISA M. GUADAGNA *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 15 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

A highly disciplined and structured crew system design process is being developed to improve the efficiency and effectiveness by which advanced cockpits can be fielded. As an initial implementation of the CAT design process, a Cockpit Automation Design Support System (CADSS) is being developed to provide a computer aided design environment, including the software design tools and the simulation utilities that can facilitate the development of the crew system in synchrony with the development of the avionics and weapon system. The rationale underlying the CADSS is described in terms of the system components, which include a Designer's Computer Aided Design System (DCADS) processor, new software tools and a breadboard cockpit simulator which are envisioned to complement, but not replace, existing development facilities. This implementation of the cockpit design support system is described in relation to the overall CAT program activities and schedule. Author

N88-23786# Societe Nationale Industrielle Aerospatiale, Marignane (France). Div. Helicopteres.
DESIGN AND DEVELOPMENT OF AN AVIONICS SYSTEM ADAPTED TO HELICOPTER MISSIONS [CONCEPTION ET DEVELOPPEMENT D'UN SYSTEME AVIONIQUE ADAPTE AUX MISSIONS DES HELICOPTERES]
DANIEL BOUHERET and JEAN LOUIS ROCH (Crouzet Aerospace and Systems, Valence, France) *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 16 p (SEE N88-23767 17-06) Dec. 1987 In FRENCH
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The development of the avionics system for the Dauphin 365 F configured for search and rescue operations is discussed. A general description of flight missions and system architecture is presented with particular emphasis being given to the navigation and mission management subsystems. The system is based on a Nadir Mk2 microprogrammable computer capable of an execution rate of 1 MOPS. The interactive relationship between the system designers and integrators is described along with the design support tools that aid in achieving successful interaction. Author

N88-23787# Hughes Aircraft Co., Fullerton, CA.
OPERATION AND PERFORMANCE OF AN INTEGRATED HELICOPTER COMMUNICATION SYSTEM
WALTER R. FRIED *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 8 p (SEE N88-23767 17-06) Dec. 1987 Previously announced in IAA as A87-31469
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The unique operational and performance requirements of the communication system for modern tactical Army helicopters are described. An integrated system architecture is described which satisfies these requirements and incorporates very high levels of automation, thereby reducing pilot workload. The automation concepts include the use of a preloaded communication data base and a centralized communication processor containing advanced control, reconfiguration and message formatting software. Link analysis and simulation results are presented to show the performance capabilities of the system with respect to the projected mission requirements. Author

N88-23788# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
DESIGNING FOR DESIGN EFFECTIVENESS OF COMPLEX AVIONICS SYSTEMS
KENNETH R. BOFF *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 9 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The Integrated Perceptual Information for Designers (IPID) Project is a multiagency supported effort to aid the accessibility and use of human performance data in system design. It is formulated around five information management objectives: (1) identifying, collecting, and consolidating human performance data of potential value to system design; (2) human factoring these data to enable their direct use by system designers; (3) establishing an institute with responsibility for maintenance, update and analysis of these resources to support crew system design; (4) developing and sponsoring educational opportunities to train and sensitize system designers in the value and application of human performance data to crew system design; and (5) conducting exploratory research to define and evaluate requirements for an automated design support capability to aid engineers to access and tradeoff human performance data with other technical information germane to the effective design of crew systems.
Author

N88-23789# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
DESIGN FOR INTEROPERABILITY (INTERCHANGEABILITY)
GEORGE KONOMOS *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 5 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Interoperability of the various elements used in a system is the design property which allows the intermixing of elements from various sources (manufactures) without any impact on the performance of the system or the operational hardware. Here, the line replaceable module approach is discussed. This is a new approach to avionics where a processor module is a 6 inch by 6 inch plug-in board with processing power many times higher than that of older line replaceable units. Author

N88-23790# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Equipaggiamenti.
THE ELECTROMAGNETIC THREAT TO FUTURE AVIONIC SYSTEMS
BRUNO AUDONE *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 10 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The electromagnetic threat to future aircraft is studied and evaluated on the basis of the evolution of the avionic systems. The high level of integration of these systems combined with the increased number of electromagnetic sources which may interfere with the performance of the overall weapon system create the need to reexamine the usual design and testing approach in order to reach an adequate level of aircraft hardening. It is essential to design and test at system level rather than at hardware level. System design guidelines are discussed. Areas where basic research studies need to be undertaken are highlighted. Author

N88-23791# Thorn EMI, Hayes (England). Radar Div.
THE INTEGRATION, CHARACTERISATION AND TRIALLING OF A MODERN COMPLEX AIRBORNE RADAR
ROGER ROY HOGBEN and FRANK N. MORPHET *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 5 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The process of commissioning, testing and conducting trials of complex aircraft radar is discussed. An attempt is made to show how vital an informed and methodical approach is to achieving success. It is argued that it is essential to the approach that higher management understands and supports it. Author

N88-23793# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario). Human Engineering Section.
EXPERIENCE IN THE INTEGRATION OF HUMAN ENGINEERING EFFORT WITH AVIONICS SYSTEMS DEVELOPMENT
D. BEEVIS *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 9 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Based on a review of human engineering activities in ten major acquisition projects, some conclusions aimed at facilitating the integration of human engineering activities with the development of advanced avionics are outlined. Conclusions are also drawn about the systems design and human engineering processes, and the role that mission, function, and task analysis can play in integrating human engineering and systems development activities. It is concluded that an approach that combines the interaction of hardware, software, and human functions is made especially necessary by the impact of advanced technology on the roles of human operators and maintainers, on the man-machine interface, and on the system development process itself. Finally, it is argued that there is a need to establish standardized approaches to the application of human engineering in avionics system design.
Author

N88-23794# Electronique Serge Dassault, Saint Cloud (France).
TESTING COMPLEX AVIONICS SOFTWARE: A PRACTICAL EXPERIENCE [LE TEST DE LOGICIELS AVIONIQUES COMPLEXES: UNE EXPERIENCE PRATIQUE]
M. MUENIER *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 16 p (SEE N88-23767 17-06) Dec. 1987 In FRENCH
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The methods used at Dassault for testing avionics software, particularly the operational programs used on the Mirage F1 and Mirage 2000 aircraft, are presented. The MINERVE software development methodology is briefly described. The objective of MINERVE is to facilitate software production while ensuring control of quality, costs and development delays. The various software tools used to perform unitary, integration, functional and final software validation and testing are described. These tools provide hardware environment simulation, graphic output and various operational modes. A trend towards the integration of front-end tools (specification tools) and back-end tools (test tools) is noted and a natural progression from specification tool to semiformal specification, to prototype, to stimuli, to test tools is foreseen.
Author

N88-23796# Naval Postgraduate School, Monterey, CA. Dept. of Computer Science.
INTERFACING AND INTEGRATING HARDWARE AND SOFTWARE DESIGN SYSTEMS
DANIEL DAVIS *In AGARD, The Design, Development and Testing* of Complex Avioncs Systems 8 p (SEE N88-23767 17-06) Dec. 1987 Sponsored in part by the Naval Weapons Center, China Lake, Calif., and the Naval Ocean Systems Command, San Diego, Calif.
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Fundamental problems in interfacing and integrating information between diverse design systems are examined. Specifically, design problems associated with the contexts of meaning that are required to understand information in diverse systems are examined. Increased research into a general theory of design is advocated. The resolution to some integration problems is suggested on the basis of some recent developments and experience with a functional design theory. Author

N88-23797# Air Force Test Pilot School, Edwards AFB, CA.
A LOOK TOWARD THE FUTURE OF COMPLEX AVIONICS SYSTEMS DEVELOPMENT USING THE USAF TEST PILOT SCHOOL'S AVIONICS SYSTEMS TEST TRAINING AIRCRAFT
WILLIAM H. BROOME, JR. and MIKE PARRAG (Calspan Corp., Buffalo, N. Y.) *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 16 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The Avionics Systems Test Training Aircraft (ASTTA) is a special configuration of the NC-131H Total In-Flight Simulator (TIFS), and was developed to fill a significant gap in the education and

experience of the avionics systems test community. It provides a cost effective means of quickly exposing both designers and testers to the key issues of systems development and in-flight testing, especially the operator to systems interface human factors issues. Its benign flight environment is conducive to both initial and advanced training in flight test techniques. Author

N88-23799# Avions Marcel Dassault, Saint-Cloud (France).
AVIONICS SYSTEMS: DEVELOPMENT METHOD AND COMPUTER TOOLS [SYSTEME AVIONIQUE-METHODE DE DEVELOPPEMENT ET OUTILS INFORMATIQUES]
P. LAROCHE-LEVY *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 13 p (SEE N88-23767 17-06) Dec. 1987 In FRENCH
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The avionics development system based on the use of computer automation tools is described. The problems posed in the development of avionics are defined and the various phases constituting the development life cycle for avionics systems are characterized. The capabilities of the computer tools and how they are used in various development stages are described. Finally, the benefits gained through the use of such a development methodology are discussed. Author

N88-23801# National Aerospace Lab., Amsterdam (Netherlands).
DEVELOPMENT OF AN AIRBORNE FACILITY FOR ADVANCED AVIONICS RESEARCH
N. VANDRIEL *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 14 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Based on its flight test and simulator experience, the Netherlands National Aerospace Laboratory (NLR) has started the development of an airborne avionics research facility. In the framework of the Avionics Research Testbed (ART) project, NLR's Metro research airplane is being equipped with a number of advanced avionics systems, including programmable electronic flight instrument system, flight management computer, microwave landing system, global positioning system and secondary surveillance radar. Author

N88-23802# Avions Marcel Dassault, Saint-Cloud (France). Aerospatiale Div. Helicopteres.
WORKSHOPS FOR THE DESIGN OF AVIONICS SYSTEMS AND THE DEVELOPMENT OF ONBOARD SOFTWARE [ATELIERS DE CONCEPTION DE SYSTEMES AVIONIQUES ET DE REALISATION DE LOGICIELS EMBARQUES]
MONIQUE SLISSA and PHILIPPE LAROCHE-LEVY *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 13 p (SEE N88-23767 17-06) Dec. 1987 In FRENCH
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

An avionics development system based on an open-ended suite of integrated computer tools is described. Additions and changes to the basic tool set can be implemented to suit the requirements of the specific project or individual contractor. A hosting structure tool that ties the whole system together is described along with three other basic tools: OCS, a system design aid; DLAO, a computer aided software definition tool; and SAO, a graphic, detailed specification aid. Author

N88-23804# Service Techniques des Programmes Aeronautiques, Paris (France).
DEVELOPMENT OF COMPLEX AVIONICS SYSTEMS: EXPERIENCE FROM FRENCH MILITARY PROGRAMS [DEVELOPPEMENT DES SYSTEMS AVIONIQUES COMPLEXES: EXPERIENCE ISSUE DES PROGRAMMES MILITAIRES FRANCAIS]
ANTOINE COURSIMAULT *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 15 p (SEE N88-23767 17-06) Dec. 1987 In FRENCH
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The principles used to guide the development of the avionics systems for the Mirage 2000 and ATL2 aircraft are discussed. In addition, the anomalies discovered during these development experiences and improvements contributing to the current ACT program are examined. The various development, verification, and production stages are characterized. Emphasis is placed on the importance of requirements analysis and specifications development. Author

N88-29719# Technische Univ., Brunswick (Germany, F.R.). Inst. for Guidance and Control.
FLIGHT TEST EQUIPMENT FOR THE ON-BOARD MEASUREMENT OF WIND TURBULENCE
G. SCHAENZER, M. SWOLINSKY, and P. VOERSMANN (Aerodata Flugmesstechnik G.m.b.H., Brunswick, West Germany) *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 11 p (SEE N88-29717 24-01) Jun. 1988
(AGARD-R-734-ADD) Avail: NTIS HC A06/MF A01

The knowledge of the actual wind and turbulence situation along the flight path of an aircraft is an important factor in the area of meteorological and aeronautical research. Different flight test programs for the onboard implementation of offline and online wind and turbulence measuring systems are presented. The theoretical principle of the determination of all three components of the wind vector is stated. A summary of the installed sensors, the data acquisition systems and computer equipment is presented and the essential effects of sensor errors on the accuracy of wind determination are discussed. Author

N88-29730# National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.
THE NAE ATMOSPHERIC RESEARCH AIRCRAFT
J. I. MACPHERSON and S. W. BAILLIE *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 19 p (SEE N88-29725 24-01) Dec. 1987
(AGARD-R-734) Avail: NTIS HC A09/MF A01

The Flight Research Laboratory of the NAE of Canada operates a T-33 and a Twin Otter aircraft instrumented for atmospheric research studies. The instrumentation in the aircraft is described with emphasis on the strapped down inertial Doppler system used to derive the mean and turbulent components of the atmospheric motion. Example data from several research projects are presented to demonstrate the measurement and analysis capabilities of the aircraft and their data playback facilities. Author

N89-10834# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Avionics Lab.
ADVANCED AVIONICS ARCHITECTURE PAVE PILLAR
JOHN C. OSTGAARD *In* AGARD, Computing Systems Configuration for Highly Integrated Guidance and Control Systems 8 p (SEE N89-10831 02-01) Jun. 1988
(AGARD-LS-158) Avail: NTIS HC A08/MF A01

The increased use of advanced electronics has given modern combat aircraft phenomenal levels of performance, but at a stiff price in initial cost, maintenance workload and aircraft availability. Hence, aircraft design is shifting to give equal emphasis on performance, affordability, maintainability, and reliability in the development of avionic systems. The paper discusses the challenges and benefits of an avionics architecture concept which integrates avionic functions at the system level thereby improving the system's accuracy, increasing its immunity to failure, and decreasing its reliance on multiple redundant sensors. This design philosophy, which permits resources to be shared across subsystems, requires a highly coupled system-wide management and control program (operating system) supported by a wide-band distribution network, high-speed data and signal processors, and extensive mass memory. The implementation strategy for this avionics architecture is the system-wide utilization of common modular building blocks using advanced microelectronics such as VHSIC, standard 3/4 ATR modules and integrated racks, all interconnected by fiber optic networks. The generic integration approach and architecture produced by the PAVE PILLAR program is the foundation for avionics development in the next generation aircraft for the U.S. DOD and include such aircraft as the USAF Advanced Tactical Fighter (ATF). Author

N89-10835# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Data and Signal Processing Group.
DATA AND SIGNAL PROCESSING ARCHITECTURES FOR FUTURE AVIONICS
MARK T. MICHAEL *In* AGARD, Computing Systems Configuration for Highly Integrated Guidance and Control Systems 12 p (SEE N89-10831 02-01) Jun. 1988
(AGARD-LS-158) Avail: NTIS HC A08/MF A01

Pave Pillar architecture incorporates a Common Signal Processor (CSP) concept as a key building block of a USAF advanced avionics suite. This concept embodies the use of standard internal interfaces, a family of modules, use of the programming language Ada to express application program for the data processors within CSP, and the use of a Graph Notation to represent signal processing functions for the signal processing components of the CSP. The modularity permits upgrading any hardware or software component with minimal disruption to the rest of the design. CSP is an open architecture in that the interfaces and module specifications are non-proprietary and can be built by other vendors. The paper will address the system concept, hardware architecture, and software philosophy comprising the CSP system. It will describe in general terms how the CSP hardware works and its expandability. Existing modules will be listed and potential future modules identified. A brief description of the Graph Notation and its advantages will be provided. The CSP Local Operating System capabilities and use will be summarized. Application studies to determine the suitability of the CSP concept for different avionic applications such as radar, electronic warfare, communications, and electro-optical sensors will be briefly summarized. The role of the MIL-STD-1750A processors in CSP and their limitations will be touched on, and future upgrades to 32-bit machines discussed. Author

N89-10836# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
FIBER OPTIC BUSES AND NETWORKS FOR ADVANCED AVIONICS ARCHITECTURES
R. W. UHLHORN *In* AGARD, Computing Systems Configuration for Highly Integrated Guidance and Control Systems 15 p (SEE N89-10831 02-01) Jun. 1988
(AGARD-LS-158) Avail: NTIS HC A08/MF A01

An avionics architecture exploiting high-speed, high density VLSI and VHSIC technology by repartitioning the traditional avionics suite requires subsystem interconnection via backbone and backplane buses and networks operating at data rates far exceeding those used for avionics in the past. In fact, the rates are high enough that fiber optics is the only interconnect technology that does not impose substantial size, weight, and life cycle cost penalties on the overall system. In the Pave Pillar architecture the fiber optic multiplex bus for command and control, block transfer, and flight control functions, based on a variation of the IEEE 802.4 and 802.2 token-passing bus protocol for the physical and data link layers, operates at 50 Mbps. A number of specific implementations have emerged. The parallel internal bus protocol ties users (data processors) together in the backplane and through a bus interface unit to the multiplex bus. Other kinds of networks are used to serve subsystems connecting video terminals, sensors, signal processors, etc. An overview of the multiplexed high-speed data bus and parallel backplane bus designs and their interface is presented. The implementation details and options for the fiber optic network which supports the interconnection of avionics bus interface modules in different physical locations are discussed. Passive and active star-coupled networks are compared and conclusions drawn. The state of the art in packaging of the avionics bus interface and related line replaceable modules is illustrated.
Author

N89-16780# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
ENGINE CONDITION MONITORING: TECHNOLOGY AND EXPERIENCE
Oct. 1988 462 p In ENGLISH and FRENCH Symposium held in Quebec City, Quebec, 30 May - 3 Jun. 1988
(AGARD-CP 448; ISBN-92-835-0481; AD-A203800) Avail: NTIS HC A20/MF A01

Topics addressed include: military operations; civil experience; manufacturer's perspective; turboprops and turboshafts; systems; diagnostic methods; and advanced technologies. Questions and answers of the discussions follow each paper. For individual titles, see N89-16781 through N89-16819.

N89-16785# German Air Force Air Armament Directorate, Cologne (Germany, F.R.).
ON BOARD LIFE MONITORING SYSTEM TORNADO (OLMOS)
J. H. KUNZ and U. SCHULZ (Dornier-Werke G.m.b.H., Friedrichshafen, Germany, F.R.) *In* AGARD, Engine Condition Monitoring: Technology and Experience 6 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The development of the onboard life monitoring system (OLMOS) of the GE Tornado proved, that on-board monitoring is possible, and the received data can be used in the logistic system. The Tornado OLMOS is a system which serves engine, structure, and functional equipment. The level of integration is high, but due to the structured software approach the system can be handled. The software was developed by four companies, and in the using phase the same companies are sharing the SW maintenance. High integrated systems definitely do need a very close management on both sides, the government and the industry. The OLMOS proves that even commercial and proprietary aspects can be worked out. Author

N89-16786# Royal Air Force, London (England).
INFORMATION MANAGEMENT SYSTEMS FOR ON-BOARD MONITORING SYSTEMS
P. J. JENKINS *In* AGARD, Engine Condition Monitoring: Technology and Experience 8 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

With the advent of microprocessors is a phase which has heralded a host of advances in aircraft mounted equipment. It promises to yield rich dividends for the hard pressed maintenance engineer by providing detailed information on equipment performance to enable defects to be accurately and rapidly diagnosed. Latest develpments in the propulsion field show the potential of being able to anticipate certain types of defects and thus achieve true on-condition maintenance in these cases. The aim is to highlight the vitally important role played by maintenance information management systems in storing, analyzing, and displaying the data captured by on-board monitoring systems and to make recommendations for a code of practice for the successful implementation of such systems. Author

N89-16788# Rockwell International Corp., Lakewood, CA.
B-1B CITS ENGINE MONITORING
B. LAINE and K. DERBYSHIRE *In* AGARD, Engine Condition Monitoring: Technology and Experience 12 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The Central Integrated Test Systems (CITS) is a real-time tests system which continually monitors the performance of the 34 principal systems, onboard the B-1B aircraft, including the four General Electric F101 turbofan engines. The CITS consists of an onboard computer, four data acquisition units, a data conversion unit, a printer, a magnetic tape recorder, and a control and display panel. Approximately 19,000 parameters are available for recording and display purposes. The engine diagnostic algorithm was designed in close coordination with General Electric. Information obtained from early test cell runs was utilized in the original logic design. Many modifications were made as a result of flight test experience, but the overall test sequence has remained unchanged. The engine diagnostic software utilizes approximately 100 parameters per engine. The test logic is exercised four time per second and a fault is declared is a failure condition occurs for six consecutive passes. Every effort is made to ensure that a single failure will result in only one fault code out of 154 possible codes per engine. The B-1B engine diagnostic program is the most advanced flying test algorithm. Its inherent complexities are due to calculations of test limits based on aircraft flight mode, environmental conditions, and engine control schedules. These limits are then compared to actual engine readings, and if established limits are exceeded, a fault code is annunciated.
Author

N89-16789# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
ENGINE LIFE CONSUMPTION MONITORING PROGRAM FOR RB199 INTEGRATED IN THE ON-BOARD LIFE MONITORING SYSTEM
J. BROEDE *In* AGARD, Engine Condition Monitoring: Technology and Experience 11 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The On-board Life Monitoring System (OLMOS) of the GE Tornado consists of on-board equipment (data acquisition unit, DAU) where the majority of the data processing is carried out, and of ground equipment (OLMOS Ground Station, OGS, connected to the Central Logistic Support System, BMS) where the majority of the data management tasks are carried out. The Engine Life Consumption Monitoring Program (ELCMP) is part of OLMOS. Its main task is LCF life consumption calculation, which consists of data acquisition and data checking, calculation of temperatures and stresses, as well as damage assessment. A general view of the calculation path within ELCMP is given, and the hardware structure of the system is presented. Some advantages of individual and complete engine monitoring are pointed out. Author

N89-16792# Deutsche Lufthansa A.G., Hamburg (Germany, F.R.). Maintenance Systems and Reliability.
ENGINE CONDITION MONITORING: STATE-OF-THE-ART CIVIL APPLICATION
HEINRICH SCHLUETER and ROLF SCHOEDDERT *In* AGARD, Engine Condition Monitoring: Technology and Experience 8 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

With the introduction of the AIRBUS A-310, an enhanced ECM concept was established at Lufthansa. Highlights of the theme include application areas and the economic aspects of everyday airline operation. The ECM information system supports maintenance personnel in detecting incipient engine failures, in carrying out optimum adjustment of engine controls, and in cutting down the number of engine run-ups. It also assists overhaul personnel in removal planning and overhaul planning. All data are acquired by an aircraft integrated data system through expanded engine instrumentation and are periodically reported through an on-board printer. Data printouts are entered into the Lufthansa computer network from each flight destination station. A high degree of actuality data are processed on-line in the central computer at the Frankfurt maintenance base. In addition to engine modular performance and mechanical parameter analysis, data processing also performs automatic trend recognition and alert report generation. Author

N89-16793# Air France, Paris. Direction du Materiel.
THE CFM 56-5 ON THE A-320 AT AIR FRANCE [LE CFM 56-5 SUR A320 A AIR FRANCE]
P. CHETAIL *In* AGARD, Engine Condition Monitoring: Technology and Experience 19 p (SEE N89-16780 09-06) Oct. 1988 In FRENCH
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

A brief history of engine monitoring strategies used by Air France is presented and the systems limitations encountered in service are discussed. The engine monitoring system to be used for the A-320 aircraft is described. The use of the AIRCOM system, the automatic alert function, and the use of the GEM (Ground based Engine Monitoring) program for data analysis are discussed.
M.G.

N89-16794# Aerospatiale Usines de Toulouse (France). Aircraft Div.
IMPLICATION OF ENGINE PERFORMANCE MONITORING FOR THE AIRCRAFT MANUFACTURER [IMPLICATION DE L'AVIONNEUR DANS LE SUIVI DES PERFORMANCES DU MOTEUR]
A. VIEILLARD *In* AGARD, Engine Condition Monitoring: Technology and Experience 6 p (SEE N89-16780 09-06) Oct. 1988 In FRENCH
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The experience acquired by Aerospatiale in the Airbus and ATR programs has highlighted the necessity for the aircraft manufacturers to be associated with Engine Conditioning Monitoring (ECM) system implementation. The aircraft manufacturer will thus be more involved as regards: the acquisition of information on the design of airborne systems and validation of measurement systems on the basis of flight tests; and the use of information to ensure the consistency of and engine models used by the aircraft in engine monitoring systems and familiarity with the ECM system. The predictable growth of this performance monitoring activity will necessitate closer coordination with the engine manufacturers and airlines, the objective still being to quantify the deterioration of each aircraft subassembly, i.e., the engines, the airframe and their respective components. Author

N89-16795# Pratt and Whitney Aircraft, West Palm Beach, FL.
F100-PW-220 ENGINE MONITORING SYSTEM
DENNIS A. MYERS and G. WILLIAM HOGG *In* AGARD, Engine Condition Monitoring: Technology and Experience 9 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The development and operational experience is reviewed of the F100-PW-220 Engine Monitoring System currently in service with the U.S.A.F. and other national defense air forces utilizing the F100-PW-220 engine and its derivatives. The F100-PW-220 Engine Monitoring System (EMS) is an advanced logistics support tools in production for the Pratt and Whitney F100 family of gas turbine engines. The introduction of the PW-220 EMS represents over 10 yrs of diagnostic system and maintenance technology development using aerospace electronic component design and digital engine control system implementation. The PW-220 EMS is a comprehensive engine support system that is fully integrated with in-flight aircraft operating systems, as well as, ground based maintenance and logistics systems. Author

N89-16797# Rolls-Royce Ltd., Bristol (England). Engine Data Systems.
MILITARY ENGINE CONDITION MONITORING SYSTEMS: THE UK EXPERIENCE
C. M. OCONNOR *In* AGARD, Engine Condition Monitoring: Technology and Experience 8 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The monitoring of engine usage is probably as old as the gas turbine engine itself. However, it was not until the mid-seventies that the concept of engine monitoring became viable following the appearance and general availability of digital electronics, including the minicomputer. Since, the proliferation of engine condition monitoring has resulted in the development of many different systems and it is now customary for defense organizations to include it among their requirements for new military aircraft. The functional requirements for engine condition monitoring are usually defined in general terms, except for the life usage monitoring of major rotating components, these being the discs and the turbines. The level of importance afforded to the monitoring of these components is attributable to safety and economic factors. Engine condition monitoring in the UK military has been built on the foundations of usage monitoring. It is interesting that except for vibration and oil system monitoring, the engine parameters required for usage monitoring can provide enough data for many other condition monitoring functions. This idea is further expanded and detailed. Author

N89-16798# General Electric Co., Cincinnati, OH. Monitoring Systems Engineering.
MILITARY ENGINE MONITORING STATUS AT GE AIRCRAFT ENGINES, CINCINNATI, OHIO
R. J. E. DYSON and M. J. ASHBY *In* AGARD, Engine Condition Monitoring: Technology and Experience 11 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The design and development of GE Aircraft engines of recent military engine monitoring systems is described. In particular, the systems for the F101-GE-102 engine in the B-1B aircraft and the F110-GE-100 engine in the F-16C/D are used as examples. Since both of these systems have recently been introduced into service, this experience is discussed together with operational status. These present systems are compared with future evolutionary trends which are affected by the development of miniaturized, rugged electronics and by the desire to minimize the unique hardware and software required for engine monitoring. A discussion of interfaces, both airborne to the flight crew, and, through support equipment and

ground analysis programs, to the ground crew, is included.
Author

N89-16799# General Electric Co., Cincinnati, OH. Monitoring Systems Engineering.
COMMERCIAL ENGINE MONITORING STATUS AT GE AIRCRAFT ENGINES, CINCINNATI, OHIO
R. J. E. DYSON and J. E. PAAS *In* AGARD, Engine Condition Monitoring: Technology and Experience 12 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The design, introduction and development of expanded commercial engine monitoring systems by GE Aircraft Engine is described. The history of present systems is outlined, starting from the introduction of the CF6-80A3 engine for the A310 aircraft of the Propulsion Multiplexer (PMUX) which has led to similar systems on the CF6-80C2 engine. The impact of the full authority digital control on future systems is also discussed. The introduction and application of the Ground-based Engine Monitoring (GEM) software developed by GE in conjunction with several airline users is recounted. The original software development occurred in parallel with the expanded sensor complement and digitization of data. A description of the functions of a typical ground software program is provided together with proposed improvements and future directions. Author

N89-16801# Bureau Veritas, Paris (France).
TREND MONITORING OF A TURBOPROP ENGINE AT LOW AND MEAN POWER [TREND-MONITORING DES TURBO-PROPULSEUR DE PETITE ET MOYENNE PUISSANCE]
PHILIPPE VAQUEZ *In* AGARD, Engine Condition Monitoring: Technology and Experience 9 p (SEE N89-16780 09-06) Oct. 1988 In FRENCH
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Trend monitoring relates to the observation, between two maintenance periods, of changes in certain parameters that represent the physical state of an engine. The experiences of French engineers with the use of this method are discussed. Specifically, the application of trend monitoring to the Pratt and Whitney PT6 A and PW 120, and the General Electric CT 7 turboprop engines is discussed. The engines were mounted on various single and twin engine aircraft. Author

N89-16807# Stewart Hughes Ltd., Southhampton (England).
GETTING MORE FROM VIBRATION ANALYSIS
R. M. STEWART, I. C. CHEESEMAN, and K. LIBROWSKI *In* AGARD, Engine Condition Monitoring: Technology and Experience 12 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Traditional vibration monitoring of gas turbines has been restricted to activation of alarms from overall levels and shaft orders. Use of more of the information contained in the signal could improve fault coverage and diagnostics. The practical problem is one of being able to model the vibration of an engine in sufficient detail. Furthermore, some problems experienced in the field have origins that no designer could be expected to predict, i.e., module mismatch. How then to proceed. Any practical system must incorporate an evolutionary mechanism that feeds skilled field operator experience to a computer based monitoring system. This is based on the machine designer's knowledge and improves its performance by this feedback. Fortunately, there is a growing body of technology on the vibration produced by gas turbine engines both to do with its interpretation and signal processing which make such a system feasible. Two areas of application are dealt with, the first connected with engine module roughness diagnostics and the second with fault identification of individual components such as main line bearings and accessory drive gears. For both, much of the hardware required to gather the necessary data is being specified and constructed, so overcoming a major objection to furtherance of this technology. Author

N89-16810# National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.
DISCRETE OPERATING CONDITIONS GAS PATH ANALYSIS
A. STAMATIS and K. D. PAPAILIOU *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The implementation of a reliable Diagnostic System based on a Gas Path Analysis (GPA) approach is not always feasible. Extra instrumentation is required in order to predict, detect, and isolate failures. Discrete Operating Conditions Gas Path Analysis (DOCGPA), presented here, is an extended version of the conventional GPA algorithm, providing the capability of increased reliability when using only existing sensors for estimating engine malfunctions. Author

N89-16811# Hochschule der Bundeswehr, Hamburg (Germany, F.R.).
GAS PATH MODELLING, DIAGNOSIS AND SENSOR FAULT DETECTION
R. LUNDERSTAEDT and K. FIEDLER *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The gas path analysis (GPA) becomes more and more an important method for the diagnosis of jet engines. Here, a fundamental way of finding the mathematical engine model is shown, especially with regard to the adaptation of the coefficients of the system matrix to the gradients of the characteristic curves of the turbomachines. The theoretical fundamentals are applied to a two-shaft jet engine. In order to test the method some faults in the engine are simulated. All faults are detected very accurately and the method shows by this its efficiency. For practical use of the method, the faults of the measuring device (sensors) are to be taken into consideration. Therefore filter algorithms are outlined to diminish the stochastic parts of these faults. For the systematic parts (offsets), a special and new theory is developed for compensation. For both, simulation results are given based on actual test stand data. Author

N89-16812# Technische Univ., Munich (Germany, F.R.). Inst. fuer Luft-und Raumfahrt/Flugantriebe.
SYSTEM-THEORETICAL METHOD FOR DYNAMIC ON-CONDITION MONITORING OF GAS TURBINES
F. HOERL, G. KAPPLER, and H. RICK *In* AGARD, Engine Condition Monitoring: Technology and Experience 17 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

In order to ensure reliability and safety of such complex technical systems as aero-engines, model-related diagnostic techniques must be applied. The basis for this is a linear, time-invariant, dynamic engine state space model derived from system analysis. Due to the model order and the associated difficulties, order reduction procedures are used. The diagnostic parameters to be taken into account are integrated into a dynamic disturbance model. This disturbance model and the reduced engine model form the extended dynamic engine state space model. A detailed investigation of the dynamic system for observability and disturbability is essential. Because of measuring/process noise and other system disturbances, dynamic state estimation methods are applied in the diagnosis, whereby the synthesis of such observer systems is a crucial point. The usefulness of the dynamic monitoring method is demonstrated on the example of the helicopter engine using computed simulations. A sensitivity analysis allows the accuracy of the diagnostic results to be estimated. Author

N89-16817# Stewart Hughes Ltd., Southhampton (England). Centre for Advanced Technology.
GAS PATH CONDITION MONITORING USING ELECTROSTATIC TECHNIQUES
CELIA FISHER *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p (SEE N89-16780 09-06) Oct. 1988 Sponsored by Ministry of Defence Procurement Executive, London, United Kingdom
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The concept of condition monitoring using electrostatics offers the opportunity to monitor gas path faults as they occur. It is based on the assumption that gas path distresses, such as blade

rubs and combustor burns, cause the production of minute particles of debris, which carry electrostatic charge, and can be monitored on suitable sensors mounted in the engine. The engine has a normal level of charge, which produces a background signal. The debris produced by distresses causes a change in the signal which can be monitored using suitable signal processing techniques. Described here is the research work which was necessary to provide an understanding of the mechanisms involved. This forms the basis of the technique which is described, with examples of the application of the systems to various engines. Author

N89-16818# Atomic Energy of Canada Ltd., Pinawa (Manitoba).
AN INTELLIGENT SENSOR FOR EQUIPMENT HEALTH MONITORING OF FERROMAGNETIC WEAR DEBRIS CONCENTRATION IN FLUIDS
K. W. CHAMBERS, M. C. ARNESON, J. L. MONTIN, W. DUECK, and C. A. WAGGONER (Defence Research Establishment Pacific, Victoria, British Columbia) *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

FERROSCAN R is a device that has been developed for the Canadian Department of National Defence by Atomic Energy of Canada Limited (AECL) for monitoring the relative concentration of ferromagnetic wear debris in fluid systems. FERROSCAN R generates a wear profile in real time and uses it to detect the onset of an increase in the rate of wear of ferromagnetic components. Described here are the background, development and operating principles of the sensor. Some engineering test results are given. Author

N89-16819# Rolls-Royce Ltd., Derby (England).
COMPASS (TRADEMARK): A GENERALIZED GROUND-BASED MONITORING SYSTEM
M. J. PROVOST *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Condition monitoring has developed from simple hand recording and analysis of cockpit instrumentation to the use of electronic systems selecting and recording a multitude of measurements for transmission to ground-based computer systems, which store and analyze data from an entire fleet. COMPASS (Condition Monitoring and Performance Analysis Software System) is a ground-based computer system, currently being developed by Rolls-Royce plc for application on the Rolls-Royce RB211 and Tay and International Aero Engines (IAE) V2500 turbofans. After discussing the benefits of monitoring system, COMPASS, its sources of data and its analytical functions, including details of new techniques developed to improve the usefulness of the analysis that is done are described. Also shown is how COMPASS is designed in two parts: - analytical functions specific to a given application and general host routines, providing all the housekeeping functions required in any monitoring system, including smoothing and trending, alert generation, fleet averaging, compression, data management and data plotting. The use of the general host routines could be extended to cover any operation. The approach Rolls-Royce plc is adopting to enable the COMPASS host to be made available for widespread application is discussed. Author

N89-18446# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
SOFTWARE ENGINEERING AND ITS APPLICATION TO AVIONICS
Nov. 1988 405 p In ENGLISH and FRENCH Symposium held in Cesme, Turkey, 25-29 Apr. 1988
(AGARD-CP-439; ISBN-92-835-0483-6; AD-A203892) Avail: NTIS HC A18/MF A01

Software engineering has evolved rapidly but the gap between demand and software output continues to grow. By the end of the decade research programs in North America, Europe, and Japan will begin to produce results in the areas such as software tools, and computer architecture. The symposium considered how their advances might be applied to the avionics systems of the nineties and beyond and their impact on the aspirations in areas such as operation, and fault tolerances. The software element of modern weapons systems continues to grow in size and complexity; offering major advantages but also potential risks. For individual titles, see N89-18447 through N89-18486.

N89-18447# Test Wing (6510th), Edwards AFB, CA. F-16 Combined Test Force.
MEASURES OF MERIT FOR ADVANCED MILITARY AVIONICS: A USER'S PERSPECTIVE ON SOFTWARE UTILITY
MARK C. DICKERSON and VICTOR M. LASAXON (Computer Sciences Corp., Edwards AFB, CA.) *In* AGARD, Software Engineering and Its Application to Avionics 14 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Recommendations are provided for improving the software development process. The recommendations are the result of discussions with F-15, F-16, and HH-60 test pilots, navigators, and flight test engineers. Because today's aircraft are becoming so software intensive, and because the development process is so involved, users and developers must redouble efforts to design systems correctly for the first time. Although 29 specific recommendations are given, they can be boiled down to four general guidelines: keep switch actions to a minimum; keep switchology consistent; tailor displays by flight phase, but keep other options visible; tailor displays by flight phase, but keep other options visible; and most important, carefully process and meter the information presented to avoid pilot overload. Author

N89-18448# French Air Force, Paris. Div. Nouveaux Avions de Combat.
RESPONSIBLE REQUIREMENTS DEFINITION FOR COMBAT AIRCRAFT IN LIGHT OF UNCERTAINTIES LINKED TO ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS TECHNIQUES [LE RESPONSABLE DE L'EXPRESSION DU BESOIN FACE AUX INCERTITUDES LIEES AUX TECHNIQUES DE L'INTELLIGENCE ARTIFICIELLE ET DES SYSTEMS EXPERTS SUR LES AVIONS DE COMBAT]
JEAN-GEORGES BREVOT *In* AGARD, Software Engineering and Its Application to Avionics 8 p (SEE N89-18446 11-06) Nov. 1988 In FRENCH
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The factors involved in the definition of requirements for combat aircraft are discussed with particular attention being given to the development of operational specifications, prediction of future combat mission conditions, technology advances, cost and development problems, and crew workloads. The application domains of artificial intelligence and expert systems are outlined and the advantages and disadvantages of the systems are discussed. Author

N89-18452# Aerospatiale, Marignane (France). Div. Helicopteres.
CONTROL OF ON-BOARD SOFTWARE [MAITRISE DES LOGICIELS EMBARQUES]
MONIQUE SLISSA and PIERRE VILLEDIEU *In* AGARD, Software Engineering and Its Application to Avionics 10 p (SEE N89-18446 11-06) Nov. 1988 In FRENCH
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Various aspects of the flight software development process are examined including the evolution of the industrial environment, the general strategy for system management, and the politics of software development. Productivity concepts such as code reusability and error minimization are addressed. Specific attention is given to the software development cycle and methodologies utilized by the Aerospatiale Helicopter Division. Author

N89-18454# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
AVIONICS SYSTEMS ENGINEERING AND ITS RELATIONSHIP TO MISSION SOFTWARE DEVELOPMENT
HERBERT KLENK and HELMUT RAPP *In* AGARD, Software Engineering and Its Application to Avionics 13 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The introduction of digital avionics into military fighter aircraft and the accompanying transition from electromechanical to software-intensive systems are forcing the aviation industry into new approaches to systems design, development, integration, and test. The avionic systems development and methodology established and used at MBB, its relationship to software

development and the experiences made by the application of this development methodology and its related tools to such major programs as the development of the Electronic Combat Reconnaissance Tornade, the integration of the HARM missile into the Interdiction Strike Tornado and the Improved Combat Efficiency Program of the German F-4F Phantom. As far as the weapon system Tornado is concerned, avionics system design, integration, and test as well as system software are trinational under takings which include three different customers and different operational needs. Any systems development methodology has to reflect these prerequisites. Therefore, also addressed are the problems and solutions for international cooperation in systems and software development and their impact upon project management and control. The toolset in use for system development requires further enhancements. Potential improvements of existing and requirements for additional tools are also being described. Author

N89-18469# Allgeimeine Elektrizitaets-Gesellschaft, Ulm (Germany, F.R.). Airborne Radar System Group.
AVIONICS EXPERT SYSTEMS
ULRICH D. HOLZBAUR *In* AGARD, Software Engineering and Its Application to Avionics 18 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Some experiences and ideas on the expert systems (XS) approach to solving problems of avionic data processing are presented. The focus is on problems concerning fighter aircraft and within these mainly on radar components. Avionics expert systems may be a development tool, part of a ground support system or integrated in an avionics data processing system. In the aircraft, main applications comprise mission oriented tasks like pilot's associate and sensor oriented tasts like navigation or radar. Areas in which more intelligent radar data processing is needed comprise situation awareness, mode selection, and electronic counter countermeasures (ECCM), noncooperative target identification (NCI), and radiation management. To show the applicability of the expert systems approach to identification tasks, a demonstration system for the recognition of aircraft from the textural description of a picture was developed and tested. Author

N89-18470# Aerospatiale, Paris (France).
CONTRIBUTION OF EXPERT SYSTEMS TO AVIONICS ADVANCE APPLICATION ON AS30 LASER WEAPON SYSTEM
SERGE DUPUY *In* AGARD, Software Engineering and Its Application to Avionics 7 p (SEE N89-18446 11-06) Nov. 1988 Previously announced as N88-29449
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Artificial intelligence and expert systems are introduced. The interest and difficulties relating to this technique are exposed. An example of expert system development for AS30L weapon system illustrates the points stated. Prospects of this technique for avionics are assessed. ESA

N89-18471# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
INTEGRATION OF VOCAL DIALOGUE ON-BOARD A COMBAT AIRCRAFT [INTEGRATION DU DIALOGUE VOCAL A BORD D'UN AVION DE COMBAT]
J. L. BUSTAMANTE *In* AGARD, Software Engineering and Its Application to Avionics 10 p (SEE N89-18446 11-06) Nov. 1988 In FRENCH
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The integration and use of vocal dialogue methods in combat aircraft is examined. In particular, research related to the simulation and implementation of such methods on the Rafale demonstrator aircraft is described. Integration of voice command capabilities with head-up and other visual displays is addressed. A tapping rhythm task was performed to assess pilot performance with and without voice dialogue. Author

N89-18472# General Dynamics Corp., Fort Worth, TX.
INTEGRATION OF ADVANCED SAFETY ENHANCEMENTS FOR F-16 TERRAIN FOLLOWING
JAMES BLAYLOCK, DONALD SWIHART, and WILLIAM URSCHEL (Aeronautical Systems Div., Wright-Patterson AFB, OH.) *In* AGARD, Software Engineering and Its Application to Avionics 10 p (SEE N89-18446 11-06) Nov. 1988 Previously announced as A88-22573
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Application of System-Wide Integrity Management (SWIM) to the maximization of flight safety for the F-16 terrain following (TF) system is considered. The architecture of the F-16 TF system is discussed, identifying areas where conventional self-test is not sufficient to ensure flight safety. Detection of flight-critical malfunctions by SWIM is followed by an automatic recovery maneuver consisting of a roll to wings-level fly-up for the F-16 system. The addition of SWIM to the single-thread configuration of the F-16 TF system results in 14 percent predicted mishap rate reduction at far less cost and installation impact then the redundant configuration (which offers a 17 percent reduction). Author

N89-18481# Thomson-CSF, Malakoff (France). Radar, Counter-Measure, Missile Div.
REAL TIME EXPERT SYSTEM FOR ONBOARD RADAR IDENTIFICATION
THIERRY SCHANG and FRANCOIS FAGES (Thomson-CSF, Orsay, France) *In* AGARD, Software Engineering and Its Application to Avionics 7 p (SEE N89-18446 11-06) Nov. 1988 Sponsored in part by DRET
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The use of expert system techniques for radar identification in countermeasure systems was widely discussed in literature. The main advantages of such a system are that it is easily adaptable to the ever changing operational field and that is can identify modern radars with their increasingly complex signals. These systems are however very demanding on computing resources and their adaptation to on-board, real-time processing is not straightforward. The application under consideration is first briefly described. The constraints that arise out of its real time operation are then detailed along with how each one can be eliminated. The application of these concepts to a real time radar identification function is then described. Finally, future objectives in the integration of artificial intelligence techniques for on-board processing are described. Author

N89-18483# Electronique Marcel Dassault, Saint Cloud (France).
UTILIZATION OF EMICAT FOR THE DEVELOPMENT OF AEROSPACE EXPERT SYSTEMS [UTILISATION DE EMICAT POUR LE DEVELOPPEMENT DE SYSTEMES EXPERTS AEROSPATIAUX]
BRUNO MEHU and ANTOINE VIVANCOS *In* AGARD, Software Engineering and Its Application to Avionics 8 p (SEE N89-18446 11-06) Nov. 1988 In FRENCH
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The major difficulties encountered during the development of PROLOG expert systems in an industrial environment are discussed. The necessity for the extension from PROLOG to an object oriented language is explained and strategies for the facilitation of expert system programming are described. In addition, the environment constructed on the PROLOG extension (EMICAT) for knowledge representation and exploitation in the form of production rules is described. Four applications in the areas of aeronautics and aerospace are discussed including: an expert system for defining aircraft electronic circuits (BASILE); an expert system for satellite battery monitoring and management (GIBUS); an expert system diagnostic aid for satellite orbit and attitude control (SCAO); and an expert system for satellite power supply management and fault detection (PCS). Author

N89-18486# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.) Military Aircraft Div

ADA IN EMBEDDED AVIONIC SYSTEMS

W. MANSEL *In* AGARD, *Software* Engineering and its Application to Avionics 7 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Ada will be used for real-time avionic software on the Tornado aircraft upgrade program and on the EFA program. For the HARM integration program onto the Tornado aircraft an Ada crosscompiler based on the Karlsruhe compiler technology configured to a multiprocessor avionic computer is used. Software prototyping was applied to gain experience with Ada avionics application. The results will be discussed as well as the experience from benchmark tests on different Ada crosscompiler systems for the single processor MC 68000 and 68020 microprocessor targets. Special emphasis will be taken on Ada tasking and the parallelism in avionic software. Author

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and onboard auxiliary power plants for aircraft.

N87-21184# Imperial Coll. of Science and Technology, London (England) Dept. of Mechanical Engineering

VELOCITY AND TEMPERATURE MEASUREMENTS IN A CAN-TYPE GAS-TURBINE COMBUSTOR

A. F. BICEN, M. V. HEITOR (Instituto Superior Tecnico, Lisbon, Portugal), and J. H. WHITELAW *In* AGARD Advanced Instrumentation for Aero Engine Components 12 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Velocity and temperature measurements have been obtained in a can-type combustor operating at near atmospheric pressure. Velocity characteristics were determined with a laser Doppler velocimeter and a digitally compensated fine bare-wire thermocouple was used to measure the mean and rms values of temperature fluctuations. The experimental methods are emphasized. The main sources of imprecision are identified, the estimate of the related errors are evaluated. Sample results are given so as to demonstrate the effect of air-fuel ratio on the velocity and temperature characteristics of the combustor. The imprecision in velocity measurements was mainly associated with statistical errors and velocity gradient broadening effects due to the finite size of the measurement volume. The maximum statistical errors were of the order of 2 and 3% for the mean and rms values and the broadening effects can lead to overestimation by up to 25% in the rms values of the swirl velocity component near the swirl center. The error in the mean temperature was mainly due to radiation losses which monotonically increased with temperature and were less than 8%. The catalytic effects were small and limited to regions close to the fuel injector, causing a maximum increase in the mean temperature by no more than 70 K. The uncertainties in the time constant resulted in a maximum error in the rms values of the order of 7%. The effect of AFR on the velocity and temperature characteristics was relatively weak in the primary zone of the combustor. Author

N87-21927# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

TRANSONIC AND SUPERSONIC PHENOMENA IN TURBOMACHINES

Mar. 1987 374 p In ENGLISH and FRENCH Meeting held in Munich, West Germany, 10-12 Sep. 1986
(AGARD-CP-401; ISBN-92-835-0413-5; AD-A182996) Avail: NTIS HC A16/MF A01

The Specialists' Meeting was arranged in the following sessions: Experimental Data on Shock Structures; Shock Induced Losses Including Shock Boundary Layer Interaction; Computational Results; and Blade Design Methods. In order to maintain high efficiency and reliability of advanced engines with high speed in compressors and turbines, a deep understanding of the influence of transonic and supersonic phenomena is essential. The meeting was aimed at providing a contribution to this goal. For individual titles, see N87-21928 through N87-21951.

N87-21929*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

SHOCK STRUCTURE MEASURED IN A TRANSONIC FAN USING LASER ANEMOMETRY

JERRY R. WOOD, ANTHONY J. STRAZISAR, and P. SUSAN SIMONYI (Sverdrup Technology, Inc., Middleburg Heights, Ohio.) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 14 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01 CSCL 21E

Shock structure measurements acquired in a low aspect ratio transonic fan rotor are presented and analyzed. The rotor aspect ratio is 1.56 and the design tip relative Mach number is 1.38. The rotor flowfield was surveyed at near maximum efficiency and near stall operating conditions. Intra-blade velocity measurements acquired with a laser fringe anemometer on blade-to-blade planes in the supersonic region from 10 to 60 percent span are presented. The three-dimensional shock surface determined from the velocity measurments is used to determine the shock surface normal Mach number in order to properly calculate the ideal shock jump conditions. The ideal jump conditions are calculated based upon the Mach numbers measured on a surface of revolution and based upon the normal Mach number to indicate the importance of accounting for shock three dimensionality in turbomachinery design. Comparison of the shock locations with those predicted by a 3-D Euler code showed very good agreement and indicated the usefulness of integrating computational and experimental work to enhance the understanding of the flow physics occurring in transonic turbomachinery passages. Author

N87-21930# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Dept. of Engineering Sciences.

WAKE AND SHOCK INTERACTIONS IN A TRANSONIC TURBINE STAGE

D. L. SCHULTZ, A. B. JOHNSON, D. A. ASHWORTH, M. J. RIGBY, and J. E. LAGRAFF (Syracuse Univ., N. Y.) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 16 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

The strong trailing-edge shock waves from the nozzle guide vanes of transonic turbine stages can give rise to interactions with the downstream rotor which are significantly more severe than is the case with lower pressure ratio stages. It is therefore important to study such effects in detail both from the point of view of stage power output and more importantly from that of heat transfer rates. Transonic rotor profile was made in a static cascade in which the effect of shock wave interaction is simulated by means of an array of bars rotating at the correct speed and spacing upstream of the stationary rotor blades. Detailed heat transfer rate measurements made with rapid response gauges enable the wake and shock phenomena to be separated. Author

N87-21931# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Entwurfsaerodynamik.

THE BOUNDARY LAYER BEHAVIOUR OF HIGHLY LOADED COMPRESSOR CASCADE AT TRANSONIC FLOW CONDITIONS

H. HOHEISEL and N. J. SEYB (Rolls-Royce Ltd., Bristol, England) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 17 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

The design of efficient blade profiles for gas turbine compressors can no longer be effectively carried out through the use of correlations of 2D-cascade data. For the description of the real flow field three dimensional effects have to be taken into account. Modern theoretical calculation methods which involve the determination of blade profile pressure distribution and the associated boundary layer parameters, are now becoming accepted practice. However before the engine designer can have confidence in these methods the predicted performance must be demonstrated to be in good agreement with experimental data. An accurate set of experimental measurements of blade profile pressure

distributions and boundary layer parameters are presented under quasi-3D-flow conditions and these are compared with the predicted performance for a high deflection transonic compressor cascade. It is shown that for conditions near minimum loss incidence the agreement between measure and predicted values is achieved to an adequate engineering standard and that the two most important aspects, choking flow and boundary layer separation are well predicted. Also the data presented could be used to further update and improve the current prediction methods. Author

N87-21932*# Massachusetts Inst. of Tech., Cambridge. Gas Turbine Lab.

VORTEX SHEDDING IN COMPRESSOR BLADE WAKES

A. H. EPSTEIN, J. B. GERTZ, P. R. OWEN, and M. B. GILES *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 13 p (SEE N87-21927 15-07) Mar. 1987 Sponsored by NASA. Lewis Research Center and AFOSR

(AGARD-CP-401) Avail: NTIS HC A16/MF A01 CSCL 21E

The wakes of highly loaded axial compressor blades were often considered to be turbulent, unstructured flows. Recent work has suggested that the blade wakes are in fact dominated by a vortex street-like structure. The work on the wake structure at MIT is reviewed, the results of a viscous numerical simulation are presented, the blade wake vortices are compared to those shed from a cylinder, and the implications of the wake structure on compressor performance are discussed. In particular, a two-dimensional, time accurate, viscous calculation shows both a periodic wake structure and time variations in the passage shock strength. The numerical calculations are compared to laser anemometer and high frequency response probe data. The effect of the wake structure on the entropy production and apparent adiabatic efficiency of the compressor rotor is discussed. Author

N87-21934# Cambridge Univ. (England). Whittle Lab.

MEASURED AND PREDICTED LOSS GENERATION IN TRANSONIC TURBINE BLADING

W. N. DAWES, J.-J. CAMUS, L. P. XU, and C. G. GRAHAM (Rolls-Royce Ltd., Bristol, England.) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 11 p (SEE N87-21927 15-07) Mar. 1987

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

For a typical transonic turbine rotor blade, designed for use with coolant ejection, the trailing edge, or base loss is three to four times the profile boundary layer loss. The base region of such a profile is dominated by viscous effects and its seems essential to attack the problem of loss prediction by solving the compressible Navier-Stokes equations. However, such an approach is inevitably compromised by both numerical accuracy and turbulence modeling constraints. A Navier-Stokes solver written for 2D blade-blade flows and employing a simple two-layer mixing length eddy viscosity model are described. Then, measured and predicted losses and base pressures are presented for two transonic rotor blades and attempts are made to assess the capabilities of the Navier-Stokes solver and to outline areas for future work. Author

N87-21935# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).

INFLUENCE OF SHOCK AND BOUNDARY-LAYER LOSSES ON THE PERFORMANCE OF HIGHLY LOADED SUPERSONIC AXIAL FLOW COMPRESSORS

K. D. BROICHHAUSEN and H. E. GALLUS (Technische Hochschule, Aachen, West Germany.) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 14 p (SEE N87-21927 15-07) Mar. 1987

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

Performance and losses of trans/supersonic axial flow compressors are influenced by shock structure, shock-boundary layer interactions and boundary layer separation. The combination of these phenomena and their effects on the flow characteristics of supersonic compressors are discussed. For this purpose experimental results are compared with theoretical approaches involving different semi-empirical correlations for shock and boundary layer losses, for separation and flow deviation. By an appropriate combination of these models the flow characteristics of supersonic compressors are interpreted and the performance of such compressors is successfully reproduced in a wide range. Finally, generally valuable statements on the design of highly loaded supersonic compressors are derived and possible perspectives are described. Author

N87-21936# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

SHOCK WAVES LOSSES ANALYSIS

ANTOINE FOURMAUX and ALAIN LEMEUR *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 11 p (SEE N87-21927 15-07) Mar. 1987 In FRENCH; ENGLISH summary

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

In advanced technology turbomachinery design, reducing aerodynamic losses is an important matter. Schematically, these losses have 3 origins: losses related to the leading-edge shock; losses related to the main-compression shock; and friction losses, related to the boundary layer evolution. For given inlet and outlet conditions, a judicious designing of the blade profiles may induce a minimum loss level. In order to successfully conclude such a design, some rather experimental work was recently performed in ONERA, the main results of which are presented. Leading edge shock (the influence of the leading edge shape on the shock and on its impingement on the lower blade section surface); experimental analysis of a single blade-to-blade passage in order to validate certain principles concerning shock/boundary layer interaction; and experimental analysis of a cascade in which the blade profile is specially designed to minimize the losses are examined. All projects were done on two-dimensional flow. The alternate use of theoretical and experimental methods will be emphasized. Author

N87-21937# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.

EXPERIMENTAL INVESTIGATIONS ON SHOCK LOSSES OF TRANSONIC AND SUPERSONIC COMPRESSOR CASCADES

H. A. SCHREIBER *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 15 p (SEE N87-21927 15-07) Mar. 1987

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

The losses of transonic and supersonic compressor bladings are due to viscous effects and due to entropy rises in shock waves arising in the entrance regions and passages of the blades. Depending on inlet Mach number, inlet flow angle, and back pressure the shock loss level reaches 40 to 70 percent of the overall losses. Most of the loss prediction models in use consider viscous and shock losses separately. However, very few quantitative experimental data of shock losses are available to verify these models. A separation of the viscous and shock losses is performed by the analysis of wake measurements behind some compressor cascades. The cascade tests were performed in the inlet Mach number range from 0.8 to 1.7. Detailed information is presented about the shock structure and the region of shock boundary layer interaction in the blade passage of a supersonic cascade obtained with the aid of laser anemometry. Author

N87-21938# Alfa Romeo S.p.A., Naples (Italy).

OPTIMISATION OF A TRANSONIC FLOW RADIAL VANED DIFFUSER

SALVATORE COLANTUONI and RENE VANDENBRAEMBUSSCHE (Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese, Belgium) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 10 p (SEE N87-21927 15-07) Mar. 1987

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

The transonic flow in an existing radial vaned diffuser was analyzed with a time dependent finite area calculation method. The calculated Mach number distribution indicates a strong bow shock upstream of the throat. Based on this experience, new diffusers were designed in order to optimize the Mach number distribution in the semi-vaneless space by designing for a shock-free deceleration. The best predictions are obtained with a modified version of the design method of Herbert and Came in which a radial change of diffuser width is incorporated. Experimental results obtained with this optimized design show an important increase in range and confirms the shock-free deceleration of the flow. The difference between the calculated and measured pressure distribution can be explained by incidence effect due to an incorrect estimation of the boundary layer blockage on the lateral walls. Better predictions will be possible only if a more precise definition

of the real flow conditions at the diffuser inlet becomes available.
Author

N87-21940# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
THREE-DIMENSIONAL COMPUTATION AROUND TURBOMACHINE BLADES WITH FINS [CALCUL TRIDIMENSIONNEL DANS LES AUBABES DE TURBO-MACHINES AVEC NAGEOIRE]
T. DERRIEN *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 15 p (SEE N87-21927 15-07) Mar. 1987 In FRENCH
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

The numerical solution of the Euler equations governing the flow at finned blades of a rotating wheel is presented. An explicit domain method, selected for its simplicity, is used. The analysis of the computation results, comparing blades in the same conditions with and without fins, allowed the principle influences of the fins on the aerodynamic field to be revealed. M.G.

N87-21941# Stuttgart Univ. (Germany, F.R.). Inst. fuer Luftfahrtantriebe.
A QUASI THREE DIMENSIONAL METHOD FOR THE CALCULATION OF TRANSONIC FLOWS IN TURBOMACHINES
JOERG HALLER *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 12 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

A procedure based on the iterative coupling of flow calculations on S1 blade-to-blade stream surfaces and a flow calculation on an S2 hub-to-tip stream surface is described. The solutions on S1 surfaces of revolution are obtained by a time marching method in finite volume form, whereas a finite difference method is used for the S2 calculation. The finite difference method uses a stream function formulation based on a passage averaging technique in order to account for non-axisymmetric flows, especially with shocks inside a blade row. Sample calculations of a single-stage and a two-stage compressor are presented and compared with measurements. Author

N87-21942# Politecnico di Milano (Italy). Dipt. di Energetica.
TRANSONIC THREE-DIMENSIONAL INVISCID CALCULATIONS IN TURBOMACHINES
F. BASSI and M. SAVINI (National Center for Energetics and Propulsion, Peschiera Borromeo, Italy) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 10 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

A finite volume Euler solver which was applied to the calculation of the three-dimensional transonic flow field through straight cascades is described. The numerical algorithm, based on Jameson's approach, uses a centered space discretization, with explicit adaptive dissipation terms, and a three-stage Runge-Kutta method for the time integration; the convergence to the steady state solution may be enhanced by using local time step, residual smoothing, and enthalpy damping. The calculations were performed in a O-type grid, obtained by means of a constructive approach which guarantees good properties of smoothness, orthogonality, and resolution near the body. The computational code was applied to two turbine blade cascades in transonic regime tested at the von Karman Institute. Three-dimensional effects were introduced by imposing an inlet velocity profile normal to the endwall. The computational results show good agreement with the blades pressure experimental data and the code performed well in the prediction and development of the secondary flow vortices.
Author

N87-21943# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
COMPUTATION OF TRANSONIC 2D CASCADE FLOW AND COMPARISON WITH EXPERIMENTS
H.-W. HAPPEL, H. J. DIETRICHS, and K. LEHMANN *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 19 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

A time-marching finite area method to obtain the steady 2D blade-to-blade solution along an axisymmetric stream surface with changing radius and stream tube thickness is described. The conservation laws are solved in a rotating frame. The numerical scheme is explicit and first order accurate in time and space. To achieve stability, explicit numerical viscosity is added. Three alternative methods of ensuring the zero normal velocity condition along the solid walls are analyzed and their application is discussed. In order to increase the convergence speed, a sequential grid-refining procedure and a multiple-grid algorithm are used in the code. The accuracy and computational efficiency of the computer code are demonstrated for agreement for turbine and compressor cascades. Author

N87-21944# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
A NUMERICAL STUDY OF UNSTEADY FLOW EFFECTS IN A SUPERSONIC COMPRESSOR CASCADE
SCOTT M. RICHARDSON *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 11 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

Recent experimental evidence exists which suggests that compressor cascades operating supersonically may pass a higher mass flow with a periodic inflow condition than with the thermodynamically equivalent mass-averaged steady condition. Since most compressor design methods rely on the use of an axisymmetric analysis, any excursion in mass flow caused by blade row interactions will not be accounted for in the design. The two-dimensional Navier-Stokes equations are solved using the MacCormick explicit algorithm to obtain the flow in a subsonic rotor cascade for both periodic and steady flow inlet conditions. A outflow boundary condition is presented to model the unsteady cascade exit flow conditions by using localized heat addition to produce a choke point near the downstream boundary. A computational study of the wake model parameters used in the periodic inlet boundary condition is performed to determine their effect on the cascade mass flow swallowing capacity. Author

N87-21945# Cambridge Univ. (England). Whittle Lab.
A NUMERICAL STUDY OF THE 3D FLOWFIELD IN A TRANSONIC COMPRESSOR ROTOR WITH A MODELLING OF THE TIP CLEARANCE FLOW
W. N. DAWES *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 12 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

Modeling the complex flowfield in a transonic axial compressor rotor is a considerable but worthwhile challenge for flow prediction methods. A computer code aimed at solving the equations of three dimensional viscous compressible flow in turbomachine geometries is described. The code is applied to the study of the flowfield in a transonic axial compressor rotor at design speed for both maximum flow and towards stall. The rotor was designed and tested using laser two-focus velocimetry. The rotor has a hub-tip ratio of 0.5 and design speed of 20,260 rpm. At the design point the rotor pressure ratio is 1.626 and the mass flow 17.1 kg/s. The predicted flowfield is compared with the laser measurements and the performance of the code discussed. In addition the discussion highlights the changes in the predicted endwall and tip clearance flows as the rotor operating point is moved towards stall. Author

N87-21947# Rolls-Royce Ltd., Bristol (England). Theoretical Science Group.
SOME TURBOMACHINERY BLADE PASSAGE ANALYSIS METHODS: RETROSPECT AND PROSPECT
D. CARRAHAR and T. R. KINGSTON *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 16 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

The development of time marching methods to analyze blades started at Rolls-Royce in the mid seventies, when sufficient computing power was becoming available. It was recognized that such methods had much to offer, especially for transonic and supersonic flows. Since then several different algorithms were developed to predict both quasi-3D and 3D flows. At present the time-marching methods are used to solve the unsteady Euler/Navier-Stokes equations to produce a time steady solution. Future developments are aimed towards predicting loss accurately, and to investigated unsteady effects such as vortex shedding and incoming wakes. Author

07 AIRCRAFT PROPULSION AND POWER

N87-21949# Technische Hochschule, Hanover (Germany, F.R.). Inst. fuer Stroemungsmaschinen.

DOWNSTREAM FLOW ANGLE CORRELATIONS FOR TURBINE CASCADES IN SUBSONIC AND TRANSONIC FLOW CONDITIONS

W. RIESS, P. DALBERT, P.-A. GIESS, and H.-J. HEINEMANN (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany) *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 20 p (SEE N87-21927 15-07) Mar. 1987

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

Extensive experimental and theoretical investigations of different turbine cascades were performed within the transonic Mach number range. Some problems related to measurements in rectilinear cascades are discussed. The flow field calculations performed using a time-marching Euler code limitations can be determined when applying the computer code itself as well as when comparing the calculated data with experimental ones. Experimental and theoretical results within the subsonic Mach number range are used to check the accuracy of simplified methods for calculating the downstream flow angle. Author

N87-21950# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.

A SHOCK LOSS MODEL FOR SUPERCRITICAL SUBSONIC FLOWS IN TRANSONIC AXIAL FLOW COMPRESSORS

R. J. DUNKER *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 15 p (SEE N87-21927 15-07) Mar. 1987

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

This investigation was aimed at developing more sophisticated models to be incorporated in an off-design performance prediction method for transonic axial flow compressor stages for more accurate flow prediction. Primary emphasis was given to the improvement of shock models used for evaluating the shock losses, especially, at supercritical subsonic, but also at supersonic inflow conditions. The developed and refined methods were verified by calculating, investigating, and analyzing the losses of compressor cascades, as well as a transonic axial flow compressor. Author

N87-21951# KHD Luftfahrttechnik G.m.b.H., Oberursel (Germany, F.R.).

COMPARISON BETWEEN INVERSE DESIGNED (PVD) AIRFOILS AND STANDARD SERIES AIRFOILS FOR HIGH LOADED AXIAL TURBINE NOZZLE APPLICATION

M. HORSMANN and M. SCHMIDT *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 6 p (SEE N87-21927 15-07) Mar. 1987

(AGARD-CP-401) Avail: NTIS HC A16/MF A01

Guide vane profiles with transonic flow regions in the flow field were developed for a high loaded one stage axial turbine. The profiles were designed in two different ways: first, using standard design techniques and second, using an inverse design method, where the profile shape is computed from prescribed velocity distributions (PVD). The results of both design methods will be presented. Comparison is made by using another computer program system to calculate the velocity distributions in the flow field, the boundary layer parameters, and the profile losses. The computed results of the first application of an inverse design method on axial turbine guide vanes show that improvements can be made Author

N87-22670# Rolls-Royce Ltd., Bristol (England).

PROPULSION SYSTEM TECHNOLOGIES FOR THRUST VECTORING

P. ROUND and R. F. TAPE (Rolls-Royce, Inc., Atlanta, Ga.) *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 12 p (SEE N87-22663 16-05) Dec. 1986

(AGARD-CP-409) Avail: NTIS HC A07/MF A01

The Harrier/AV-8 aircraft, with its Rolls-Royce Pegasus engine, was developed primarily for vertical or short takeoff and landing operations. To achieve this it employs nozzles capable of vectoring through more than 90 deg to provide lift and a reaction control system to provide aircraft control in low or zero forward speed operation. These features of the aircraft have also been employed to advantage during combat by vectoring in forward flight (VIFFING). Operational analysis studies have identified the potential combat advantage of post-stall maneuvering (PMS) to improve rate of turn and vehicle/weapon pointing. To achieve any or all of these capabilities will require some degree of propulsion system thrust vectoring. Some particular requirements that the need for thrust vectoring place on the engine design and the technologies involved are addressed. Author

N87-24464# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

ENGINE RESPONSE TO DISTORTED INFLOW CONDITIONS

Mar. 1987 304 p In ENGLISH and FRENCH Meeting held in Munich, West Germany, 8-9 Sep. 1986

(AGARD-CP-400; ISBN-92-835-0412-7; AD-A182635) Avail: NTIS HC A14/MF A01

The papers presented at the Propulsion and Energetics Panel 68th Specialists' Meeting are compiled. Individual sessions covered the following subjects: unsteady flow and validation of empirical distortion parameters; computation techniques for engine/compressor performance predictions of distorted inflow; distorted inflow detection; and experimental investigations of engine instability and response to flow distortion. A technical evaluation report summarizing the conference is also presented. For individual titles, see N87-24465 through N87-24480.

N87-24465# Rolls-Royce Ltd., Bristol (England). Dept. of Installation Technology.

REVIEW OF CURRENT KNOWLEDGE ON ENGINE RESPONSE TO DISTORTED INFLOW CONDITIONS

D. D. WILLIAMS *In* AGARD Engine Response to Distorted Inflow Conditions 32 p (SEE N87-24464 18-07) Mar. 1987

(AGARD-CP-400) Avail: NTIS HC A14/MF A01

An overview to the 68th Propulsion and Energetics Panel (PEP) Specialists Meeting is presented. Some current aspects of time-variant, spatial total-pressure distortion and other forms such as swirl, static-pressure distortion, planar-wave perturbations of total pressure, and total temperature distortion are reviewed. Engine response considerations include the influence of engine spool coupling on stability, developments in the modeling of total-pressure circumferential extent effects, and swirl/total-pressure interactions. Guidelines for the formulation of distortion descriptors and performance/stability assessments are reviewed. Author

N87-24466# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

AIR INLET/ENGINE COMPATIBILITY: IMPACT OF THEORETICAL AND EXPERIMENTAL METHODS [COMPATIBILITE ENTREE D'AIR-MOTEUR IMPACT DES METHODES THEORIQUES ET EXPERIMENTALES]

MARIUS GOUTINES and HUGUES JOUBERT *In* AGARD Engine Response to Distorted Inflow Conditions 20 p (SEE N87-24464 18-07) Mar. 1987 In FRENCH

(AGARD-CP-400) Avail: NTIS HC A14/MF A01

Work carried out at SNECMA (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation) to develop clean-flow surge line predictions and numerical distortion-response codes is reported. The experimental efforts defined a state-of-the-art, time-invariant total pressure data acquisition system and a simple means of generating and simulating dynamic pressure distortion. Parametric studies indicate that compressor inlet guide vanes, low-aspect-ratio blades, and small blade row gaps increase stall margin and reduce compressor distortion sensitivities. M.G

N87-24467# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Group.

NEW TRENDS IN INTAKE/ENGINE COMPATIBILITY ASSESSMENT

F. AULEHLA and D. M. SCHMITZ *In* AGARD Engine Response to Distorted Inflow Conditions 24 p (SEE N87-24464 18-07) Mar. 1987

(AGARD-CP-400) Avail: NTIS HC A14/MF A01

The measurement of dynamic distortion requires considerable effort in instrumentation and data processing. Distortion measurement methods which are time and cost efficient are described. Experience gained from the Tornado aircraft indicates that the relevance of dynamic distortion on intake/engine compatibility has been overestimated and, in fact, swirl emerged as the decisive compatibility parameter. Also, during the Airbus A-300 APU intake development swirl turned out to be an important

criterion. In conclusion, it is argued whether in many cases dynamic distortion measurements can be avoided in favor of swirl measurements in combination with simplified methods for dynamic distortion predictions based on steady state measurements and, in some cases, on statistical models. Author

N87-24468# Technische Hochschule, Aachen (Germany, F.R.). Inst. for Jet Propulsion and Turbomachinery.
EFFECT OF STEADY STATE INLET TEMPERATURE DISTORTION ON THE ENGINE COMPRESSOR FLOW
W. KOSCHEL, H. KUENKLER, and H. TOENSKOETTER (Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn, West Germany) *In* AGARD Engine Response to Distorted Inflow Conditions 19 p (SEE N87-24464 18-07) Mar. 1987
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

A prediction model for the effects of a steady state temperature distortion on the overall performance of a multistage engine compressor is presented. In contrast to the well known parallel compressor model this model takes into account the circumferential interaction of the distorted and undistorted compressor flow. An extensive experimental program was carried out on a single-spool jet engine with steady-state inlet temperature and pressure distortion tests. The experimental set-up is briefly described. Detailed results of the flow measurements obtained at the compressor inlet and exit and at the compressor interstage positions are presented and discussed. The experimental results support the validity of the prediction model developed as part of this project. Author

N87-24469*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
VISCOUS ANALYSES FOR FLOW THROUGH SUBSONIC AND SUPERSONIC INTAKES
LOUIS A. POVINELLI and CHARLES E. TOWNE *In* AGARD Engine Response to Distorted Inflow Conditions 20 p (SEE N87-24464 18-07) Mar. 1987
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

A parabolized Navier-Stokes code was used to analyze a number of diffusers typical of a modern inlet design. The effect of curvature of the diffuser centerline and transitioning cross sections was evaluated to determine the primary cause of the flow distortion in the duct. Results are presented for S-shaped intakes with circular and transitioning cross sections. Special emphasis is placed on verification of the analysis to accurately predict distorted flow fields resulting from pressure-driven secondary flows. The effect of vortex generators on reducing the distortion of intakes is presented. Comparisons of the experimental and analytical total pressure contours at the exit of the intake exhibit good agreement. In the case of supersonic inlets, computations of the inlet flow field reveal that large secondary flow regions may be generated just inside of the intake. These strong flows may lead to separated flow regions and cause pronounced distortions upstream of the compressor. Author

N87-24470*# Cambridge Univ. (England).
CALCULATIONS OF INLET DISTORTION INDUCED COMPRESSOR FLOWFIELD INSTABILITY
T. P. HYNES, R. CHUE, E. M. GREITZER, and C. S. TAN (Massachusetts Inst. of Tech., Cambridge.) *In* AGARD Engine Response to Distorted Inflow Conditions 16 p (SEE N87-24464 18-07) Mar. 1987
(Contract NSG-3208)
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

Calculations are presented predicting the onset of flow instability for a multistage low speed axial compressor operating in circumferentially distorted inlet flow. The most important feature of the model used is that it attempts to properly account for the fluid dynamic interaction between the spoiled and unspoiled sectors of the compressor. The calculations show that there is an approximate stability criterion, the annulus averaged slope of the compressor pressure rise characteristic equal to zero, that is valid whenever the dynamics of the compressor distorted flowfield can be considered independent of the compressor environment. This approximate criterion is used to investigate the relationship between the present model and the parallel compressor model. Further calculations are performed to investigate cases of interest when the dynamics of the flowfield are coupled to the environment. Resonant cases and cases when the distortion is unsteady are studied. In particular, it is shown that rotating distortions which propagate in the rotor direction can have a greater effect on stability margin than stationary or counter-rotational ones. Finally, it is shown that the general predictions of the model are insensitive to the details of the unsteady bladerow dynamics. Author

N87-24471# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NUMERICAL STUDY OF THE PROPAGATION OF AN INLET FLOW DISTORTION THROUGH AN AXIAL COMPRESSOR
GERMAIN BILLET, PHILIPPE CHEVALIER, and PIERRE LAVAL *In* AGARD Engine Response to Distorted Inflow Conditions 14 p (SEE N87-24464 18-07) Mar. 1987 In FRENCH; ENGLISH summary Sponsored by DRET
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

A model representing the response of fixed or rotating axial compressor blade rows is coupled to a 3-D numerical simulation of the flow outside the blade rows. The code can be used to study nonuniform compressible 3-D flows through turbomachines. The fluid is assumed to be inviscid in the space outside the rows, while viscous effects are taken into account inside. Numerical results are compared with experimental data in the case of a low speed single stage compressor with an inlet steady total pressure distortion. These comparisons show that the numerical approach is able to predict the global response of the compressor. This work is part of a larger project aimed at predicting the response of a compressor to a nonuniform inlet flow that is periodic in time, or fully unsteady. Author

N87-24472# Societe Bertin et Cie, Plaisir (France).
CALCULATION OF CASCADE FLOW BEHAVIOR IN A DYNAMIC STALL REGIME [CALCUL DU DPMIPRTE,EMT D'UNE GRILLE D'AUBES EN REGIME DE DECROCHAGE DYNAMIQUE]
P. GILLANT, P. SAGNES, and J. P. OLLIER *In* AGARD Engine Response to Distorted Inflow Conditions 20 p (SEE N87-24464 18-07) Mar. 1987 *In FRENCH*
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

An overview is presented of a singularity method coupled with an unsteady boundary layer calculation for modeling unsteady subsonic cascade flow in unstalled and dynamic stall regimes. The short term aim of the work is to provide a method for assessing the distortion sensitivity of multistage axial compressors. Good numerical results have been obtained for steady flow and unsteady attached flow but quantitative validation is difficult due to the paucity of relevant experimental data. For dynamic stall, the studies show the importance of correct modelling of the flow in the neighborhood of the separation point. M.G.

N87-24473# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
IMPROVEMENT OF THE PARALLEL COMPRESSOR MODEL BY CONSIDERATION OF UNSTEADY BLADE AERODYNAMICS
M. LECHT *In* AGARD Engine Response to Distorted Inflow Conditions 13 p (SEE N87-24464 18-07) Mar. 1987
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

The parallel compressor model has been applied to predict compressor performance with circumferential total inlet distortion. In comparison with experiment data, however, this model gives pessimistic results for the predicted stall line shift considering sector angles of distortion up to 120 deg. Detailed experimental evaluation of a compressor stage leads to unsteady performance effects obviously being responsible for this discrepancy. In order to improve the original model the performance characteristic of the compressor was extended to account for a short time overload capability analogous to an airfoil in an unsteady flow. The governing factor of this modification is the time-to-stall versus the time for a blade channel to pass the distorted sector. The model improvement was demonstrated for a DFVLR and a NASA single stage transonic compressor subjected to a screen induced total pressure distortion. Author

N87-24474# General Electric Co., Evendale, OH. Aircraft Engine Business Group.
TURBOFAN ENGINE POST-INSTABILITY BEHAVIOR: COMPUTER SIMULATIONS, TEST VALIDATION AND APPLICATION OF SIMULATIONS
WILLIAM G. STEENKEN *In* AGARD Engine Response to Distorted Inflow Conditions 11 p (SEE N87-24464 18-07) Mar. 1987
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

A method that can be used to predict the post-stability operation of a turbofan engine and is based upon extending the capabilities of engine transient cycle decks is described. Typical predictions are presented and compared with results obtained from the testing of a modern augmented turbofan engine. The potential manners in which this digital computer simulation tool may be utilized are also discussed. Author

N87-24475# Royal Aircraft Establishment, Farnborough (England).
TRANSMISSION OF INLET DISTORTION THROUGH A FAN
J. E. FLITCROFT, J. DUNHAM, and W. A. ABBOTT *In* AGARD Engine Response to Distorted Inflow Conditions 11 p (SEE N87-24464 18-07) Mar. 1987
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

The effect of inlet swirl on the propagation of total pressure distortion through a three-stage fan without inlet guide vanes was investigated on a compressor rig. The tests gave the unexpected finding that the presence of a swirl counter to the rotation of the fan generally reduced the level of steady state distortion transmitted to the core compressor. Dynamic pressure measurements made at the exit from the fan, however, revealed that the swirl also caused a sudden early breakdown of the flow in a sector of the hub region, resulting in high time-invariant distortion levels in the core flow. This observation is compatible with the destabilizing effect of a swirl counter to fan rotation on engines. A theoretical analysis confirmed that a swirl, concentrated at the fan tip at entry, could drive some of the hub blade rows strongly towards stall. Author

N87-24476# Alfa Romeo S.p.A., Naples (Italy). Direzione R and D.
EXPERIMENTAL INVESTIGATION ON SMALL TURBOPROP BEHAVIOUR UNDER COMPRESSOR ROTATING STALL FOR DIFFERENT INLET FLOW CONDITIONS
S. COLANTUONI and G. LIOTTI *In* AGARD Engine Response to Distorted Inflow Conditions 16 p (SEE N87-24464 18-07) Mar. 1987
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

An experimental investigation on compressor rotating stall and acoustic noise in a small turboprop is discussed. The intent of the study, undertaken in Alfa Romeo Avio using the engine test bed during the initial phase of the AR 318 turboprop development program, was to clarify the noisy and unstable behavior of some engines at part-speeds. The overall performances of the centrifugal compressor, the time-dependent wall static pressure measurements used to visualize impeller rotating stall regions on the compressor map, and the acoustic noise signals detected at the engine-intake inlet are presented. Finally, the engine performances in stalled compressor conditions are analyzed and main results are discussed. Author

N87-24477*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SUMMARY OF INVESTIGATIONS OF ENGINE RESPONSE TO DISTORTED INLET CONDITIONS
THOMAS J. BIESIADNY, WILLIS M. BRAITHWAITE, RONALD H. SOEDER, and MAHMOOD ABDELWAHAB *In* AGARD Engine Response to Distorted Inflow Conditions 21 p (SEE N87-24464 18-07) Mar. 1987 Previously announced as N86-26336
(AGARD-CP-400) Avail: NTIS HC A14/MF A01

A survey is presented of experimental and analytical experience of the NASA Lewis Research Center in engine response to inlet temperature and pressure distortions. Results of experimental investigations and analytical modeling are reviewed together with a description of the hardware and the techniques employed. Distortion devices successfully simulated inlet distortion, and knowledge was gained on compression system response to different types of distortion. A list of NASA research references is included Author

N88-13231# Johns Hopkins Univ., Laurel, MD. Applied Physics Lab.
HYPERSONIC AIRBREATHING PROPULSION: EVOLUTION AND OPPORTUNITIES
P. J. WALTRUP *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 29 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

A history of the evolution of airbreathing propulsion, with emphasis on the development of supersonic combustion ramjet (scramjet) engines, is presented. The current status of scramjet engines is discussed and deficiencies in fundamental and applied data and/or knowledge, which comprise opportunities for future work, are noted. Author

N88-13344# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
APPLICATION OF MODIFIED LOSS AND DEVIATION *CORRELATIONS TO TRANSONIC AXIAL COMPRESSORS*
M. CETIN, A. S. UECER, CH. HIRSCH, and G. K. SEROVY Nov. 1987 74 p
(AGARD-R-745; ISBN-92-835-0346-4; AD-A191187) Avail: NTIS HC A04/MF A01

The goal was to analyze the transonic compressor tests available in the open literature and to propose possible improvements in total loss and turning correlations. From the work performed six conclusions could be drawn for the achievement of better loss predictions. A comparison with results of a two-stage compressor showed that the results of the new correlation set were satisfactory. For more accurate predictions a consistent end-wall boundary layer and secondary loss calculation method must be applied; in multi-stage compressors, spanwise loss mixing procedures must be used. Author

N88-17647# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
ADVANCED TECHNOLOGY FOR AERO GAS TURBINE COMPONENTS
Sep. 1987 541 p In ENGLISH and FRENCH Symposium held in Paris, France, 4-8 May 1987
(AGARD-CP-421; ISBN-92-835-0433-X; AD-A198664) Avail. NTIS HC A23/MF A01

The Symposium is aimed at highlighting the development of advanced components for new aero gas turbine propulsion systems in order to provide engineers and scientists with a forum to discuss recent progress in these technologies and to identify requirements for future research. Axial flow compressors, the operation of gas turbine engines in dust laden atmospheres, turbine engine design, blade cooling, unsteady gas flow through the stator and rotor of a turbomachine, gear systems for advanced turboprops, transonic blade design and the development of a plenum chamber burner system for an advanced VTOL engine are among the topics discussed. For individual titles, see N88-17648 through N88-17681.

N88-17648# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Turbine Engine Div.
THE COMING REVOLUTION IN TURBINE ENGINE TECHNOLOGY
JAMES S. PETTY and ROBERT E. HENDERSON *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p (SEE N88-17647 10-07) Sep. 1987
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

A major change in turbopropulsion technology development philosophy is now being pursued by the U.S. Air Force Wright Aeronautical Laboratories (AFWAL) which will provide revolutionary advancements in overall operational performance capability for future military aircraft and aerospace weapon systems. An historical perspective illustrates the significance of the advancements being pursued, with engine thrust-to-weight used as the principal performance figure-of-merit. The High Performance Turbine Engine Technologies (HPTET) effort, begun in 1982, is discussed. The overall goal of the effort is to provide the advanced materials, innovative structural concepts and advanced aerothermodynamics to double turbopropulsion capability by the year 2000 Author

N88-17649# Rolls-Royce Ltd., Bristol (England). Lift Engines and Future Technology Demonstrators.

OPTIMISATION OF MILITARY COMPRESSORS FOR WEIGHT AND VOLUME

K. R. GARWOOD *In* AGARD Advanced Technology for Aero Gas Turbine Components 7 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by Procurement Executive Ministry of Defence, United Kingdom

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The high pressure compression system for future fighter engines has been projected at two different proven technology standards. For a given cycle of approximately 175 lbs. and 25:1 overall pressure ratio, three compressors have been evaluated, ranging from a seven stage unit with medium loading, to a five and a four stage unit with high loading. Test data of the original research parent compressors and two project specific units was commonised to the engine size and conditions. It is shown that apparent benefits between machines are negated and no significant advantage for lower work per stage could be identified at a given blading technology standard. Relative to the seven stage unit, a weight advantage of 20 percent is gained by the adoption of a four stage unit, and it is associated with an airfoil count reduction of 15 percent. Author

N88-17650# Royal Aircraft Establishment, Farnborough (England).

AN EXAMINATION OF THE IMPAC OF POTENTIAL ADVANCES IN COMPONENT TECHNOLOGY FOR FUTURE MILITARY ENGINES

M. R. LITCHFIELD and M. G. PHILPOT *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The prospects for major advances in gas turbine engine component technology over the next 20 years are examined. For future military engines and aircraft, these advances could lead to considerably higher thrust/weight ratios than are currently available. The gains in engine performance resulting from various specific technology advances are outlined and their impact on sizing and performance of a typical combat aircraft are considered. In conjunction with these future projections, an examination is also made of the influences of the main engine cycle parameters such as overall pressure ratio, bypass ratio, and rating philosophy on the mass and performance of the aircraft/engine combination. Author

N88-17651# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

SPECIFICATION OF AN ENGINE AND ITS COMPONENTS STARTING FROM A CONSIDERATION OF AIRCRAFT MISSIONS [SPECIFICATION DU MOTEUR ET DE SES COMPOSANTS A PARTIR DES MISSIONS DE L'AVION]

A. LARDELLIER and I. DUFAU *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

A computer implemented methodology for the optimization of engine cycles is described. The integrated technique considers engine size and mechanical design features, basic aircraft aerodynamic and weight/size characteristics, and aircraft mission operational requirements. Three applications of the method are discussed: the influence of engine weight on the aircraft and mission characteristics; the influence of afterburn on supersonic cruise missions; and the influence of mission parameters on engine cycle and aircraft size. Author

N88-17652# Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Strahlantriebe und Turboarbeitsmaschinen.

APPLICATION OF HIGHLY LOADED SINGLE-STAGE MIXED-FLOW COMPRESSORS IN SMALL JET-ENGINES

R. MOENIG, K. D. BROICHHAUSEN (Motoren- und Turbinen-Union Muenchen G.m.b.H., West Germany), and H. E. GALLUS *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by Bundesamt fuer Wehrtechnik und Beschaffung, Fed. Republic of Germany

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The predominant requirements on small jet engines are high power-to-weight ratio and low specific fuel consumption in combination with structural simplicity. The consequent demands on the compressor can be fulfilled either by a conventional two-stage unit or by an extremely loaded single stage. This single stage compressor has to be able to perform at a sufficiently large massflow and total pressure ratio. Consequently, the application of a mixed flow compressor with supersonic flow at rotor- or stator-inlet (supersonic mixed-flow compressor) turns out to be advantageous. The conception of a jet engine with a supersonic combustor demonstrates the significantly reduced size compared with other engines of the same thrust class. Author

N88-17653# Societe Turbomeca, Bordes (France).

THE ADVANTAGE OF VARIABLE GEOMETRY FOR TURBINE ENGINES AT LOW POWER [INTERET DE LA GEOMETRIE VARIABLE POUR LES TURBOMOTEURS DE FAIBLE PUISSANCE]

H. VIGNAU, R. RODELLAR, and J. SILET *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

To reduce the specific fuel consumption of gas turbines at low power, various cycles of free and bound turbine engines were studied. A variable output engine permits a significant reduction of specific consumption at partial capacity. The variation in power is obtained through the change in the variable geometry component output; engine operating pressure, turbine intake temperature, and rotation velocity constants. The models which take variable geometry systems into account should be improved to specify the potential gains of such techniques. The results of a study on a centrifugal compressor with a compression rate of 8.5 and with a variable-setting radial diffuser show that an output variation of 50 percent can be obtained with a slight variation in efficiency and low sensitivity. Author

N88-17654# Calspan Advanced Technology Center, Buffalo, NY.

OPERATION OF GAS TURBINE ENGINES IN DUST-LADEN ENVIRONMENTS

M. G. DUNN, C. PADOVA, and R. M. ADAMS (Defense Nuclear Agency, Washington, D.C.) *In* AGARD Advanced Technology for Aero Gas Turbine Components 16 p (SEE N88-17647 10-07) Sep. 1987

(Contract DNA001-83-C-0182)

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

Results are reported for a measurement program designed to investigate the performance deterioration of gas turbine engines and the associated auxiliary equipment difficulties when operating in dust laden environments. Three TF33 turbofan engines and one J57 turbojet engine have been tested with two different dust blends. The predominant damage mechanism in all the engines was compressor blade erosion. The length of dust exposure time required to cause engine damage was dependent upon power setting and dust concentration. The turbine inlet temperature for these engines was too low to realize deposition of glassy material on the hot section components. The Environmental Control System (ECS) was monitored to ascertain the amount of injested material and the size distribution of material that makes its way to the ECS. A significant fraction of the dust is not centrifuged out of the flow and does end up in the control system air. These particles have a mean size on the order of 6 microns. The engine parameters most indicative of degradation were identified and are discussed. Author

N88-17655# National Research Council of Canada, Ottawa (Ontario). Gas Dynamics Lab.
A RESEARCH PROGRAM ON THE AERODYNAMICS OF A HIGHLY LOADED TURBINE STAGE
R. G. WILLIAMSON, S. H. MOUSTAPHA, J. P. HUOT, and U. OKAPUU (Pratt and Whitney Aircraft of Canada Ltd., Longueuil, Quebec) *In* AGARD Advanced Technology for Aero Gas Turbine Components 17 p (SEE N88-17647 10-07) Sep. 1987
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The main conclusions drawn from recent work in an on-going experimental program of research on the aerodynamics of a highly loaded turbine stage are discussed. Detailed data have been secured relating to the aerodynamic performance of transonic nozzles of high turning angle (tested with two outer wall contours) and the influence of the stage environment on such measurements. Further work addresses rotor performance (as affected by blade loading), and also overall stage performance. The ultimate objective of the work is the extension of turbine design methods to regimes combining high stage loadings with high pressure ratios, with special emphasis on small blade sizes. Author

N88-17656*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL EVALUATION OF A TRANSLATING NOZZLE SIDEWALL RADIAL TURBINE
RICHARD J. ROELKE and CASIMIR ROGO (Teledyne CAE, Toledo, Ohio.) *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p (SEE N88-17647 10-07) Sep. 1987
(AGARD-CP-421) Avail: NTIS HC A23/MF A01 CSCL 21E

An experimental performance evaluation was made of two movable sidewall variable area radial turbines. The turbine designs were representative of the gas generator turbine of a variable flow capacity rotorcraft engine. The first turbine was an uncooled design while the second turbine had a cooled nozzle but an uncooled rotor. The cooled nozzle turbine was evaluated both with and without coolant flow. The test results showed that the movable nozzle wall is a viable and efficient means to effectively control the flow capacity of a radial turbine. Peak efficiencies of the second turbine with and without nozzle coolant were 86.5 and 88 percent respectively. These values are comparable to pivoting vane variable geometry turbines; however, the decrease in efficiency as the flow was varied from the design value was much less for the movable wall turbine. Several design improvements which should increase the turbine efficiency one or two more points are identified. These design improvements include reduced leakage losses and relocation of the vane coolant ejection holes to reduce mainstream disturbance. Author

N88-17657# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
AN INTEGRATED AERO/MECHANICAL PERFORMANCE APPROACH TO HIGH TECHNOLOGY TURBINE DESIGN
J. HOURMOUZIADIS and G. ALBRECHT *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by German Ministry for Research and Technology, Fed. Republic of Germany
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

Analytical and experimental experience from an advanced technology gas generator program is used to define the requirements on the engineering sciences involved in the design of gas turbine engines. Some aerodynamic, performance and cooling problems to be solved in a common approach with mechanical design for radial clearance control, hot gas path sealing and life are discussed. Author

N88-17658# Royal Aircraft Establishment, Farnborough (England).
DESIGN AND TEST OF A HIGH BLADE SPEED, HIGH WORK CAPACITY TRANSONIC TURBINE
R. C. KINGCOMBE, J. D. BRYCE, and N. P. LEVERSUCH *In* AGARD Advanced Technology for Aero Gas Turbine Components 17 p (SEE N88-17647 10-07) Sep. 1987
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

A high rim-speed turbine was designed and tested. A major objective in the design was to achieve high aerodynamic efficiency at high work capacity by way of reduced stage loading facilitated by high blade speed. The design includes three dimensional features such as a parabolic distribution of exit angle and compound trailing edge lean on the nozzle guide vane and a thick root, highly tapered rotor blade - necessary in an engine turbine to reduce blade stress. Author

N88-17659# Rolls-Royce Ltd., Bristol (England). Advanced Turbine Technology Dept.
ADVANCED TECHNIQUES EMPLOYED IN BLADE COOLING RESEARCH
H. E. ROGERS, C. GRAHAM, and K. MCNICHOLAS *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by Procurement Executive Ministry of Defence, United Kingdom
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The design of an advance cooling system for moderately cooled second stage gas turbine engine blades was undertaken as part of a demonstration project. The design process involving complex computer modeling and hot rig testing of the blades is described. The test results confirmed that substantial increases in cooling efficiency can be gained by introducing small scale turbulators into radial hole cooling systems. A development temperature measurement technique based on a video camera operating in the near infrared region is described. The results of video pyrometry were validated from results obtained from a series of demonstrator hot rig tests. Also discussed are a number of problems relating to surface temperature measurement. Author

N88-17660# Stuttgart Univ. (Germany, F.R.). Inst. fuer Aerodynamik und Gasdynamik.
THE UNSTEADY GAS FLOW THROUGH STATOR AND ROTOR OF A TURBOMACHINE
K. M. FOERSTER *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p (SEE N88-17647 10-07) Sep. 1987
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The difficulties of computing unsteady transonic flow in multiple connected domains with a minimum of neglections and approximations have been overcome by using individual computational grids fixed to each cascade, a novel gridless finite difference scheme, and physically real inflow and outflow boundaries. The resulting computer program is capable of computing the inviscid, plane gas flow through the stator and rotor of a turbomachine stage made from arbitrarily shaped (thick, round nosed) blades of arbitrary spacing, up to local Mach numbers of 1.8. Author

N88-17661# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
DESIGN AND TESTING OF A SMALL RADIAL TURBINE FOR AUXILIARY POWER UNITS [ETUDE ET ESSAIS D'UNE PETITE TURBINE RADIALE POUR GROUPES AUXILIAIRES DE PUISSANCE]
Y. RIBAUD, C. FRADIN, and C. MISCHEL (Microturbo, Toulouse, France) *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH Sponsored in part by Ministere de la Defense, France
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

A project for the development of a small centripetal turbine with an expansion ratio of 3.6 is being undertaken by the Societe MICROTURBO with computational and test analysis support from ONERA. The design goals and strengths are outlined. Preliminary calculations for the design of the nozzle and wheel blades are discussed along with quasi-three dimensional calculations. Results from cold bench tests and corresponding hot engine tests were used to evaluate performance. Presizing and flow field calculations were confirmed in view of the high values of isentropic output obtained. The flow measurements downstream from the wheel, at a nominal operating point, gave the best picture of the fluid characteristics. Author

N88-17662# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec). Turbine Aerodynamics.
DESIGN AND AERODYNAMIC PERFORMANCE OF A SMALL MIXED-FLOW GAS GENERATOR TURBINE
U. OKAPUU *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p (SEE N88-17647 10-07) Sep. 1987
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

Design details and results from aerodynamic rig tests are presented for four variants of a mixed flow turbine having a design

target pressure ratio of 3:1. This experimental turbine, designed to satisfy the aerodynamic requirements of a gas generator turbine in a hypothetical small turboprop engine, demonstrated a design point efficiency substantially in excess of that predicted for a single stage axial turbine of equivalent duty. Design and material implications are discussed and potential constraints identified. Author

N88-17663# Ecole Centrale de Lyon (France).
NUMERICAL SIMULATION OF DIFFUSER/COMBUSTOR DOME INTERACTION [SIMULATION NUMERIQUE DE L'INTERACTION DIFFUSEUR TETE DE CHAMBRE]
O. JEANDEL, G. BRUN, S. MEUNIER, and M. DESAULTY (Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel, France) *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The design of a turbojet diffuser and combustion chamber dome can be realized, not only by researching low pressure loss, but also by assuring flow stability around a flame tube. A finite element method developed by Ecole Centrale de Lyon is described. The method employs an elliptic logic and a triangular type mesh which is well adapted for simulating complex geometric configurations. The application of the algorithm to various elementary and industrial configurations demonstrates the method's robustness and its ability to describe the principal flow characteristics in combustion dome regions. Author

N88-17664# Rolls-Royce Ltd., Bristol (England).
DEVELOPMENT OF A PLENUM CHAMBER BURNER SYSTEM FOR AN ADVANCED VTOL ENGINE
J. S. LEWIS, T. W. MURRAY, and D. STEELE *In* AGARD Advanced Technology for Aero Gas Turbine Component 10 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by Procurement Executive Ministry of Defence, United Kingdom
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The research and development programs that were carried out on model and full size rigs to design and evaluate advanced concepts to meet the anticipated thrust requirements for a plenum chamber burner system for an advanced vertical takeoff and landing (VTOL) aircraft are described. The system characteristics of pressure loss, ignition, efficiency, thermal integrity and velocity profiles at nozzle exit under non-combusting (dry) and combusting conditions are discussed. Author

N88-17665# Lucas Aerospace Ltd., Birmingham (England). Engine Systems Div.
PUMPING SYSTEMS AND FLOW INTERFACES FOR RAPID RESPONSE ELECTRONIC REHEAT CONTROLS
THOMAS C. YATES and TREVOR S. SMITH *In* AGARD Advanced Technology for Aero Gas Turbine Components 20 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by Procurement Executive Ministry of Defence, United Kingdom
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The problems of fuel pumping and metering which are associated with digital electronic reheat controls are discussed. A survey is carried out of various pumping options including reheat and main engine fuel pumping. A technical description of single, twin, and three pump systems, including rotordynamic and positive displacement pumps is given together with comments on the relative advantages and disadvantages of the various options. A fuel flow interface designed for rapid response reheat control systems is described. The application is a digital electronic control for a future bypass engine. Comparison is made between computer simulation of the control characteristics and test results of the hardware. Author

N88-17666*# General Electric Co., Cincinnati, OH. Aircraft Engine Business Group.
AERODYNAMIC PERFORMANCE OF A SCALE-MODEL, COUNTER-ROTATING UNDUCTED FAN
THOMAS J. SULLIVAN *In* AGARD Advanced Technology for Aero Gas Turbine Components 16 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by NASA, Washington, D.C.
(AGARD-CP-421) Avail: NTIS HC A23/MF A01 CSCL 21E

The aerodynamic performance of a scale model, counter-rotating unducted fan has been determined and the results are discussed. Experimental investigations were conducted using the scale model propulsor simulator and uniquely shaped fan blades. The blades, designed for a high disk loading at Mach 0.72 at 35,000 feet altitude maximum climb condition are aft-mounted on the simulator in a pusher configuration. Data are compared with analytical predictions at the design point and show good agreement. Author

N88-17667*# General Motors Corp., Indianapolis, IN. Gas Turbine Div.
GEAR SYSTEMS FOR ADVANCED TURBOPROPS
DOUGLAS A. WAGNER *In* AGARD Advanced Technology for Aero Gas Turbine Components 9 p (SEE N88-17647 10-07) Sep. 1987 Sponsored by NASA, Washington, D.C.
(AGARD-CP-421) Avail: NTIS HC A23/MF A01 CSCL 21E

A new generation of transport aircraft will be powered by efficient, advanced turboprop propulsion systems. Systems that develop 5,000 to 15,000 horsepower have been studied. Reduction gearing for these advanced propulsion systems is discussed. Allison Gas Turbine Division's experience with the 5,000 horsepower reduction gearing for the T56 engine is reviewed and the impact of that experience on advanced gear systems is considered. The reliability needs for component design and development are also considered. Allison's experience and their research serve as a basis on which to characterize future gear systems that emphasize low cost and high reliability. Author

N88-17668# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Entwurfsaerodynamik.
NUMERICAL METHODS FOR PROPELLER AERODYNAMICS AND ACOUSTICS AT DFVLR
N. KROLL, D. LOHMANN, and J. SCHOENE *In* AGARD Advanced Technology for Aero Gas Turbine Components 15 p (SEE N88-17647 10-07) Sep. 1987
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

Linear and nonlinear analysis methods for flow fields around propellers were developed. Here, two singularity methods are presented. In the first, a doublet point scheme was formulated for the calculation of steady and unsteady loads on surfaces having helical motion in an incompressible medium, e.g., propellers in uniform and nonuniform inflows and counter rotating propellers. The second is a surface panel method for computations of steady subsonic flows around propeller blades moving in a compressible medium. The method has been extended for the prediction of acoustic quantities. In order to predict the characteristics of transonic propeller flow fields, a Euler code for solving the three dimensional Euler equations was extended. The equations are formulated in a rotating cartesian reference frame. The solution procedure is based on a finite volume method using an explicit Runge-Kutta time stepping scheme. Numerical results for various propeller geometries are presented and compared with experimental data. Author

N88-17669# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ANALYSIS OF HIGHSPEED PROPELLERS AERODYNAMICS
J. M. BOUSQUET *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH; ENGLISH summary
(AGARD-CP-421) Avail: NTIS HC A23/MF A01

Highspeed propellers are studied. A synthesis of aerodynamic developments leading to the HT3 propeller definition and test in the S1 Modane wind tunnel is presented. The validity of the main calculation methods used in this research is analyzed. Counterrotating highspeed propellers are also studied. Their performance benefits against single rotation propellers are presented. Author

07 AIRCRAFT PROPULSION AND POWER

N88-17670# Fiat Aviazione S.p.A., Turin (Italy). Direzione Progettazione.

ANALYSIS OF POSSIBLE TRANSMISSION ARRANGEMENTS APPLICABLE FOR DRIVING SINGLE OR TWIN COUNTERROTATING FANS ON PROPFAN ENGINES

L. BATTEZZATO and S. TURRA *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

A number of different designs of propfan engines are now being defined by the main engine manufacturers in the world. Some of these designs require a reduction gearbox between the LP turbine and the propfan; the propfan itself is conceived as single stage, variable pitch blade or double counterrotating stage variable pitch solution. In order to satisfy these requirements, the authors propose different mechanical arrangements of the reduction gearbox and, for given engine interfaces, compare their relative merits in order to eventually show the optimum solution. The comparison is made on the basis of various aspects: lightness, quietness, life, reliability, safety and maintainability. Author

N88-17671# Stuttgart Univ. (Germany, F.R.). Inst. fuer Aero- und Gasdynamik.

TRANSONIC BLADE DESIGN ON ROTATIONAL STREAM SURFACES

F. KLIMETZEK and E. SCHMIDT *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-42) Avail: NTIS HC A23/MF A01

A method enabling the computation of cascade profiles from prescribed velocity distributions in a relative system is presented. The optimization of the velocity distributions in a relative system is presented. The optimization of the velocity distribution to attain definite values in parameters such as turning angle, chord length or profile thickness is also included. Comparisons between the inverse design method with various analysis programs for cascades in both absolute and relative systems show good agreement. Author

N88-17672# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).

INVESTIGATION OF DIHEDRAL EFFECTS IN COMPRESSOR CASCADES

F. A. E. BREUGELMANS *In* AGARD Advanced Technology for Aero Gas Turbine Components 14 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

An experimental investigation of the influence of blade dihedral on the secondary flow in the two dimensional NACA 65-series compressor cascade is performed. Different inlet boundary layer thicknesses are used on the endwalls. Three different stacking lines have been chosen, namely a straight line inclined at 15, 25 and 35 degrees, a circular arc and an elliptic arc. The incidence range up to stall has been investigated and the local and overall losses are compared. The obtuse angle between the blade suction surface and the endwall has a beneficial effect on overall and secondary flow loss. Some limitations have to be accepted, depending on boundary layer thickness and incidence. Author

N88-17673# Ecole Centrale de Lyon (France). Lab. de Mecanique des Fluides.

PARAMETRIC STUDY OF CHOKE FLUTTER WITH A LINEAR THEORY

PASCAL FERRAND *In* AGARD Advanced Technology for Aero Gas Turbine Components 14 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH; ENGLISH summary Sponsored by Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, France

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

When the choke flutter problem arises in the stator, the incidence is slightly negative and the inlet Mach number is subsonic. A one dimensional unsteady approach is used in the blade channel and out of the cascade. The equations describe the unsteady two dimensional periodical flow field. The results are compared to experimental data from tests. A parametric study was developed to understand the influence of stationary velocity gradient and shock wave movement. The results obtained do not contradict each other, but they lead to different explanations. For instance, the shock wave movement was found to depend highly upon upstream perturbations, but weakly upon downstream flow. For the first time, these results point toward possibilities for limiting the choke flutter domain. Author

N88-17674# Technische Univ., Hanover (Germany, F.R.). Inst. fuer Stroemungsmaschinen.

POSSIBILITIES FOR ON-LINE SURGE SUPPRESSION BY FAST GUIDE VANE ADJUSTMENT IN AXIAL COMPRESSORS

W. RIESS and U. BLOECKER *In* AGARD Advanced Technology for Aero Gas Turbine Components 15 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The usual surge suppression regulation is realized by integration of a fixed limit line into the regulation system at a safe distance from the stability limit of the compressor. With appropriate means for detection of stall and surge in addition to fast response of the guide vane adjustment, an adaptive system for surge suppression which takes into account the actual state of the compressor could be realized. Experimental results for stall detection and for different modes of guide vane adjustment are presented. A six stage axial compressor is equipped with fast acting guide vane adjustment in all stages. Author

N88-17675# Norges Tekniske Hoegskole, Trondheim. Div. of Hydro- and Gas Dynamics.

RADIAL COMPRESSOR DESIGN USING AN EULER SOLVER

JAN TORE BILLDAL and ANDREW WILSON *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The steady inviscid flow through a radial compressor is computed by solving the three dimensional Euler equations on both an H-type and O-type grid. The centered finite volume method with an explicit integration scheme is used to solve the equations. The numerical programs were developed as a tool in the design process of new, high pressure radial compressors with complex geometries and spitterblades. Author

N88-17676# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.

SECONDARY FLOW MEASUREMENTS WITH L2F-TECHNIQUE IN CENTRIFUGAL COMPRESSORS

H. KRAIN *In* AGARD Advanced Technology for Aero Gas Turbine Components 10 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The flow characteristics of a 30 degree backswept impeller are analyzed by means of the L2F measurement technique. Significant cross flows, noticeable distortions of the through flow patterns and considerable velocity fluctuations were found inside the blade passages of the impeller. The distortions of the velocity patterns are smoothing towards the impeller exit. A detailed analysis of the measured data reveals the existence of two counter rotating channel vortices that are significantly influencing the overall flow character. Author

N88-17677# Centre National de la Recherche Scientifique, Marseilles (France).

METHOD FOR PREDICTING PERFORMANCE LIMITS OF CENTRIFUGAL COMPRESSORS [METHODE DE PREVISION DES LIMITES DE FONCTIONNEMENT EN DEBIT DES COMPRESSEURS CENTRIFUGES]

H. MITON, G. SENATORE, and J. CHAUVIN (LEMFI, Orsay, France) *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p (SEE N88-17647 10-07) Sep. 1987

In FRENCH

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

Currently, the phenomena which impose performance limits in centrifugal compressors are not clearly identifiable. If pumping and rotating stall are frequently observed at partial output, it is not certain whether the pumping limit is imposed by purely nonstationary phenomena. The approach described here consists of determining that limit by specifically applying the load criteria in the axial region of the moving impeller and the diffuser semi-blade section. The performance limit is assumed to be reached when impeller and diffuser are simultaneously stalled. The results of a simple analysis method, applied to two compressors having very

different geometric characteristics, show a fairly good agreement between the performance limit defined with this criterion and the experimental pumping limit. M.G.

N88-17678# Pratt and Whitney Aircraft, West Palm Beach, FL. Engineering Div.

DESIGN AND DEVELOPMENT OF AN ADVANCED F100 COMPRESSOR

CHARLES M. LOVE *In* AGARD Advanced Technology for Aero Gas Turbine Components 12 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

The aerodynamic and mechanical design features of an advanced F100 compressor are described. The design objectives were to increase the efficiency and stability, along with simplifying the mechanical configuration in order to reduce the number of parts. Test results from a compressor rig and core engine are shown. Comparisons of the performance to the current F100 compressor are made. Results of testing with inlet pressure distortion are shown. Configuration features to improve reliability, durability, maintainability and producibility are shown. Author

N88-17679# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

DESIGN AND TESTING OF A FRONT STAGE FOR AN ADVANCED HIGH PRESSURE COMPRESSOR [CONCEPTION ET ESSAIS D'UN ETAGE DE TETE D'UN COMPRESSEUR HP AVANCE]

MARIUS GOUTINES and HENRI NAVIERE *In* AGARD Advanced Technology for Aero Gas Turbine Components 15 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH Sponsored by Direction des Recherches, Etudes et Techniques du Ministere de la Defense, France

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

Studies of an advanced high pressure compressor show that the front stage rotor is supersonic all along the span of the blades. SNECMA designed and constructed a monostage compressor to evaluate performances, especially secondary flows. The approach used in the compressor project, the design configuration, and velocity triangles selected for nominal operation level are described. The supersonic profiles were optimized by the direct solution of the three dimensional Euler equations. The subsonic profiles were optimized by a direct potential method coupled with a boundary layer calculation. The global performances are addressed. The measured aerodynamic fields and azimuthal means are compared to the theoretical predictions for the front wall secondary flow region. Author

N88-17680# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.

EXPERIMENTAL INVESTIGATION OF A SUPERCRITICAL COMPRESSOR ROTOR BLADE SECTION

R. FUCHS, R. KAYMAZ, H. STARKEN, and W. STEINERT *In* AGARD Advanced Technology for Aero Gas Turbine Components 11 p (SEE N88-17647 10-07) Sep. 1987

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

A controlled diffusion rotor blade section was designed for a supercritical inlet Mach number of M sub 1 equals 0.85 and a flow turning of 29 degrees. The blade section has been tested in a cascade wind tunnel under various inlet flow conditions and axial velocity density ratios. A detailed investigation about transition and separation points was carried out at the design and at two off-design inlet flow conditions. The results are presented and discussed. Author

N88-17681# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).

COMPUTATION OF SECONDARY FLOWS IN AN AXIAL MULTISTAGE COMPRESSOR [CALCUL DES ECOULEMENTS SECONDAIRES DANS UN COMPRESSEUR AXIAL MULTIETAGE]

F. FALCHETTI and J. BROCHET *In* AGARD Advanced Technology for Aero Gas Turbine Components 13 p (SEE N88-17647 10-07) Sep. 1987 In FRENCH; ENGLISH summary Sponsored by Direction des Recherches, Etudes et Techniques, France and Societe National d'Etude et de Construction de Moteurs d'Aviation, France

(AGARD-CP-421) Avail: NTIS HC A23/MF A01

SNECMA has developed and extended the use of a secondary flow computation method for axial flow compressors. This method takes into account the secondary phenomena through a viscous correction applied to a through flow calculation. This correction is calculated to the complete meridan plane, including the bladerows. A set of equations deduced from three dimensional parabolized and pitchwise averaged Navier-Stokes equations are solved. A classical coupling process between the secondary flow and the through flow computations is insured through mass flow injection. After reviewing the main features of the method, an application to a multistage compressor is presented. The application of this method to the design of end-bend blades is shown. Author

N88-28926# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).

AGARD ENGINE DISC COOPERATIVE TEST PROGRAMME

A. J. A. MOM and M. D. RAIZENNE (National Aeronautical Establishment Ottawa, Ontario) Aug. 1988 87 p

(AGARD-R-766; ISBN-92-835-0475-5; AD-A199759) Avail: NTIS HC A05/MF A01

The initial results of an AGARD test program on fatigue behavior of engine disc materials are described. The first phase of the program, the Core Program, was aimed at test procedure and specimen standardization and calibration of the various laboratories. A detailed working document is included which describes the testing fundamentals and procedures and includes the analysis procedures used for handling the test data. Fatigue crack initiation and propagation testing was performed on Ti-6Al-4V material under room temperature and constant amplitude loading conditions using four different specimen designs. All results were statistically analyzed for possible significant differences in material behavior due to disc processing variables, specimen location in the disc or testing laboratory. Author

N88-29911# Pratt and Whitney Aircraft, West Palm Beach, FL. Engineering Div.

FUEL PROPERTY EFFECTS ON THE US NAVY'S TF30 ENGINE

S. A. MOSIER and P. A. KARPOVICH (Naval Air Propulsion Test Center, Trenton, N.J.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 15 p (SEE N88-29910 24-25) Jun. 1988

(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The TF30 engine was introduced into Navy service in 1972 and is scheduled to continue to power the carrier based F14 for some time. Although the engine was designed and developed to operate on specification grade JP-5 fuel, it is conceivable that during its lifetime, the TF30 might have to operate on out-of-spec or broadened-spec fuels. This contingency could arise should the availability of high grade petroleum crude oil used for aircraft fuel production be decreased. Therefore, a program of experimentation and analysis was conducted to evaluate the effects of broadened-spec petroleum fuels on the performance, durability and operability of the TF30-P-414A engine. As fuel quality detenorated, some reductions in engine performance characteristics were observed. However, based upon limited time testing, the TF30-P-414A engine was shown to be capable of operating on liquid petroleum fuels having a wide range of properties. Author

N89-10008# Imperial Coll. of Science and Technology, London (England).
STRUCTURAL DYNAMIC CHARACTERISTICS OF INDIVIDUAL BLADES
D. J. EWINS and R. HENRY (Institut National des Sciences Appliquees, Lyon, France) *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 27 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

The basic characteristics of blade vibration properties are outlined. The design features are identified which have an influence on the IR values. Simple models of blades were used, then the methods were applied to calculation of the structural dynamic properties of real blades. The natural frequencies and mode shapes of a blade in its operational environment may differ considerably from those calculated for the same blade as an isolated component. These differences are examined. Author

N89-10009# Imperial Coll. of Science and Technology, London (England). Dept. of Mechanical Engineering.
STRUCTURAL DYNAMIC CHARACTERISTICS OF BLADED ASSEMBLIES
D. J. EWINS *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 37 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

Considerable efforts were expended in order to make accurate predictions for the essential structural dynamic properties of typical turbomachine blades. In the pursuit of accuracy in these predictions, the effect of the coupling between one blade and its neighbors via the structure connections which exist, was neglected. The patterns of both natural frequencies and mode shapes for various assemblies are illustrated and the major controlling factors in each case identified. Simplified mathematical models of a bladed assembly are used that permit detailed parametric studies necessary to determine the patterns of behavior. Author

N89-10010# Rolls-Royce Ltd., Bristol (England).
FATIGUE AND ASSESSMENT METHODS OF BLADE VIBRATION
E. K. ARMSTRONG *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 34 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

Fatigue is the failure mode of a metal which was subjected to a large number of applications of stress. In a fatigue failure a component suffers the development of a crack, which propagates very quickly across the section of the component. In the majority of the cases this stress is a result of the vibration of the blades, compressor, or turbine, at a significant amplitude. It is necessary to appreciate the major factors controlling the fatigue of blading which are encountered in the actual operation of gas turbines and the practical steps which can be taken to assess the levels of vibration which are present, to ensure as far as possible that blade failures due to this cause are minimized. Author

N89-10011# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
LIFE TIME PREDICTION: SYNTHESIS ON ONERA'S RESEARCH IN VISCOPLASTICITY AND CONTINUOUS DAMAGE MECHANICS, APPLIED TO ENGINE MATERIALS AND STRUCTURES
R. LABOURDETTE *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 15 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

Improvements in the metallurgy of superalloy materials make it possible to use them at higher temperatures. However, it follows from the increase in temperature that more severe thermomechanical problems are encountered when dealing with the design and life prediction of turbine blades. Roughly speaking, two phenomena are to be described for such a prediction: creep and fatigue. The main steps for the method of life prediction developed at ONERA are: behavior of the macroscopic volume element; damage accumulation under creep-fatigue conditions; and numerical methods of stress and damage calculation in complex structures undergoing thermomechanical loading. The steps are described in detail. Author

N89-10012# United Technologies Research Center, East Hartford, CT.
AEROELASTIC COUPLING: AN ELEMENTARY APPROACH
FRANKLIN O. CARTA *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 16 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

It was shown in the original 1967 paper that the energy method, using unsteady isolated airfoil theory, and applied to actual multiblade rotors, yielded results that were remarkably accurate. This fortuitous agreement was sufficiently encouraging to foster a continuing development of the technique and its constituent aerodynamic and structural dynamic components. As shown in these two volumes and in the several citations to advanced analyses, current practice has gone well beyond the relatively simplistic view of the early paper. The aerodynamic input now encompasses multiblade systems subjected to compressible flows, and structures are modeled to include nonlinearities and mistuning. Nevertheless, the paper has served its purpose well. In its original form it set the stage for the continual improvement of engine flutter prediction methods, and in this manual it provides the reader with a vehicle for coordinating the separate disciplines which, together, represent the modern approach to flutter prediction of turbomachinery blade rows. Author

N89-10013# Massachusetts Inst. of Tech., Cambridge. Gas Turbine Lab.
AEROELASTIC FORMULATION FOR TUNED AND MISTUNED ROTORS
EDWARD F. CRAWLEY *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 24 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

The topics to be addressed are: the formulation of the aeroelastic problem, including a summary of the relations necessary to transform various diverse structural and aerodynamic models to a consistent notation; a brief review of the solution techniques applicable; the trends in aeroelastic stability for tuned rotors; and the effects of mistuning on stability. Author

N89-10014# Pratt and Whitney Aircraft, East Hartford, CT.
FAN FLUTTER TEST
HANS STARGARDTER *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 35 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

The objective is to describe an aeroelastic investigation of fan flutter. Discussion includes test procedures for flutter evaluation, data acquisition and reduction, safety, and instrumentation. Some data contents are included, but are not the primary concern. Initially, a complete sequence of preparation, testing, and analysis of an ideal fan flutter test is presented. This is followed by identification of dangerous blade vibrations, a case history of a NASA/Pratt and Whitney Subsonic/Transonic Flutter Study, and a discussion and analysis of the program results. Lastly, a summary relating this test to the overall discussion of fan flutter testing is presented. It will be noted that many of the steps in the ideal test situation were omitted in the actual case history. Most of these differences are in the test preparation area because the case history used a previously tested design in which much of the preliminary work and safety screening was already accomplished. Author

N89-10015# Jeffers (James D., III), Tampa, FL.
AEROELASTIC THERMAL EFFECTS
JAMES D. JEFFERS, III *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 6 p (SEE N89-10006 01-02) Jun. 1988
(AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

The adverse effect of increasing temperature on the stability of turbomachinery airfoils was long recognized but remains today one that is not fully understood. The quantitative effect on the

reduced frequency parameter, k = omega c/V, which was experimentally and analytically shown to be one of the most influential stability parameters, is readily calculated. The effects of increasing temperature on the parameters that comprise reduced frequency are well known. Unfortunately, the resulting effect on aeroelastic stability, particularly for stall flutter, is not. This inability to completely assess thermal effects, among others, was dramatically underscored by an occurrence of subsonic stall flutter in the first stage fan rotor of the F100 turbofan engine early in the development program. The severity of the problem prompted an intensive experimental test program and analysis to first determine a solution and, further, to assess the design techniques used to avoid the problem. As a result, a decade of extensive analytical and experimental research was conducted at the Government Products Division of Pratt and Whitney Aircraft, the United Technologies Research Center, and the NASA Lewis Research Center. The following is a summary of some of the findings of these investigations. Author

N89-16781# NATO European Fighter Management Agency, Munich (Germany, F.R.).
OPERATIONAL REQUIREMENTS FOR ENGINE CONDITION MONITORING FROM THE EFA VIEWPOINT
J. V. GOODFELLOW *In* AGARD, Engine Condition Monitoring: Technology and Experience 4 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The Engine Health Monitoring (EHM) System for the European Fighter Aircraft (EFA) is to be an integral part of the overall Weapons Systems Integrated Monitoring and Recording System. This will include both an on-aircraft element and a ground-based station which will have to interface with the different logistics ADP systems being developed. By means of measurements and analyses the EHM is required to automatically and continuously monitor the condition of the engine and to detect and accurately diagnose any need for immediate and future maintenance actions. The purpose is to provide for a rapid turn-around at the flight line and to reduce both the need and the time required for all maintenance thereby increasing the overall availability for operational use. The intention is that this shall contribute to the significant improvement in weapon system cost effectiveness that is believed to be achieveable through greater attention to reliability, maintainability, and testability. Author

N89-16782# Naval Air Systems Command, Washington, DC.
AN OVERVIEW OF US NAVY ENGINE MONITORING SYSTEM PROGRAMS AND USER EXPERIENCE
ANDREW J. HESS *In* AGARD, Engine Condition Monitoring: Technology and Experience 16 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The Naval Air System Command (NAVAIR) has made a commitment to require inflight engine monitoring capabilities and Engine Monitoring Systems (EMS) on all new aircraft and engine programs. The current EMS requirement and system design concepts are the end result of over 15 years of developing system capabilities and justifying system benefits. These requirements and system design concepts are based on the lessons learned from the F/A-18 and A-7E Inflight Engine Condition Monitoring System (IECMS) program. The highly successful A-7E IECMS is the cornerstone on which all Navy EMS are based today. NAVAIR has revised the general engine specifications to contain detailed requirements for a comprehensive EMS. These requirements were included for flight safety, maintenance, engineering management, and operational support benefits. These specification requirements were used on all new aircraft/engine programs (e.g., F-14A+, F-14D, A-6F, AV-8B, E-2C re-engine, and V-22). When justifiable, EMS is also being considered for retrofit on several older aircraft/engine applications. An overview is given of the U.S. Navy EMS program status. Established EMS functional capabilities and requirements are discussed and detailed specification items are reviewed. Current EMS projects are examined with respect to system description, program status and individual peculiarities. Finally, conclusions are given on EMS projected benefits, user experience, lessons learned, and future directions of this technology Author

N89-16783# Royal Air Force, London (England).
ENGINE USAGE CONDITION AND MAINTENANCE MANAGEMENT SYSTEMS IN THE UK ARMED FORCES
W. D. M. FLETCHER and N. A. BAIRSTO *In* AGARD, Engine Condition Monitoring: Technology and Experience 5 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The cost effectiveness of engine condition monitoring is often questioned. The Royal Air Force (RAF) has considerable experience in engine condition monitoring based on a series of trials. Recently aircraft were introduced with comprehensive monitoring systems. Previous condition usage monitoring trials are outlined together with the reasons for changing from scheduled based maintenance to condition based maintenance. The cost effectiveness of various methods is revealed and the difficulty of justifying the retrofit of equipment fleetwide is discussed. Finally, some of the current activities in the RAF on condition monitoring are presented. Author

N89-16784# National Defence Headquarters, Ottawa (Ontario). Directorate of Transport and Helicopter Engineering and Maintenance.
CANADIAN FORCES AIRCRAFT CONDITION/HEALTH MONITORING: POLICY, PLANS AND EXPERIENCE
CHRISTOPHER SCHOFIELD, ROSS LAGRANDEUR, FRANCOIS DUBE, THOMAS HARRIS, ROBERT W. CUE, and ALAIN LEBLANC *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Current Canadian Forces (CF) policy with respect to aircraft Engine Condition/Health Monitoring (ECM/EHM) is highlighted. In doing so, a summary of CF aircraft types and the ECM/EHM techniques applied to each is presented. The CF's experience to date with the development and application of ECM/EHM is reviewed. This includes an examination of the effectiveness of the CF Spectrometric Oil Analysis Program and the use of magnetic particle detectors and manual performance trending. Present plans for further development and implementation of policy; methodologies and techniques; and for the integration of these into an effective ECM/EHM capability that will pay benefits both in terms of life cycle costs and operational availability, are presented. Author

N89-16787# GasTOPS Ltd., Ottawa (Ontario).
CF-18 ENGINE PERFORMANCE MONITORING
D. E. MUIR, D. M. RUDNITSKI, and ROBERT W. CUE (National Defence Headquarters, Ottawa, Ontario) *In* AGARD, Engine Condition Monitoring: Technology and Experience 20 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The Canadian Forces (CF) have adopted a conditional maintenance concept for the engines of the CF-18 fighter aircraft. In support of this concept, advanced engine performance monitoring procedures are being developed to track the general performance level of each engine and identify problematic engine components. The procedures are based on takeoff ground roll data recorded by the aircraft In-Flight Engine Condition Monitoring System and steady-state data obtained from automated Engine Test Facilities. The development and field evaluation of these procedures is described. A discussion of future development work and related research activities is also included. Author

N89-16790# Ministry of Defence, London (England). Directorate of Engines
RECENT UK TRIALS IN ENGINE HEALTH MONITORING: FEEDBACK AND FEEDFORWARD
M. J. SAPSARD *In* AGARD, Engine Condition Monitoring: Technology and Experience 8 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Engine health monitoring effectiveness had to be quantified prior to large scale commitment by the UK Services. Some of the activities undertaken in Air Staff Target 603 are described. A program was set up to assess that effectiveness. Also described are some of the incidental lessons learned from this and other related health monitoring exercises. Author

07 AIRCRAFT PROPULSION AND POWER

N89-16791# Turkish Air Force, Ankara. Aircraft Engines Branch.

F110 ENGINE MONITORING AND MAINTENANCE MANAGEMENT SYSTEMS FOR F-16 C/D

F. ALGUN *In* AGARD, Engine Condition Monitoring: Technology and Experience 12 p (SEE N89-16780 09-06) Oct. 1988 (AGARD-CP-448) Avail: NTIS HC A20/MF A01

The engine monitoring and management systems employed by the Turkish Air Force for F110-GE-100 engines of F-16 C/D aircraft are described. These systems include the Engine Monitoring System (EMS) and the Minimum Essential Engine Tracking System (MEETS). The EMS performs the acquisition, transfer and processing of engine data for maintenance use. The systems monitors engine operation, and determines engine exceedances and faults; isolates faults to appropriate level and processes data to interface with other data systems. The MEETS provides an automated means of managing on-condition maintenance of fighter engines. This system tracks engines and components in terms of operation time, temperature, and cycle limits, and also forecasts remaining flying and engine operation hours for an individual engine, aircraft, or the whole fleet. The operation of the systems and future plans to develop and implement a unique data automation systems are discussed. This automated data system will be capable of supporting all the base level functions of aircraft, engines, trainers, support equipment, test equipment, missiles, munitions and communications/electronics. Author

N89-16796# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).

SERVICE LIFE CALCULATOR FOR THE M53 TURBOFAN ENGINE [LE CALCULATEUR DE POTENTIEL SUR LE REACTEUR M53]

CLAUDE SPRUNG *In* AGARD, Engine Condition Monitoring: Technology and Experience 15 p (SEE N89-16780 09-06) Oct. 1988 In FRENCH (AGARD-CP-448) Avail: NTIS HC A20/MF A01

The functional requirements for a service life calculator are defined and the flight and ground equipment comprising such a system are described. A system utilization philosophy is defined and preliminary results from studies considering the application of service life calculators are presented. Author

N89-16800# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).

THE ADVANTAGE OF A THRUST RATING CONCEPT USED ON THE RB199 ENGINE

P. THEIMER *In* AGARD, Engine Condition Monitoring: Technology and Experience 15 p (SEE N89-16780 09-06) Oct. 1988 (AGARD-CP-448) Avail: NTIS HC A20/MF A01

The control system of the RB199 engine was designed for a rating, using the HP-turbine inlet temperature as a limiter. The engine has now been in service for 7 years and still uses the original concept throughout all fleets in the UK, Italy and Germany, although new digital engine control units are being introduced which will allow considerable improvements. For some fleets a thrust rating concept based on the original control system design has been installed recently. The concept is described and the procedure explained. A comparison is made between the existing full thrust concept at the maximum cleared HP turbine temperature and the applied thrust rating concept. Besides the basic behavior of seal gaps, the influence of thrust rating in view of the life usage of life-limited parts as well as in the change of the maintenance material costs is explained. The assumptions for the comparison with their background are described. Finally, a refined thrust rating concept is introduced. Author

N89-16802# Aeronautical Research Labs., Melbourne (Australia).

GAS PATH ANALYSIS AND ENGINE PERFORMANCE MONITORING IN A CHINOOK HELICOPTER

D. E. GLENNY *In* AGARD, Engine Condition Monitoring: Technology and Experience 14 p (SEE N89-16780 09-06) Oct. 1988 (AGARD-CP-448) Avail: NTIS HC A20/MF A01

Periodic and consistent assessment of engine performance in military helicopters is essential if in-service operating margins are not to be eroded by harsh environmental conditions. Manually initiated GO-NO-GO pre-flight checks (HIT, etc.) or ad-hoc in-flight performance checks rarely provide sufficiently reliable data for maintenance or diagnostic purposes. In contrast, performance assessment methods based on gas path analysis principles and engine/aircraft data, automatically recorded during flight, offer a potentially attractive alternative. ARL has investigated a number of these alternatives, and has carried out an in-service trial on a Boeing CH47C Chinook helicopter operated by the RAAF. In the trial existing aircraft/engine instrumentation was complemented by specially designed probes located at module interfaces while the data was recorded on an ARL designed acquisition system. The performance-fault algorithms used in the analyses were configured for a range of engine operating speeds. Results for the trial are presented in terms of deviations from pre-established baseline conditions. Statistical analyses using linear regression fits and Kalman filtering techniques have been investigated to minimize the effects of data uncertainty. The applicability of the procedures, including thermodynamic analyses and equipment are discussed in terms of fleetwide adoption of the Chinook. Author

N89-16803# National Research Council of Canada, Ottawa (Ontario).

THE EFFECTS OF A COMPRESSOR REBUILD ON GAS TURBINE ENGINE PERFORMANCE

J. D. MACLEOD and J. C. G. LAFLAMME (Canadian Forces Base, Baden-Soellingen, Germany, F.R.) *In* AGARD, Engine Condition Monitoring: Technology and Experience 14 p (SEE N89-16780 09-06) Oct. 1988 (AGARD-CP-448) Avail: NTIS HC A20/MF A01

The Canadian Department of Defence, in conjunction with the Engine Laboratory of the National Research Council Canada, initiated a project for the evaluation of gas path coatings on the Allison T56 engine. The objective of this work was to evaluate blade coatings in terms of engine performance effects and material durability. The project included a study of the influence of rebuilding the compressor on performance, since dismantling and rebuilding was required in the coating process. Described is the compressor rebuild study, including the overall objectives, the test set-up, the performance effects, and the uncertainty of the measured results. The impact of this work on the coatings project is also documented. Author

N89-16804# GEC Avionics Ltd., Rochester (England). Future Systems Group.

SYSTEM CONSIDERATIONS FOR INTEGRATED MACHINERY HEALTH MONITORING

R. M. TESTER *In* AGARD, Engine Condition Monitoring: Technology and Experience 14 p (SEE N89-16780 09-06) Oct. 1988 (AGARD-CP-448) Avail: NTIS HC A20/MF A01

Aircraft engine health monitoring, and other related machinery condition monitoring, has been gaining in credibility and implementation over recent years. It is destined to become standard fit on all new major aircraft programs in the near future. To date the monitoring systems have mainly been stand-alone in form, and have been treated as separate functions. This paper discusses the considerations for integrating health monitoring into other aircraft systems, and reviews the potential benefits to be gained by such integration. In conclusion, the paper presents two products from both ends of the spectrum, representing a simple single unit integration, and a full aircraft-wide implementation. Author

N89-16805# Societe de Fabrication d'Instruments de Mesure, Massy (France). Measurement and Flight Test Dept.

MAINTENANCE AID SYSTEM FOR WIDE BODY AIRCRAFT

ALBERT LEVIONNOIS *In* AGARD, Engine Condition Monitoring: Technology and Experience 7 p (SEE N89-16780 09-06) Oct. 1988 (AGARD-CP-448) Avail: NTIS HC A20/MF A01

Aircraft maintenance personnel when troubleshooting aircraft failures, must first acquire a great deal of information about the aircraft's engines before being able to arrive at any kind of diagnosis. Computerized modern aircraft provide all necessary parameters with good precision. Aircraft condition monitoring systems centralize information from data buses, compute flight phases, determine the reports to be made per flight phase and function, and carry out automatic parameter identification. Should an incident occur, then the parameter's history is stored before and after the incident, together with its evolution. All this information

is stored in static memory for transmission by data link, is printed during or after the flight, or downloaded when the aircraft is back at its base. Today between 35 and 40 reports are currently produced by wide body aircraft. This technology is easily adaptable to combat aircraft. Author

N89-16806# Computing Devices Co., Ottawa (Ontario).
INSTALLED THRUST AS A PREDICTOR OF ENGINE HEALTH FOR JET ENGINES
G. B. MACKINTOSH and M. J. HAMER *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Extensive installed and uninstalled gross thrust measurements were made over one complete maintenance cycle on 19 afterburning turbojet engines. Installed measurements utilized a sensor which can compute the thrust in real time from engine tailpipe pressure measurements. Correlation of installed thrust with maintenance history indicated a maximum degradation below which engines were removed from service. The engines were trimmed uninstalled using lapse rate charts to produce a specific value of uninstalled thrust, corrected to standard conditions. Significant variations in installed corrected thrust resulted. Higher initial values of installed corrected thrust resulted in more rapid engine degradation and a shorter time before maintenance was required. Author

N89-16808# Rolls-Royce Ltd., Bristol (England). Mechanical Technology (Military) Dept.
A JOINT STUDY ON THE COMPUTERISATION OF IN-FIELD AERO ENGINE VIBRATION DIAGNOSIS
H. R. CARR, G. J. IVES, and P. JENKINS (Ministry of Defence, London, England.) *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p (SEE N89-16780 09-06) Oct. 1988 Sponsored by Ministry of Defence Procurement Executive, London, United Kingdom
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Test House methods used by the RAF for diagnosing causes of excessive vibration in Military Engines are based on a visual comparison of the test signatures with those from built-in-fault tests. Interpretation depends largely on operator experience. A joint program was launched in 1984 to develop a software-based analyzer to diagnose a range of mechanical abnormalities including unbalance, malalignment of bearings and shafts, and squeeze film bearing functions. The analyzer would handle a variety of engine types and would be suitable for inexperienced operators. The ensuing program between MOD and RR plc developed data acquisition and interpretive routines, and provided recorded engine signatures from both the RAF and Rolls-Royce plc test beds. Important aspects were the essential combination of intuitive operator experience, detailed, strip and inspection of problem engines, and an engineering understanding from Rolls-Royce plc. The current intention is to install an Automatic Data Processing system by 1990/1991. This paper reviews the successes achieved and problems encountered. Author

N89-16809# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
FAULT MANAGEMENT IN AIRCRAFT POWER PLANT CONTROLS
S. MAZAREANU and A. NOBRE *In* AGARD, Engine Condition Monitoring: Technology and Experience 16 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The advent of Digital Electronics in aviation has opened new doors to fault management as a tool to enhance aircraft operability and safety in flight. Today it is possible to integrate flight control systems with power plant management systems. Operability of a battle-damaged aircraft can be enhanced under certain conditions through sophisticated fault management systems. This paper reviews some of the considerations applicable to engine control fault management systems in commercial aviation. Engine control systems have evolved in the last decade from being primarily hydromechanical to being primarily electronics. This rapid growth in acceptance of the electronic systems by the aviation industry was due to the improvement in reliability of the digital system over analog systems previously in use. The fault management system is a powerful tool to organize and optimize maintenance logistics. Operating costs can be significantly reduced with an appropriate fault management system on board. The paper presents (1) a brief review of the evolution of engine controls; (2) the emergence of fault management systems (as part of engine control systems); (3) maturity of fault management systems (still evolving); and (4) future potential. Author

N89-16813# Aeronautical Research Labs., Melbourne (Australia).
IDENTIFICATION OF DYNAMIC CHARACTERISTICS FOR FAULT ISOLATION PURPOSES IN A GAS TURBINE USING CLOSED-LOOP MEASUREMENTS
G. L. MERRINGTON *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p (SEE N89-16780 09-06) Oct. 1988
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

Combat aircraft, because of the mission profiles involved, tend to rarely operate with their engines in a steady-state condition for extended periods. Furthermore, current generation aircraft contain Engine Monitoring Systems (EMS) which automatically capture a record of important engine parameters when a parameter exceedance is detected. It follows then that any subsequent post-flight data analysis for fault isolation purpose will often necessitate the extraction of the required diagnostic information from transient data records. This generally contrasts with past practice where most of the available fault diagnostic procedures have been derived from steady-state information. In an attempt to overcome this, and thereby provide effective tools for diagnosing faults from transient data records, a procedure is outlined to extract information about the dynamic characteristics of gas turbines from input/output measurements. The parameter estimator technique involved has the potential to provide a means of detecting changes in some unmeasured/unrecorded parameter, such as shifts in variable geometry schedules. Thus in essence, it provides a tool for identifying problems from simple transient test data which were previously inaccessible or difficult to obtain. Author

N89-16814# Canadian Forces Base Trenton, Astra (Ontario). Aerospace Maintenance Development Unit.
CF-18/F404 TRANSIENT PERFORMANCE TRENDING
J. R. HENRY *In* AGARD, Engine Condition Monitoring: Technology and Experience 13 p (SEE N89-16780 09-06) Oct. 1988
(Contract FE220786FRMC4; ARP-3610-147)
(AGARD-CP-448) Avail: NTIS HC A20/MF A01

The on condition concept of aircraft engine maintenance has led to intensive analysis of the data recorded by Engine Health Monitoring systems during steady-state operation of the engine. To date however the transient data acquired during take-off or in-flight have received far less attention. Presented here are the results of an investigation into the feasibility of utilizing engine data acquired during take-off to trend the performance of a modern turbofan engine (GE-F404). Factors influencing the repeatability of take-off data such as throttle rate, variable geometry and instrumentation effects are discussed. Using engine data from operational aircraft, various trending parameters are evaluated using a data capture window developed to minimize the scatter of nominal engine performance. A statistical tool to identify performance shifts is briefly described, and is shown to successfully detect a shift in the take-off performance of a recently repaired engine. It is concluded that the trending of transient performance data is a viable means of detecting certain engine faults and recommendations are made concerning the implementation of such a program for the F404 engine. Author

N89-16853# National Aerospace Lab., Amsterdam (Netherlands).
MEASUREMENT UNCERTAINTY OF THE AGARD/PEP UNIFORM ENGINE TEST PROGRAM
J. P. K. VLEGHERT *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 12 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

In the AGARD/PEP Uniform Engine Test Program (UETP) two engines were tested in 8 facilities in 5 different countries to compare measuring practices and results. An overview is given of the UTEP with the emphasis on Uncertainty Assessment according to the method proposed by Dr. Abernethy in which the total uncertainty is split in a random error (scatter, precision) and a bias error or

offset. The results show that the random error is small but that appreciable bias error exists between participants. Author

N89-16854# Sverdrup Technology, Inc., Arnold Air Force Station, TN. Instrumentation and Controls.
AN OVERVIEW OF THE APPLICATION OF STANDARD MEASUREMENT UNCERTAINTY METHODOLOGY TO PROPULSION TESTING
J. W. THOMPSON, JR., W. F. KIMZEY, and W. O. BOALS, JR. *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 15 p (SEE N89-16846 09-09) Jul. 1988 Prepared in cooperation with Arnold Engineering Development Center, Arnold Air Force Station, TN
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

In the past several years, a standard measurement uncertainty methodology has been adopted by the SAE, ASME, AIAA, ISA, JANNAF, and ISO. This standard methodology has significantly improved the ability to resolve and understand measurement systems accuracies in the engine test facility at AEDC. The measurement accuracy assessment methodology and its development background is examined. The procedural steps in making an uncertainty analysis are reviewed, and typical results of an analysis effort are illustrated by reviewing the elemental errors and uncertainties for state-of-the-art measurement systems used in simulated altitude tests of air breathing engine propulsion systems. Typical elemental and combined uncertainties for measured values of pressure, force, flow, and temperature and uncertainties of propulsion system thrust and specific fuel consumption performance parameters are included. Author

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

N86-30739# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AIRCRAFT RESPONSE TO TURBULENCE
1985 32 p Presented at the 61st Meeting of the Structures and Materials Panel of AGARD, Oberammergau, West Germany, 8-13 Sep. 1985
(AGARD-R-738; ISBN92-835-0393-7; AD-A171307) Avail: NTIS HC A03/MF A01

In 1985 the Structures and Materials Panel initiated an activity to consider the flight of flexible aircraft in turbulence. As a preliminary to the start of this activity, the Panel heard the two papers included in this report. One of the two papers discusses measurements of time histories of turbulence made by specially equipped aircraft and turbulence event statistics obtained from aircraft in commercial operation. The other paper considers aspects of collection and analysis of flight data, methods of calculating aircraft response and constraints in operation. Author

N86-30740# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
APPLICATION OF ADA HIGHER ORDER LANGUAGE TO GUIDANCE AND CONTROL
May 1986 106 p Presented at a Lecture Series, Ottawa, Ontario, 20-21 May 1986; London England, 2-3 Jun. 1986; and Cologne, West Germany, 5-6 Jun. 1986; sponsored by the Guidance and Control Panel and the Consultant and Exchange Programme of AGARD
(AGARD-LS-146; ISBN92-835-1527-7; AD-A171299) Avail: NTIS HC A06/MF A01

The need to reduce escalating software life-cycle costs is the rationale for Ada. Early experience with the language suggests that the promise of increased software productivity can be fulfilled. However, many problems remain; the need for validated and efficient compilers targeted for computers suitable to the guidance and control application, and software development environments built around Ada, are two among the foremost. This Lecture Series, sponsored by the Guidance and Control Panel of AGARD, has been implemented by the Consultant and Exchange Programme of AGARD. Author

N86-30741# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
GUST LOAD PREDICTION AND ALLEVIATION ON A FIGHTER AIRCRAFT
J. BECKER Jun. 1986 22 p Presented at the 61st Meeting of the Structures and Materials Panel of AGARD, Oberammergau, West Germany, 8-13 Sep. 1985
(AGARD-R-728; ISBN92-835-1532-3; AD-A169946) Avail: NTIS HC A02/MF A01

In 1985 the AGARD Structures and Materials Panel initiated an activity on the flight of flexible aircraft in turbulence. As a preliminary the Panel heard this paper which discusses the influence of turbulence -induced dynamic loads on the structural design of fighter aircraft. Methods for calculating dynamic response are given, and the problems associated with improved ride are considered. Author

N87-21901# Technische Univ., Brunswick (Germany, F.R.). Inst. for Guidance and Control.
DESIGN CRITERIA FOR MULTI-LOOP FLIGHT CONTROL SYSTEMS
G. SCHAENZER *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 12 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

The problems of design criteria and architecture of multiloop flight control systems for a realized system to achieve precise flight path guidance, safe and economic control of the aerodynamic flow (airspeed, angle of attack and lift coefficient control) and passenger comfort are discussed. Joint root locus and quality criteria design are presented. The structure of the presented multiloop flight control system consists of nonlinear open loop control for flight performance and flight management; superposed quasilinear state vector feedback; and six control surfaces (aileron, rudder, elevator, trim, throttle, direct lift/drag control). Author

N87-22674# British Aerospace Public Ltd. Co., Preston (England).
IMPROVED COMBAT PERFORMANCE USING RELAXED STATIC STABILITY AND A SPIN PREVENTION SYSTEM (FBW JAGUAR)
J. R. NELSON and T. D. SMITH *In* AGARD Improvement of Combat Performance for Existing and Future Aircraft 6 p (SEE N87-22663 16-05) Dec. 1986
(AGARD-CP-409) Avail: NTIS HC A07/MF A01

The theoretical performance benefits that can be obtained by designing an aircraft that is naturally unstable in pitch and artificially stabilized by use of active control technology including an integral stall departure and spin prevention/g limiting function are described. How many of these benefits have been successfully demonstrated during flight trials on the FBW Jaguar demonstrator aircraft is discussed. The flight trials are briefly discussed including the results of the stall departure and spin prevention system assessment with examples of severe dynamic combat maneuvers made possible by such a system. The combination of leading edge wing strakes and longitudinal instability gave improvements in aircraft turn rate, acceleration, and field performance, thus providing a practical demonstration of many of the theoretical benefits described earlier. The FBW Jaguar flight control system was designed from the outset as a production system with the aim of identifying production clearance procedures so this experience leads straight into new combat aircraft such as the EFA. Author

N87-24404 Stevens Inst. of Tech., Hoboken, NJ. Dept of Mechanical Engineering.
STALL FLUTTER
F. SISTO *In* AGARD Aeroelasticity in Axial-Flow Turbomachines Volume 1: Unsteady Turbomachinery Aerodynamics 11 p (SEE N87-24398 18-02) Mar. 1987
(AGARD-AG-298-VOL-1) Avail: NTIS HC A13/MF A01

A qualitative exposition of stall flutter and the closely related phenomena of choke flutter and supersonic bending stall flutter in axial flow turbomachines is given. P.J.F.

N87-29526# British Aerospace Aircraft Group, Preston (England).
VOICE CONTROL OF COCKPIT SYSTEMS
P. BECKETT. *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 3 p (SEE N87-29503 24-06) Feb. 1987 Sponsored by Royal Aircraft Establishment, Farnborough, England.
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

The use of automatic speech recognition for cockpit management should allow more operations to be carried out head-up. In turn this should reduce the frequency and length of the periods spent looking into the cockpit. This would be particularly beneficial for the single seat pilot who could benefit from maintaining visual contact with a target or cooperating aircraft. In addition, it should generally allow more accurate flying performance and reduce the risk of collision with the ground or other aircraft. In order to assess these anticipated advantages, a simulator trial was set up at British Aerospace where a conventionally operated advanced fighter cockpit, containing electronic displays, was compared with one where Direct Voice Input (DVI) took over some of the roles normally carried out by tactile controls. The comparison was made during a simulated low level mission containing a cross section of typical cockpit activities. The comparison is discussed in detail. *Author*

N88-10796# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). *Guidance and Control Panel*
FAULT TOLERANT CONSIDERATIONS AND METHODS FOR GUIDANCE AND CONTROL SYSTEMS
MARC J. PELEGRIN (Office National d'Etudes et de Recherches Aerospatiales, Toulouse, France.) Jul. 1987 136 p
(AGARD-AG-289, ISBN-92-835-1554-4, AD-A188622) Avail: NTIS HC A07/MF A01

This AGARDograph, prepared and edited at the request of the Guidance and Control Panel of AGARD, presents a description of recent trends and developments in analysis and design methods for fault tolerant guidance and control systems architectures. The problems and issues associated with these architectures, including both hardware and software aspects, are addressed exploring the many developments under way in NATO in the following areas: advances in fault tolerant architectures; advances in analytical fault detection methods; design considerations and methods; and analysis and testing methods. For individual titles, see N88-10797 through N88-10805.

N88-10798*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE APPLICATION OF EMULATION TECHNIQUES IN THE ANALYSIS OF HIGHLY RELIABLE, GUIDANCE AND CONTROL COMPUTER SYSTEMS
GERALD E. MIGNEAULT. *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 12 p (SEE N88-10796 02-08) Jul. 1987
(AGARD-AG-289) Avail: NTIS HC A07/MF A01 CSCL 01C

Emulation techniques can be a solution to a difficulty that arises in the analysis of the reliability of guidance and control computer systems for future commercial aircraft. Described here is the difficulty, the lack of credibility of reliability estimates obtained by analytical modeling techniques. The difficulty is an unavoidable consequence of the following: (1) a reliability requirement so demanding as to make system evaluation by use testing infeasible, (2) a complex system design technique, fault tolerance, (3) system reliability dominated by errors due to flaws in the system definition, and (4) ultrahigh analytical modeling techniques whose precision outputs are quite sensitive to errors of approximation in their input data. Use of emulation techniques for pseudo testing systems to evaluate bounds on the parameter values needed for the analytical techniques is then discussed. Finally, several examples of the application of emulation techniques are described. *Author*

N88-10799# Marconi Avionics Ltd., Rochester (England). Combat Aircraft Controls Div.
SOME APPROACHES TO THE DESIGN OF HIGH INTEGRITY SOFTWARE
J. T. SHEPHERD, D. J. MARTIN, and R. B. SMITH. *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 14 p (SEE N88-10796 02-08) Jul. 1987 Sponsored by Ministry of Defence, United Kingdom
(AGARD-AG-289) Avail: NTIS HC A07/MF A01

As the complexity of aircraft systems has increased and the performance requirements for such aircraft have become more demanding the number of safety critical systems carried has increased. This allied to the preponderance of digital systems on board the aircraft has meant that the software requirements of safety critical systems have become one of the key items in the development of new aircraft. In the early days of high integrity systems analog techniques were used and a variety of redundancy techniques developed to cope with the need to obtain the required level of integrity from system elements whose inherent reliability was low. With the advent of digital systems it is necessary to consider how much integrity can be achieved with system software so that the total integrity of a safety critical system can be maintained. This can be achieved by fault avoidance or fault tolerance. To date the former has been the main method used to achieve high integrity software. However, fault avoidance to be effective must assume an error free system, which is near impossible to achieve. Fault avoidance is combined with fault tolerance, which adjusts the system to its inherent errors, and is added to assure greater reliability. *F.M.R.*

N88-10800# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling (Germany, F.R.). Inst. for Flight System Dynamics.
ROBUST CONTROL SYSTEM DESIGN
J. ACKERMANN. *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 14 p (SEE N88-10796 02-08) Jul. 1987 Previously announced as N81-11275.
(AGARD-AG-289) Avail: NTIS HC A07/MF A01

The short period longitudinal mode of an F-4E with horizontal canards is unstable in subsonic flight and insufficiently damped at supersonic speed. The control system has to provide acceptable pole locations according to military specifications for flying qualities. A fixed gain controller using three paralleled gyros is designed such that the pole region requirements in four typical flight conditions are robust with respect to a gain reduction to one third. Thus nothing bad happens immediately when one or two gyros fail. Failure detection and redundancy management may be performed at a higher hierarchical level, and not necessarily extremely fast. The use of accelerometers or air data sensors for angle of attack or dynamic pressure is totally avoided in this concept and no gain scheduling is necessary. The design for robustness with respect to different flight conditions and sensor failures is performed by a novel parameter space design tool. *Author*

N88-10801*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RELIABILITY MODELING OF FAULT-TOLERANT COMPUTER BASED SYSTEMS
SALVATORE J. BAVUSO. *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 16 p (SEE N88-10796 02-08) Jul. 1987
(AGARD-AG-289) Avail: NTIS HC A07/MF A01 CSCL 01C

Digital fault-tolerant computer-based systems have become commonplace in military and commercial avionics. These systems hold the promise of increased availability, reliability, and maintainability over conventional analog-based systems through the application of replicated digital computers arranged in fault-tolerant configurations. Three tightly coupled factors of paramount importance, ultimately determining the viability of these systems, are reliability, safety, and profitability. Reliability, the major driver, affects virtually every aspect of design, packaging, and field operations, and eventually produces profit for commercial applications or increased national security. However, the utilization of digital computer systems makes the task of producing credible reliability assessment a formidable one for the reliability engineer. The root of the problem lies in the digital computer's unique adaptability to changing requirements, computational power, and ability to test itself efficiently. Addressed here are the nuances of

modeling the reliability of systems with large state sizes, in the Markov sense, which result from systems based on replicated redundant hardware and to discuss the modeling of factors which can reduce reliability without concomitant depletion of hardware. Advanced fault-handling models are described and methods of acquiring and measuring parameters for these models are delineated. Author

N88-10802# Centre d'Etudes et de Recherches, Toulouse (France).
ISAURE: INTEGRATION OF SECURITY AND FAULT TOLERANCE IN THE REALITE 2000 SYSTEM
J. CAZIN and P. MICHEL *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 12 p (SEE N88-10796 02-08) Jul. 1987
(AGARD-AG-289) Avail: NTIS HC A07/MF A01

In the framework of the French SURF project sponsored by the Agence de l'Informatique (ADI), the ONERA/CERT research center and the Intertechnique Company have developed a fault-tolerant operating system called ISAURE. This system includes data protection features and error recovery mechanisms. It offers the same services as the REALITE 2000 system already available on the market. It used first the Multi 6-Intertechnique microprocessor, and later specific hardware implementing protection domains via a capability based addressing mechanism. The collaboration between the two systems is the result of converging and complementary aims: the Intertechnique Company is trying to set up a future range of systems and machines oriented towards management applications and offering a high level of functional security; and the CERT/ONERA research center wishes to apply methodological research results and thus continue its research work in the context of practical applications. This collaboration is one of the more original features of the project and it allows introduction of advanced concepts into the industrial sector. Author

N88-10803# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugfuehrung.
OPTIMAL DETECTION OF SENSOR FAILURES IN FLIGHT CONTROL SYSTEMS USING DETERMINISTIC OBSERVERS
NORBERT STUCKENBERG *In* AGARD, Fault Tolerant *Considerations and Methods* for Guidance and Control Systems 21 p (SEE N88-10796 02-08) Jul. 1987
(AGARD-AG-289) Avail: NTIS HC A07/MF A01

A failure detection scheme for sensors of a flight control system is presented. Based on analytic redundancy a duplex sensor configuration provides the fail-operational capability of a conventional triplex sensor system. This is achieved by using deterministic observers. It is shown how the performance of the failure detection scheme can be determined. With respect to this performance criterion the optimal observer is derived. Thus, the performance eventually achievable by an optimal failure detection scheme is also described. The operational feasibility of the proposed concept is demonstrated by flight test results. Author

N88-10804# Verilog S.A., Toulouse (France).
ASSESSMENT OF SOFTWARE QUALITY FOR THE AIRBUS A310 AUTOMATIC PILOT
R. TROY and C. BALUTEAU (Societe Francaise d'Equipements pour la Navigation Aerienne, Velizy-Villacoublay, France) *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 13 p (SEE N88-10796 02-08) Jul. 1987
(AGARD-AG-289) Avail: NTIS HC A07/MF A01

As for the whole of the Automatic Flight Control System, the automatic pilot for the AIRBUS is a computer system with high criticality. In order to assess the quality of the software, a number of observations and measurements have been made during the development cycle. A general method of evaluation, the data collected, and some evaluation results are presented. The aims of this analysis are to assess the impact of development constraints on the quality of the product and to evaluate its operational reliability. The results show conditions in which software may be adversely affected by modifications. In particular, they make it possible to appreciate the *quality of design, the effectiveness of* the verification and validation processes, and the flexibility of the software. The last part gives a tentative example of operational reliability evaluation, taking into consideration the complexity of the functions and the mission profile. Author

N88-10805*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLIGHT TEST OF A RESIDENT BACKUP SOFTWARE SYSTEM
DWAIN A. DEETS, WILTON P. LOCK, and VINCENT A. MEGNA (Draper, Charles Stark Lab., Inc., Cambridge, Mass.) *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 9 p (SEE N88-10796 02-08) Jul. 1987 Previously announced as N86-19325
(AGARD-AG-289) Avail: NTIS HC A07/MF A01

A new fault-tolerant system software concept employing the primary digital computers as host for the backup software portion has been implemented and flight tested in the F-8 digital fly-by-wire airplane. The system was implemented in such a way that essentially no transients occurred in transferring from primary to backup software. This was accomplished without a significant increase in the complexity of the backup software. The primary digital system was frame synchronized, which provided several advantages in implementing the resident backup software system. Since the time of the flight tests, two other flight vehicle programs have made a commitment to incorporate resident backup software similar in nature to the system described here. Author

N88-10806# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
KNOWLEDGE BASED CONCEPTS AND ARTIFICIAL INTELLIGENCE: APPLICATIONS TO GUIDANCE AND CONTROL
Aug. 1987 145 p Lectures held in Ottawa, Ontario, 10-11 Sep., in Monterey, Calif., 14-15 Sep., in Delft, Netherlands, 12-13 Oct., and in Lisbon, Portugal, 15-16 Oct. 1987
(AGARD-LS-155; ISBN-92-835-1588-7; AD-A191463) Avail: NTIS HC A07/MF A01

The intent of this lecture series was to clearly describe what artificial intelligence techniques mean with respect to guidance and control applications, to offer some concrete examples of applications to the maintenance area, some more speculative examples of applications to actual guidance and control tasks, and a projection of possible directions for the future. For individual titles, see N88-10807 through N88-10817.

N88-10807# General Electric Co., Binghamton, NY
OVERVIEW OF AGARD LECTURE SERIES NO. 155: KNOWLEDGE-BASED CONCEPTS AND ARTIFICIAL INTELLIGENCE APPLICATIONS TO GUIDANCE AND CONTROL
RICHARD PAUL QUINLIVAN *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 5 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

Several lectures dealing with artificial intelligence (AI) applications to guidance and control are reviewed. The use of various forms of AI techniques to help solve problems related to guidance and control is a subject of current interest, most, if not all, of the practical applications utilize knowledge based techniques to create so-called expert systems. These systems seem to offer solutions to guidance and control problems that have a large judgment content. Examples include maintenance systems and real-time, decision aiding systems. Author

N88-10808# Analytic Sciences Corp., Reading, MA
AI EXPERT SYSTEM TECHNOLOGY ISSUES FOR GUIDANCE AND CONTROL APPLICATIONS
HAROLD L. JONES *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 7 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

A perspective is provided on a set of technical issues, which, if unresolved, could limit the capability and acceptability of expert systems decision making for avionics applications. Examples from *ongoing expert* system development programs are used to illustrate likely architectures and applications of future intelligent avionics systems. Author

N88-10811# Lear Siegler, Inc., Grand Rapids, MI. Instrument and Avionic Systems Div.

APPLICATION OF KNOWLEDGE-BASED TECHNIQUES TO AIRCRAFT TRAJECTORY GENERATION AND CONTROL

MICHAEL W. BIRD *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p (SEE N88-10806 02-08) Aug. 1987

(Contract F33615-84-C-3626)

(AGARD-LS-155) Avail: NTIS HC A07/MF A01

A concept that embeds the knowledge-based techniques in a trajectory generation and control system is defined. The control system is called the Unified Trajectory Control System (UTCS). The objective of the system is to aid the pilot when operating in the intense threat environment projected for the 1990's. The UTCS has an architecture of independent trajectory generation elements whose operations are integrated by a knowledge-based system. This artificial intelligence (AI) technique utilizes production rules, an interface engine, and a system of frames for communicating with the trajectory generation elements. Author

N88-11653# National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.

INVESTIGATION OF VERTICAL AXIS HANDLING QUALITIES FOR HELICOPTER HOVER AND NOE FLIGHT

S. W. BAILLIE and J. M. MORGAN *In* AGARD, Rotorcraft Design for Operations 9 p (SEE N88-11649 03-05) Jun. 1987 Sponsored in part by Canadian Department of National Defense

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The preliminary results of two in-flight simulation programs on vertical axis rotorcraft handling qualities are presented. The parameters investigated in these studies were heave damping, thrust to weight ratio (T/W), and a number of dynamic engine governor/rotor system models. Flight tasks include hover, hover maneuvering and nap of the Earth (NOE) flight. Evaluation of nine heave damping, thrust to weight ratio configurations provides the basis to suggest Level 1 Z sub w and T/W boundary values of -0.20 sec -1 and 1.08 respectively. These boundaries are compared with other relevant work on the topic. The engine governor/rotor system evaluation results tend to disagree with handling qualities predictions based on a vertical velocity shaping parameter. Author

N88-11654# Systems Technology, Inc., Hawthorne, CA.

HANDLING QUALITIES CRITERION FOR VERY LOW VISIBILITY ROTORCRAFT

ROGER H. HOH *In* AGARD, Rotorcraft Design for Operations 15 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

This research was conducted to investigate the required visual cueing for low speed and hover and to determine if an increase in stabilization can effectively be used to compensate for the loss of essential cues. Two flight test experiments were conducted using a conventional helicopter and a variable stability helicopter, as well as electronically fogged lenses and night vision goggles with daylight training filters. The primary conclusion regarding the essential cues for hover was that fine grained texture is more important than large discrete objects or field of view. The use of attitude command augmentation was found to be effective as a way to make up for display deficiencies. However, a corresponding loss of agility occurred with the tested attitude command/attitude hold system resulting in unfavorable pilot comments. Hence, the favorable control display tradeoff must be interpreted in the context that the best solution would be to improve the vision aid. Such an improvement would require an increase in the visual microtexture, an advancement in display technology that is unlikely to be available in the foreseeable future. Therefore, a criterion was developed to systematically evaluate display quality and the associated upgrade in required stabilization as a function of increasingly degraded visual cues. Author

N88-11660# Societe Nationale Industrielle Aerospatiale, Marignane (France). Dept. Systemes.

ACTIVE CONTROL OF HELICOPTER VIBRATION USING MULTILOOP SELF-ADAPTIVE CONTROL [CONTROLE ACTIF DES VIBRATIONS SUR HELICOPTERE PAR COMMANDS MULTICYCLIQUES AUTOADAPTATIVES]

MARC ACHACHE and MICHEL GAUVRIT (Centre d'Etudes et de Recherches, Toulouse, France.) *In* AGARD, Rotorcraft Design for Operations 10 p (SEE N88-11649 03-05) Jun. 1987 In FRENCH

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

A research program for the development of a trial multiloop control system for the active control of vibration in the main rotor blades is described. This experimentation consists of the most significant applications of self-adaptive control techniques to stochastic systems. The various stages of the program are discussed, from the research on the theoretical model of helicopter vibratory behavior under the influence of multiloop control, to the system flight tests. M.G.

N88-11661# Textron Bell Helicopter, Fort Worth, TX.

CONTROLLING THE DYNAMIC ENVIRONMENT DURING NOE FLIGHT

DENNIS R. HALWES *In* AGARD, Rotorcraft Design for Operations 9 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

A six degree-of-freedom isolation system using six Liquid Inertia Vibration Eliminator (LIVE) units was installed on a Bell 206LM helicopter. The system was named the Total Rotor Isolation System (TRIS). To determine the effectiveness of TRIS in reducing helicopter vibrations, a flight verification study was conducted. The objective was to demonstrate a 90 percent (or greater) isolation of the helicopter fuselage from the main rotor forces and moments transmitted at the blade passage frequency, which is 4/rev in the case of the Bell 206LM. The flight test data indicate that the objectives were surpassed. Author

N88-11662# Westland Helicopters Ltd., Yeovil (England)

MINIMISATION OF HELICOPTER VIBRATION THROUGH ACTIVE CONTROL OF STRUCTURAL RESPONSE

S. P. KING and A. E. STAPLE *In* AGARD, Rotorcraft Design for Operations 13 p (SEE N88-11649 03-05) Jun. 1987

(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The current demonstration and installation of the Active Control Structural Response (ACSR) technique on a Westland 30 helicopter is discussed. The technique employs high frequency force actuation within the helicopter's structure. These forces are superposed onto the dominant vibratory forces in an active manner, such that the fuselage vibratory response is minimized. The basic control philosophy for ACSR is described and the current experimental demonstration status is detailed. Author

N88-13247# Waterloo Univ. (Ontario). Dept. of Applied Mathematics and Mechanical Engineering

DYNAMIC STABILITY OF HYPERSONIC CONICAL LIFTING VEHICLES ACCORDING TO NEWTON-BUSEMANN THEORY

W. H. HUI and H. J. VANROESSEL (University of Western Ontario, London.) *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 13 p (SEE N88-13219 05-02) Nov. 1987 Sponsored in part by Natural Science and Engineering Research Council of Canada

(AGARD-CP-428) Avail: NTIS HC A24/MF A01

A theory is given of the aerodynamic stability of hypersonic conical lifting vehicles performing small amplitude pitching motion about its steady flight by using the Newton-Busemann flow theory, which is the rational limit of gas dynamic theory as the flight Mach number M sub infinity yields infinite and the ratio of specific heat Gamma yields 1. This is done by reformulating the gas dynamic equations using a set of material functions as independent variables which are a generalization of the stream functions of steady flow. In this formulation, calculations of the steady flow field are reduced to finding the geodesics of the body surface. The unsteady flow field is then calculated by perturbation of the steady flow. In particular, for conical shapes it requires only numerical quadrature. The theory is applied to conical wings of parabolic cross-section. The dependence of the stiffness and damping-in-pitch derivative on the angle of attack, the slenderness, concavity and convexity of the wing, and on the pivot axis position is studied systematically. Author

N88-13319*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NONLINEAR LIFT CONTROL AT HIGH SPEED AND HIGH ANGLE OF ATTACK USING VORTEX FLOW TECHNOLOGY
JOHN E. LAMAR *In* AGARD, *Special Course on Fundamentals of Fighter Aircraft Design* 23 p (SEE N88-13315 05-05) Oct. 1987 Previously announced in IAA as A86-37050
(AGARD-R-740) Avail: NTIS HC A13/MF A01 CSCL 01C

Nonlinear lift control at subsonic, transonic and low supersonic speeds owes its origin to the separated but organized vortical flows interacting with the wing upper surface. Since most of this flow originates near the wing or control-surface leading edge, a variety of devices has been studied experimentally which interact with and/or control this flow in order to gain a beneficial effect. The benefits (effects) originally studied were associated only with lift enhancement. Whereas, now the studied benefits encompass performance increase, attention to changes in trimmed conditions and longitudinal stability, improvements in lateral stability, and the attendant variation with changing Mach number. For those devices that can be theoretically modeled, state-of-the-art computer codes have been used for device design and/or analysis. Comparisons at design and off-design conditions are presented for validation purposes Author

N88-13348# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
STATIC AEROELASTIC EFFECTS ON HIGH PERFORMANCE AIRCRAFT
Jul. 1987 186 p In ENGLISH and FRENCH Meeting held in Athens, Greece, 28 Sep. - 3 Oct. 1986
(AGARD-CP-403; ISBN-92-835-0424-0; AD-A199170) Avail: NTIS HC A09/MF A01

Modern high performance aircraft designs tend to employ very thin airfoils having a degree and a distribution of stiffness far from the ideal; in consequence, there is a loss of control effectiveness and maneuverability. Moreover, the introduction of the highly forward swept wing planform poses a static aeroelastic effect of fundamental importance; these effects are felt at model as well as at full scale. The meeting was organized not only to review instances of these problems but to see how successfully modern tools for structural and aeroelastic analysis can be applied. For individual titles, see N88-13349 through N88-13358.

N88-13349# British Aerospace Public Ltd. Co., Preston (England). Military Aircraft Div.
EXAMPLES OF STATIC AEROELASTIC EFFECTS ON PRESENT COMBAT AIRCRAFT PROJECTS
W. E. SHARPE and J. B. NEWTON *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 10 p (SEE N88-13348 05-08) Jul. 1987
(AGARD-CP-403) Avail: NTIS HC A09/MF A01

The results of static aeroelastic calculations for a recent canard/cranked delta fighter project, in which a complete aircraft aerodynamic and structural model is used to demonstrate fully interacted free aircraft deflection modes and resulting stability effects are described. The significance of these results are illustrated by comparison with corresponding fixed root calculations, thereby indicating a requirement for complete aircraft aeroelastic modeling at the earliest possible stage in project design. Aeroelastic modeling of external stores in the context of store/aircraft integration is also discussed. Finally, the correlation of high speed wind tunnel results for aeroelastic distortion is addressed, indicating those parameters which are likely to be significantly affected.
Author

N88-13350# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
TRENDS IN AEROELASTIC ANALYSIS OF COMBAT AIRCRAFT
C. PETIAU and S. BRUN *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 25 p (SEE N88-13348 05-08) Jul. 1987
(AGARD-CP-403) Avail: NTIS HC A09/MF A01

After recalling the general principles of aeroelastic coupling with structural finite element analysis, the simplifying assumptions of static aeroelasticity are explained. The technique of load basis used in a general aircraft structural analysis program is discussed. This technique allows one to separate the big expensive computation of finite element resolutions and theoretical aerodynamic analysis from aeroelastic coupling and flight maneuver computation. Author

N88-13351# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Airplane Div.
STATIC AEROELASTIC CONSIDERATIONS IN THE DEFINITION OF DESIGN LOADS FOR FIGHTER AIRPLANES
G. SCHMIDINGER and O. SENSBURG *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 20 p (SEE N88-13348 05-08) Jul. 1987
(AGARD-CP-403) Avail: NTIS HC A09/MF A01

Some typical effects of static aeroelastic correction factors in context with the definition of structural design loads for major aircraft components are discussed. The influences on response parameters and resulting design loads are shown as well as the aeroelastic optimization of trailing edge flaps with respect to geometry, efficiency, and hingemoments. Author

N88-13352# Aerospatiale Usines de Toulouse (France).
AEROELASTIC ANALYSIS OF MODERN TRANSPORT AIRCRAFT [ANALYSE AEROELASTIQUE DES AVIONS MODERNES DE TRANSPORT]
J. ROUSTAN and M. CURBILLON *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 27 p (SEE N88-13348 05-08) Jul. 1987 In FRENCH; ENGLISH summary
(AGARD-CP-403) Avail: NTIS HC A09/MF A01

Static aeroelastic phenomena play a very important role in modern transport aircraft with regard to both handling qualities and loads applied to the structure. Aerospatiale's method for taking these effects into consideration and calculating them is presented. Author

N88-13353*# National Aeronautics and Space Administration Langley Research Center, Hampton, VA.
STATIC AEROELASTIC EFFECTS ON THE FLUTTER OF A SUPERCRITICAL WING
E. CARSON YATES, JR. and LI-CHUAN CHU (PRC Kentron, Inc., Hampton, Va.) *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 14 p (SEE N88-13348 05-08) Jul. 1987
(AGARD-CP-403) Avail: NTIS HC A09/MF A01 CSCL 01C

The results of an effort to calculate the effects of angle of attack and the associated aeroelastic deformation on the flutter of a highly swept supercritical wing by use of the modified strip analysis employed in previous studies of this wing are discussed. The spanwise distributions of steady state section lift-curve slope and aerodynamic center required as input for these calculations were obtained from static aeroelastic calculations for the wing by use of the FLO22 transonic code and an assumed dynamic pressure. The process is iterative so that flutter can be obtained at the same dynamic pressure as that used to calculate the statistically deformed shape and loading about which the flutter oscillation occurs (matched conditions). The results of this investigation show that the unconventional backward turn of the transonic dip in the experimental flutter boundary for angles of attack greater than zero is caused by variations in mass ratio and not by static aeroelastic deformation, although inclusion of the latter appears to be required for quantitative accuracy in the calculations. Author

N88-13354# Royal Aircraft Establishment, Farnborough (England).
WING DIVERGENCE OF TRIMMED
LL. T. NIBLETT *In* AGARD [illegible]astic Effects on High Performance Aircraft 9 p (SE[illegible] 05-08) Jul. 1987
(AGARD-CP-403) Avail: NTIS HC A09/MF A01

By means of a simple theoretical model it is shown that wing divergence of a free aircraft can be defined using the static case of trimmed level flight. The same model also shows that the control angle per g goes to zero at a speed near the fixed root divergence speed and that there is a large change in the spanwise distribution of airload in going from a low speed to speeds above that of fixed root divergence Author

N88-13355# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Helicopter and Airplane Div.

THE USE OF AEROELASTIC WIND TUNNEL MODELS TO PROVE STRUCTURAL DESIGN

H. HOENLINGER, J. SCHWEIGER, and G. SCHEWE (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany) *In its* Static Aeroelastic Effects on High Performance Aircraft 15 p (SEE N88-13348 05-08) Jul. 1987

(AGARD-CP-403) Avail: NTIS HC A09/MF A01

In a wind tunnel study on an aeroelastic carbon fiber fin/rudder model, it is demonstrated how structural design methods can be checked by experiment beginning in an early stage of the design. Emphasis was put on the static aeroelastic investigations, which became more important in high performance A/C design. Transonic measurements with a rigid balance based on an opto-electronic deformation measurement method were performed. An attempt was made to evaluate rudder efficiencies from these aeroelastic measurements. A nonlinear behavior of the rudder based on geometrical coupling with the fin box played an important role in the test evaluation. Author

N88-13356*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

PREDICTION OF WING AEROELASTIC EFFECTS ON AIRCRAFT LIFE AND PITCHING MOMENT CHARACTERISTICS

CLINTON V. ECKSTROM *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 17 p (SEE N88-13348 05-08) Jul. 1987 Previously announced as N87-15975

(AGARD-CP-403) Avail: NTIS HC A09/MF A01 CSCL 01C

The distribution of flight loads on an aircraft structure determine the lift and pitching moment characteristics of the aircraft. When the load distribution changes due to the aeroelastic response of the structure, the lift and pitching moment characteristics also change. An estimate of the effect of aeroelasticity on stability and control characteristics is often required for the development of aircraft simulation models of evaluation of flight characteristics. This presentation outlines a procedure for incorporating calculated linear aeroelastic effects into measured nonlinear lift and pitching moment data from wind tunnel tests. Results are presented which were obtained from applying this procedure to data for an aircraft with a very flexible transport type research wing. The procedure described is generally applicable to all types of aircraft. Author

N88-13357# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

INFLUENCE OF THE STATIC DEFORMATION ON A WING IN *THE UNSTEADY AERODYNAMIC*

R. DESTUYNDER *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 8 p (SEE N88-13348 05-08) Jul. 1987 Previously announced in IAA as A87-21054

(AGARD-CP-403) Avail: NTIS HC A09/MF A01

Wind tunnel tests and related calculations were carried out to study the influence of static deformation due to steady loads on the flutter phenomenon experienced by modern civil aircraft. Consideration is also given to the nonlinearity of unsteady forces on an engine as a function of global incidence. It is found that the spanwise untwisting effect associated with positive incidences increases the flutter limits for given Mach number and dynamic pressure values. Author

N88-13358# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

MEASUREMENT OF MODEL DEFORMATION IN WIND TUNNELS

M. CHARPIN, C. ARMAND, and R. SELVAGGINI *In* AGARD Static Aeroelastic Effects on High Performance Aircraft 20 p (SEE N88-13348 05-08) Jul. 1987 In FRENCH; ENGLISH summary Original language document was announced in IAA as A87-36943

(AGARD-CP-403) Avail: NTIS HC A09/MF A01

Various techniques used at ONERA for the wind tunnel measurement of the deformation of models undergoing aerodynamic and body loading are presented. Photography of reflecting targets is used to measure trailing edge deformation. Global torsion measurement of a wing at its wing tip is performed by the torsiometer measurement of the angle between the incident and reflected laser beam. An example of the determination of airfoil trailing edge deformation by tracking the position of light sources with an optical detector is presented. Finally, a technique for computing the strain from stress measurements is presented and demonstrated with a helicopter rotor blade model. Author

N88-17682# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

EFFECTIVENESS OF VARIOUS CONTROL SURFACES IN QUASI-STEADY AND UNSTEADY CONDITIONS [EFFICACITE DE DIFFERENTES SURFACES DE CONTROLE EN QUASI-STATIONNAIRE ET INSTATIONNAIRE]

R. DESTUYNDER, R. BARREAU, and G. ANDERS Apr. 1986 26 p In FRENCH Presented at the 6th Meeting of the AGARD Panel on Structures and Materials, Oberammergau, Fed. Republic of Germany, 8-13 Sep. 1985

(AGARD-R-735; ISBN-92-835-2113-7) Avail: NTIS HC A03/MF A01

This report describes tests conducted in the Modane S1 wind tunnel in France to measure the unsteady pressures on two half-models of wings outfitted with different control surfaces such as vented or unvented spoilers, flaperons, or ailerons. One of the wings, the ZKP model, is a standard configuration from the AGARD-SMP Compendium of Unsteady Pressure Measurements. The movements imposed on the control surfaces could be white noise, fixed frequency harmonics and ramp. A data base with a very wide range of parameters such as the Mach number, wing angle of attack, deflection of one or several control surfaces, and reduced frequencies was obtained. One of the goals was to establish semiempirical corrections to the theory of the efficiency of control surfaces. All of the excitation tests and acquisition and processing work for the unsteady condition studies were completely directed by a computer. Author

N88-19458# Aeritalia S.p.A., Turin (Italy). Combat Aircraft Group.

INTERACTION BETWEEN STRUCTURAL CONSIDERATIONS AND SYSTEM DESIGN IN ADVANCED FLIGHT CONTROLS

FRANCO SELLA and GERHART SCHMIDINGER (Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, West Germany). *In* AGARD Workshop on Design Loads for Advanced Fighters 19 p (SEE N88-19449 12-05) Feb. 1988

(AGARD-R-746) Avail: NTIS HC A07/MF A01

Integration of various disciplines is the key to the optimization of a design. In particular, the integration of the flight control system (FCS) and the structural design is feasible within the currently available technology to an extent which offers significant gains over traditional approaches to the design. Realization of carefree handling features by the FCS allows the application of structural design criteria for safe structural design with significant reductions in structural mass. The impact on the FCS design is an increase in the complexity of both hardware and software and an increase in the certification effort. Author

N88-19558# Societe de Fabrication d'Instruments de Mesure, Massy (France).

AUTOMATIC FLIGHT CONTROL SYSTEM FOR MODERN HELICOPTERS [SYSTEME DE CONTROLE AUTOMATIQUE DU VOL POUR HELICOPTERES MODERNES]

J. C. DERRIEN and P. CAUVY (Societe Nationale Industrielle Aerospatiale, Paris, France) *In* AGARD Advances in Air-Launched Weapon Guidance and Control 16 p (SEE N88-19553 12-15) Dec. 1987 In FRENCH

(AGARD-CP-431) Avail: NTIS HC A06/MF A01

Research efforts in the design and development of automatic pilot systems are described. Mission operational aspects relative to helicopters in general are addressed. An attempt is made to determine the relations between operational requirements and the automatic flight control system. The theoretical aspects which are necessary for the determination of the best control laws compatible with the operational requirements of specific helicopter missions are stressed. The AP 165 automatic flight control system and the various control functions for land, air and marine missions are described. The application of this system to the Super Puma MK2 is discussed. Author

N88-29718# Federal Aviation Administration, Seattle, WA.
CURRENT AND PROPOSED GUST CRITERIA AND ANALYSIS METHODS: AN FAA OVERVIEW
TERENCE J. BARNES *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 12 p (SEE N88-29717 24-01) Jun. 1988
(AGARD-R-734-ADD) Avail: NTIS HC A06/MF A01

An FAA overview is presented of the gust criteria and analysis methods used in the various types of flight vehicle certified under the FAR's. The current criteria for small airplanes, transports, and rotorcraft are presented, and the status of proposed criteria for the tilt rotor and aerospace plane are discussed. The amount of discussion on each class of vehicle depends on the significance of gust loads as design loads, and the importance of vehicle flexibility. Transport airplane gust criteria development, usage and problems are discussed in some detail. Analysis methods used by U.S. industry are covered in a separate paper. Author

N88-29723# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
MEASURED AND PREDICTED RESPONSES OF THE NORD 260 AIRCRAFT TO THE LOW ALTITUDE ATMOSPHERIC TURBULENCE
J. L. MEURZEC and F. POIRION *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 9 p (SEE N88-29717 24-01) Jun. 1988
(AGARD-R-734-ADD) Avail: NTIS HC A06/MF A01

A program of in situ measures using the Nord 260 plane equipped with accelerometers has allowed the comparison of the predicted and the measured responses of the flexible aircraft to turbulence. It shows a good agreement between the two sets of results and it emphasizes the better modeling of the turbulence using the isotropic model rather than the cylindrical one. Author

N88-29724# Civil Aviation Authority, Redhill (England). Airworthiness Div.
A REVIEW OF MEASURED GUST RESPONSES IN THE LIGHT OF MODERN ANALYSIS METHODS
V. CARD *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 14 p (SEE N88-29717 24-01) Jun. 1988
(AGARD-R-734-ADD) Avail: NTIS HC A06/MF A01

In the past simplified models of aircraft used to assess operational gust statistics have led to conservative estimates of derived gust exceedances. Modern refinements in aircraft modeling techniques have gradually introduced conservatism in the process of calculating gust loads. Gust statistics reviewed in the light of these modern analytical methods support the CAA view that gust velocities developed for use with simple rigid aircraft models are too severe for use with a modern dynamic analysis. Even in the light of improved safety targets, a 10 per cent reduction in design gust velocity can be readily justified. Further reductions may be justified on the basis of mission analysis considerations, or by investigation of more recent acceleration statistics collected by the current generation of transport aircraft. In the latter case, it will be essential to account for all relevant features of the subject aircraft in the derivation of gust velocities so as to obtain a true picture of the gust statistics. Author

N88-29726*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STATUS REVIEW OF ATMOSPHERE TURBULENCE AND AIRCRAFT RESPONSE
J. C. HOUBOLT *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 11 p (SEE N88-29725 24-01) Dec. 1987
(AGARD-R-734) Avail: NTIS HC A09/MF A01 CSCL 01C

A brief review is made of the understanding of aircraft encounter of atmospheric turbulence, both from the point of view of describing or modeling the turbulence and with respect to the ability to calculate resulting airplane loads. Some of the more recent studies of gust measurements and of reducing airline gust response data are discussed. Special attention is given to gust analysis requirements as involved in airplane certification and whether there is a need for additional or different requirements. A review is made of a recent study in which amazingly simple and universal gust response equations were discovered; the possible impact of these new findings on future work is indicated. Author

N88-29729# Taylor (J.), Camberley (England).
AN INTERIM COMPARISON OF OPERATIONAL CG RECORDS IN TURBULENCE ON SMALL AND LARGE CIVIL AIRCRAFT
J. TAYLOR *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 31 p (SEE N88-29725 24-01) Dec. 1987
(AGARD-R-734) Avail: NTIS HC A09/MF A01

Operational records have been made on British Airways aircraft for the period May 1980 to April 1985 and analyzed for about 650,000 flying hours on a number of different aircraft. Records were obtained for about 2 to 5 minutes of Normal Acceleration, Pitch Angle, Roll Angle, Height and Speed for nearly all those events which had an increment of 1 g or more, i.e., 29 events; similar records were also obtained for nearly all those events with an increment of 0.5 g or more with flaps down from May 1983 to April 1985, i.e., 33 events. An interim examination of the 29 events with 1 excess g or more, with special emphasis on 15 of them is made and includes an estimate of the interaction of maneuvers and turbulence, an estimate of the frequency of occurrence of high level intensity gusts and of the equiprobability relationships of gust levels and gust gradients. It was found that gusts that are important for a particular response are strongly dependent on the rate per sub 5 km at which zero crossings occur in that response. Using the Kaynes formula for gust intensity and zero crossings, it was found that the equiprobability relationships of gust levels and gust gradients can be represented on a single diagram for all sizes of aircraft at all heights. Author

N88-29732# British Aerospace Aircraft Group, Weybridge (England). Military Aircraft Div.
RE-ASSESSMENT OF GUST STATISTICS USING CAADRP DATA
B. W. PAYNE, A. E. DUDMAN, and K. C. GRIFFITHS *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 22 p (SEE N88-29725 24-01) Dec. 1987
(AGARD-R-734) Avail: NTIS HC A09/MF A01

The measured incremental c.g. accelerations of the BAC 1-11 operating on scheduled flights are compared with the equivalent theoretical predictions in a gust environment. Some of the results of the study are: (1) An analysis of the measured Civil Airworthiness Authority Data Recording Program data, based upon a significant 58,733 flying hours, gave an incremental vertical c.g. acceleration of 1.25 g at the datum probability value of 2 x .00005 exceedances per hour; (2) The theoretical predictions from all the flight segments in the Mission Analysis gave an incremental c.g. acceleration of .238 g at the datum exceedance value; and (3) Therefore in the comparison between the measured and predicted analyses for a similar mission considerable differences were found with measured frequencies of exceedance of about one half those predicted using current airworthiness requirements. Author

N89-10048# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
GUIDANCE AND CONTROL SYSTEMS SIMULATION AND VALIDATION TECHNIQUES
WILLIAM P. ALBRITTON, JR., ed. (Amtec, Inc., Athens, Ala.) Jul. 1988 133 p In ENGLISH and FRENCH
(AGARD-AG-273; ISBN-92-835-0472-0; AD-A202493) Avail: NTIS HC A07/MF A01

This AGARDograph addresses simulation and validation techniques for guidance and control systems of tactical guided weapons. Many developments have taken place over the last few years. In particular, physical simulation using hybrid, hardware-in-the-loop techniques has assumed much more importance. The chapter on digital simulation techniques provides descriptions of digital simulation techniques for application to some of the more difficult aspects of tactical guided weapon guidance and control systems. Concerning hardware-in-the-loop (HITL) simulation techniques, descriptions are provided of facility design techniques for performing HITL simulation and particular information on radar simulation techniques. System Simulation and Validation

Experience presenting lessons learned type information from some of the major programs are examined. The application of the techniques to guided weapon developments is presented. For individual titles, see N89-10049 through N89-10057.

N89-10053# Boeing Aerospace Co., Seattle, WA.
COST EFFECTIVE SIMULATION FOR MILLIMETER WAVE GUIDANCE SYSTEMS
VANCE H. MAPLES and GEORGE A. EASTMAN *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 7 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

The introduction of millimeter wave (MMw) active-passive, air-to-surface missile seeker systems to counter the European armor threat has increased the need for simulators to evaluate the performance of this class of seeker. Existing simulation techniques have not proved to be cost effective, and are generally unable to obtain sufficient target spatial position control at millimeter wave frequencies to ensure high fidelity simulations. The conventional approach to simulating a target for seeker testing is to build a transponder which receives the transmitted signal to the seeker, delays it to represent range, modulates it to simulate the intended target signal, and retransmits it through an antenna array which positions the target spatially. Target modeling and position control are implemented using simulation components at the radar frequency. A concept for target simulation for FM/WC modulated radar sensors, uses the signal from the seeker transmitted to illuminate an array of target antennas. This radar scene simulation technique provides a lower cost simulation method for evaluating FM/WC modulated millimeter wave seekers. This technique is equally effective for pulse modulated seeker simulation when a millimeter wave illuminating source is added to the system. In either case, it significantly reduces the high-cost/marginal-performance millimeter wave hardware required in the simulator and can be applied to evaluation of both active and passive seeker modes.
Author

N89-10055# Raytheon Co., Bedford, MA.
SIMULATION VALIDATION EXPERIENCE: PATRIOT GUIDANCE SYSTEM
WILLIAM C. MORTON *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 11 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

The increased use of sophisticated simulations as performance prediction tools during the development of guided missiles has placed greater emphasis on comprehensive validation of the models used. Validation of several simulations was accomplished by Raytheon Company while developing the Army's PATRIOT air defense system. The validation experience is presented for two large-scale guidance simulations; the Hybrid Guidance System Simulation and the Guidance Test and Simulation Facility. Examples of the data collected are presented in the course of discussing the approach to validating all mathematical as well as hardware-in-the-loop simulations. Conclusions are drawn as to the most effective methods and the value of the validation process to the overall system development.
Author

N89-10832# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Aircraft Div.
COMPUTING SYSTEM CONFIGURATION FOR FIGHTER AIRCRAFT FLIGHT CONTROL SYSTEMS
H. J. KAUL, H. LUEERS, and J. RAUCH *In* AGARD, Computing Systems Configuration for Highly Integrated Guidance Control Systems 32 p (SEE N89-10831 02-01) Jun. 1988
(AGARD-LS-158) Avail: NTIS HC A08/MF A01

Flight Control Systems (FCS) for present and future Fighter Aircraft developments are based on three basic technologies, CCV-ACT-digital signal processing. These technologies have opened a new degree of freedom for optimizing overall weapon system performance by extending the requirements to be implemented by the FCS. The computing subsystem of the FCS is the key element of the FCS by which this performance optimization can be achieved. Digital FCS for fighter aircraft in service or under development exhibit a basically common architecture (static parallel redundancy, centralized heavily burdened computing subsystem) which has continuously evolved since the early days of CCV and ACT activities. The objectives of the paper are to relate this classical architecture to the advancing requirements and the new emerging technologies and to analyze its potentials for future developments.
Author

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RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tubes; and aircraft engine test stands.

N87-15985# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
TECHNICAL EVALUATION REPORT ON THE FLIGHT MECHANICS PANEL SYMPOSIUM ON FLIGHT SIMULATION
ANTHONY M. COOK (National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.) Oct. 1986 14 p Symposium held in Cambridge, England, 30 Sep. - 3 Oct. 1985
(ISBN-92-835-0399-6; AD-A173991; ISBN-92-835-0399-6; AGARD-AR-234) Avail: NTIS HC A02/MF A01

In recent years, important advances were made in technology both for ground-based and in-flight simulators. There was equally a broadening of the use of flight simulators for research, development, and training purposes. An up-to-date description of the state-of-the-art of technology and engineering was provided for both ground-based and in-flight simulators and their respective roles were placed in context within the aerospace scene. Author

N87-21192# Royal Aircraft Establishment, Farnborough (England).
DEVELOPMENTS IN DATA ACQUISITION AND PROCESSING USING AN ADVANCED COMBUSTION RESEARCH FACILITY
J. B. BULLARD, F. S. E. WHITCHER, and R. V. STEEDEN *In* AGARD Advanced Instrumentation for Aero Engine Components 16 p (SEE N87-21170 14-31) Nov. 1986 Previously announced as N87-16852
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

A new combustion rig is described which is designed to acquire rapid and detailed information on the combustion processes occurring within a sector of large annular gas turbine combustors operating over a range of inlet pressures and temperature representative of engine conditions. Gas samples are extracted using a probe positioned within the volume under examination and transferred to a system designed to perform analyses with a point-to-point cycle time of less than 30 seconds. A computer is used to used to control and synchronize the probe positioning and gas analysis function and to present co-ordinated results to rig controllers. The system is capable of automatic traversing within a prescribed volume or of control by a dummy traverse gear which permits tracing of air and fuel flows.
Author

N87-21205# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).
PARTICLE IMAGING VELOCIMETRY IN A LOW TURBULENT WINDTUNNEL AND OTHER FLOW FACILITIES
J. KOMPENHANS and J. REICHMUTH *In* AGARD Advanced Instrumentation for Aero Engine Components 13 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Particle imaging velocimetry (PIV) is a new technique to measure flow velocity and flow direction at one instant in time within a large area of the flow field. For that purpose PIV utilizes the light scattered by small particles in the flow, which are illuminated by two short laser pulses. The experience gained with this method is discussed. Young's fringes method to evaluate the velocity data is discussed. Examples of first experimental results are given.
Author

09 RESEARCH AND SUPPORT FACILITIES (AIR)

N87-23633# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
FLIGHT SIMULATION
Sep. 1986 360 p In ENGLISH and FRENCH Symposium held in Cambridge, England, 30 Sep. - 3 Oct. 1985
(AGARD-CP-408; ISBN-92-835-0394-5; AD-A173875) Avail: NTIS HC A16/MF A01

The objectives of the conference were to provide an up-to-date description of state-of-the-art technology and engineering for both ground-based and in-flight simulators, together with an indication of future possibilities; and to place the roles of ground-based and in-flight simulators into context with one another and within the aerospace industry. For individual titles, see N87-23634 through N87-23660.

N87-23634*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
VISUAL AND MOTION CUEING IN HELICOPTER SIMULATION
RICHARD S. BRAY *In* AGARD Flight Simulation 16 p (SEE N87-23633 17-09) Sep. 1986 Previously announced as N86-11208
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The visual cues presented in the simulator are compared with those of flight in an attempt to identify deficiencies. For the low-amplitude maneuvering tasks normally associated with the hover mode, the unique motion capabilities of the Vertical Motion Simulator (VMS) at Ames Research Center permit nearly a full representation of vehicle motion. Especially appreciated in these tasks are the vertical-acceleration responses to collective control. For larger-amplitude maneuvering, motion fidelity must suffer diminution through direct attenuation through high-pass filtering washout of the computer cockpit accelerations or both. Experiments were conducted in an attempt to determine the effects of these distortions on pilot performance of height-control tasks. Author

N87-23635# Rediffusion Simulation Ltd., Crawley (England).
VISUAL DISPLAY RESEARCH TOOL
P. M. MURRAY and B. BARBER *In* AGARD Flight Simulation 8 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The Visual Display Research Tool (VDRT) is a new concept in visual displays which utilizes area of interest approach by matching its display parameters to those of the human eye. Two fields of view are employed, a wide-angle field corresponding to the peripheral area and an area of interest field inset at its center. The combined field is coupled to head and eye movements such that the direction of gaze is followed and a detailed scene is apparent over the whole field of regard at all times. The specific design chosen for VDRT is based on helmet mounted projection of two full color rasters onto the interior surface of a spherical dome surrounding the cockpit. The VDRT has been designed to meet the specified performance in a manner which allows a great deal of flexibility in system performance under software control. It should enable a lot of experimental results to be obtained on the performance and suitability of a head mounted eye tracker area of interest system as a training device. Author

N87-23636# Singer-Link-Miles Ltd., Lancing (England). Visual Applications Group.
ADVANCED VISUALS IN MISSION SIMULATORS
D. A. COWDREY *In* AGARD Flight Simulation 10 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Modern, sophisticated full mission flight systems trainers are capable of accurate representation of the actual aircraft in many areas including handling, controls, systems, etc. The major area of inadequacy to date has been the inability to produce a satisfactory visual representation of the outside world. To produce an image to match that of the pilot's field-of-view at the required resolution is beyond the capabilities of conventional visual system technology. Various alternative techniques of satisfying this demanding field-of-view/resolution requirement including the technique developed at the Link Flight Simulation Division of the Singer Company, based on an eye-slaved area-of-interest (AOI) concept are discussed. Author

N87-23637# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
THE APPLICATION OF OPTIMAL CONTROL TECHNIQUES TO THE UTIAS RESEARCH SIMULATOR
L. D. REID *In* AGARD Flight Simualation 13 p (SEE N87-23633 17-09) Sep. 1986 Sponsored by the Natural Sciences and Engineering Research Council and the Transportation Development Centre
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Optimal control has been useful in many aerospace applications in recent years. Two such applications to flight simulators are described. The first involves the generation of wind shear effects for use in training exercises. This work included simulator trails and an assessment of the process by a number of pilots. The second application is to the generation of simulator motion-base drive signals in a six degrees-of-freedom facility. In this case the optimal controller is composed of a series of filters that act much like a classical washout algorithm. Vestibular models which predict the sensation of motion by the pilot are incorporated within the optimal controller and are also used to evaluate its overall performance. Author

N87-23638# Avions Marcel Dassault-Breguet Aviation, Istres (France).
OASIS: A MODERN TOOL FOR REAL-TIME SIMULATION
J. BENOIT *In* AGARD Flight Simulation 13 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The hardware and software of the OASIS real-time flight simulation system are discussed. Symbol generation, the performance of elementary graphic functions, the validation of system concepts, and training are briefly discussed. R.J.F.

N87-23639# Royal Aircraft Establishment, Bedford (England). FS(B)3 Div.
SIMULATOR MOTION CHARACTERISTICS AND PERCEPTUAL FIDELITY Progress Report
B. N. TOMLINSON *In* AGARD Flight Simulation 12 p (SEE N87-23633 17-09) Sep. 1986 Previously announced as X87-70218
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Information is given on a study, commissioned by the AGARD Flight Mechanics Panel, to review existing data and try to describe a relationship between certain motion system parameters, identified in an earlier AGARD Report (AR-144), and the fidelity of the pilot's perception of flight. Motion system characteristics as a whole are discussed, thus extending AR-144's treatment of motion mechanisms to include motion drive software and other features. Some of the key parameters of AR-144 are then examined in relation to total motion system fidelity. Finally, some proposals are made for a common format data structure with which to summarise research results on motion cues. Author

N87-23640# British Aerospace Public Ltd. Co., Preston (England).
SIMULATION OF AIRCRAFT BEHAVIOUR ON AND CLOSE TO THE GROUND: SUMMARY OF AGARDOGRAPH AG-285
A. G. BARNES *In* AGARD Flight Simulation 4 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

A summary of a report on the simulation of aircraft characteristics on and near the ground is given. The benefits of good handling are noted. The components needed to put together a simulation - the data set, the computer, the visual system, the motion system, and other cueing devices - are considered. Modeling of the vehicle on the ground is discussed, as are visual system requirements. R.J.F.

N87-23641# Rediffusion Simulation Ltd., Crawley (England). Research and Development Dept.
USE OF VDU'S BY FLIGHT SIMULATOR INSTRUCTORS
MARK A. BRUNT *In* AGARD Flight Simulation 6 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NT'S HC A16/MF A01

The development of Visual Display Unit (VDU)-based simulator instructor stations with some ergonomics rules are compared. Design aims and practical experience are discussed. Further rules

are developed to establish a baseline for designers, procurers and users of instructor stations. Author

N87-23642# Royal Aircraft Establishment, Bedford (England).
PROGRESS IN THE IMPLEMENTATION OF AGARD-AR-144 IN MOTION SYSTEM ASSESSMENT AND MONITORING
K. J. STAPLES, W. LOVE, and D. PARKINSON (Singer-Link-Miles Ltd., Lancing, England) *In* AGARD Flight Simulation 11 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

After a brief explanation of the techniques defined in AGARD-AR-144, a description is given of two systems which have been built and tested to satisfy the requirements of the AGARD Report. Each system is stand-alone and only requires the user to supply the sensors on the motion system itself. One system, from Singer Link Miles, is especially suited to six degree-of-freedom, synergistic motion systems, whereas the other, from Cranfield Institute of Technology, is more appropriate to systems with independent axes. The systems have each been used on several different motion systems and some examples of measured results are given. Author

N87-23643# National Aerospace Lab., Amsterdam (Netherlands).
FLEXIBLE AND HIGH QUALITY SOFTWARE ON A MULTIPROCESSOR COMPUTER SYSTEM CONTROLLING A RESEARCH FLIGHT SIMULATOR
A. P. L. A. MARSMAN *In* AGARD Flight Simulation 11 p (SEE N87-23633 17-09) Sep. 1986 Previously announced as N87-18578
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The research environment and the multiprocessor computer system required for flexible software for flight simulation programs are described. The program incorporates all hardware options with different calibration tables as the most simple solution, since for example the drive laws trimming the primary control systems are different for each system. Modularity of the simulation program allows the usage of subsets of the hardware. Even the primary controls can be replaced by inputs from a file. This enables the flexibility of parallel maintenance of hardware, while testing modified modules in the software. It reduces the costs for projects which do not need all systems. Author

N87-23645# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Flight Control Div.
TRENDS IN GROUND-BASED AND IN-FLIGHT SIMULATORS FOR DEVELOPMENT APPLICATIONS
PAUL E. BLATT and DON R. GUM *In* AGARD Flight Simulation 13 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Current capabilities and future trends for research and development simulators - both ground-based and in-flight are described. Engineering simulators are applied as design tools for synthesis and assessment of advanced aircraft, flight control systems, avionic system design, and cockpit man-machine integration. Real-time, piloted flight simulation for dynamic applications is discussed. No training simulation implications are intended. Author

N87-23646# Textron Bell Helicopter, Fort Worth, TX.
PILOTED SIMULATION IN THE DEVELOPMENT OF THE XV-15 TILT ROTOR RESEARCH AIRCRAFT
ROGER L. MARR and GARY B. CHURCHILL (Army Aeromechanics Lab., Moffett Field, Calif.) *In* AGARD Flight Simulation 15 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The effective use of simulation in the XV-15 preliminary design was demonstrated. All primary program objectives were met. The initial simulation evaluation during the source evaluation board proceedings contributed significantly to performance and stability and control evaluations. Subsequent simulation periods provided major contributions in the areas of control concepts, cockpit configuraiton, handling qualities, pilot workload, failure effects and recovery procedures. The fidelity of the simulation also provided a valuable pilot training aid as well as a means of evaluating the tilt rotor concept for various military and civil missions. Simulation continues to provide valuable design data for refinement of automatic flight control systems and design support for future tilt rotor applications. Throughout, fidelity has been a prime issue and has resulted in unique data and methods to validate and update the tilt rotor math model. Researchers participation from contractor and government agencies in the development of this simulation effort has led to a generic tilt rotor simulation capability on numerous facilities.

N87-23647# Centre d'Essais en Vol, Istres (France).
SIMULATION OF FLY-BY-WIRE CONTROL FOR CIVIL TRANSPORT AIRCRAFT AT THE FRENCH CENTRE D'ESSAIS EN VOL [SIMULATION DES COMMANDES DE VOL ELECTRIQUES AU CENTRE D'ESSAIS EN VOL FRANCAIS (CEV) POUR LES AVIONS DE TRANSPORT CIVIL]
R. VADROT *In* AGARD Flight Simulation 13 p (SEE N87-23633 17-09) Sep. 1986 In FRENCH
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

A review of the facilities and projects of the flight simulation center at Istres is presented. In particular, a joint program of the Centre d'Essais en Vol and Aerospatiale to develop simulation capabilities and conduct studies in civil aviation fly-by-wire control is discussed. The two phase project covered real-time image generation, cabin motion simulation, and control law development for the Airbus A-300 and A320 aircraft. M.G.

N87-23648# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
MANNED AIR TO AIR COMBAT SIMULATION
PAUL A. PATZNER *In* AGARD Flight Simulation 7 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The design and the development of modern fighter aircraft weapon systems has created an ever growing need for simulation activities. Especially manned simulation of combat missions in real time can provide invaluable information to the design engineers as well as to potential users of such weapon systems. The ground based Dual Flight Simulator (DFS) described here simulates air to air combat missions in real time for two different manned aircraft including avionics and armament. Each aircraft is flown by a pilot. The type of aircraft, its avionics and armament, can be modelled by exchangeable programs. In order to enlarge realism, the simulation covers a multiple target environment both in the visible range and beyond by infrared radiation radar sensors. The engagement scenario includes short range and medium range air to air missiles as well as the gun. The task area of the simulation covers mission performance assessments as well as the investigation of technical components during the research and development phase of future fighter aircraft systems. Author

N87-23649# Grumman Aerospace Corp., Bethpage, NY. Flight Test Dept.
UTILIZATION OF SIMULATION TO SUPPORT F-14A LOW ALTITUDE HIGH ANGLE OF ATTACK FLIGHT TESTING
P. CONIGLIARO and R. GOODMAN *In* AGARD Flight Simulation 15 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Ground-based flight simulation has been used successfully to support low altitude, asymmetric thrust, high angle of attack flight testing of the Grumman/Navy F-14A. The high risk nature of this flight testing, while representing a prime example of the application of simulation in the flight test environment, nonetheless generated particular problems regarding simulation fidelity and utilization requirements. As a result, new simulation capabilities were developed specifically for flight test support applications and were fully integrated into existing flight test computing/data analysis facilities. Results from the F-14 high angle of attack flight testing are used to illustrate how simulation can significantly enhance overall flight test safety and productivity. Using simulation support, an efficient test program was completed on time and allowed the F-14's departure characteristics to be safely demonstrated at angles of attack greater than 60 degrees with full engine thrust asymmetry at altitudes below 10,000 ft (3030 m) Author

N87-23650# Aeritalia S.p.A., Turin (Italy). Combat Aircraft Group.

THE USE OF AERITALIA FLIGHT SIMULATOR FOR THE DEVELOPMENT OF THE AM-X WEAPON SYSTEM

ARMANDO ARMANDO and MAURIZIO SPINONI *In* AGARD Flight Simulation 12 p (SEE N87-23633 17-09) Sep. 1986 (AGARD-CP-408) Avail: NTIS HC A16/MF A01

The use of the Aeritalia flight simulator in the development of the AM-X weapon system is discussed. A brief discription of simulator components is given. Flight mechanics, flight controls simulation, cockpit development, head-up display symbology, air-to-air gun attack simulation, in-flight refueling simulation, and aircraft formation lights positioning are among the topics covered. R.J.F.

N87-23651# Thomson-CSF, Trappes (France).

RADAR SIMULATORS

J. C. PIETREMENT *In* AGARD Flight Simulation 5 p (SEE N87-23633 17-09) Sep. 1986 (AGARD-CP-408) Avail: NTIS HC A16/MF A01

The diversity of on-board radars, the required training in their use and the need for preliminary testing prior to their definition led to the development of a multifunction radar simulator architecture offering maximum flexibility. This modular architecture makes possible a wide variety of products from simple training equipment to the most sophisticated research simulators. In addition, it can be adapted as radar techniques develop. Author

N87-23652# Air Force Flight Test Center, Edwards AFB, CA. 6520 Test Group.

THE DEVELOPMENT OF THE T-46 NEXT GENERATION TRAINER MANNED ENGINEERING SIMULATOR AT THE US AIR FORCE FLIGHT TEST CENTER

JONATHAN C. PICK *In* AGARD Flight Simulation 12 p (SEE N87-23633 17-09) Sep. 1986 (AGARD-CP-408) Avail: NTIS HC A16/MF A01

The development and structure of the T-46A flight test simulation at the U.S. Air Force Flight Test Center is described. Two interesting aspects of the simulation are emphasized: (1) An electrohydraulic force-feel system is driven by a digital computer to model a reversible flight control system. This led to some force-feel system instabilities that had to be eliminated. (2) Data for extremely high angles-of-attack are incorporated into the simulation in order to simulate aircraft stall, departure, spin, and recovery. As a tool for supporting flight test operations, the T-46 simulation will be used for planning, practice flying of flight tests, and to facilitate the development and evaluation of aircraft modifications (especially those involving the flight control system). This necessitates the use of very versatile software which can be changed daily to support daily flight operations. In addition, a simulation that can accurately model flight conditions on the edges of the flight envelope greatly enhances the safety and efficiency of flight tests. Since handling qualities is the primary area of interest in this simulation, certain elements of the simulation are of key importance. One of these is control stick feel. The use of an electrohydraulic force-feel system with digital control caused a number of challenges related to force-feel system stability, which are described along with the solutions implemented. Author

N87-23653# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).

OPERATIONAL TRAINING: APPLICATION AND EXPERIENCE

HEINZ FRIEDRICH *In* AGARD Flight Simulation 8 p (SEE N87-23633 17-09) Sep. 1986 (AGARD-CP-408) Avail: NTIS HC A16/MF A01

Possible applications and experience gained in the simulation of missions are described. At first, activities involving operational flight simulation are presented which are performed in the Dornier simulation laboratory and on the Alpha Jet simulator. Following a brief description of the simulator, typical examples are explained. Then a specific task on the simulator is detailed - the development of an air-to-air mode for the Heads Up Display (HUD). In the final section some aspects of operational training on flight simulators in the German air force are discussed Author

N87-23654# Air Force Flight Test Center, Edwards AFB, CA. 6520 Test Group.

A METHOD FOR AIRCRAFT SIMULATION VERIFICATION AND VALIDATION DEVELOPED AT THE UNITED STATES AIR FORCE FLIGHT SIMULATION FACILITY

G. R. ANDERSON *In* AGARD Flight Simulation 7 p (SEE N87-23633 17-09) Sep. 1986 (AGARD-CP-408) Avail: NTIS HC A16/MF A01

The flight simulators at the United States Air Force Flight Test Center (AFFTC), Aircraft Flight Simulation Facility (AFSF) are primarily used for performance and flying qualities studies. These high-fidelity, real-time simulators are used as an engineering tool during the flight development of new or modified aircraft. Emphasis is placed on fully developing, verifying and validating a simulation before the actual aircraft begins flight testing. The flexibility, accuracy and ease with which the facility's method of verification and validation can be learned and implemented are a few of its advantages. This is demonstrated by the number of simulations which have been developed using it. The F-16 A/B, B-1B, Shuttle, F-15 C/D, AFTI (Advanced Fighter Technology Integration) F-16, F-16 C/D, and the T-46 are examples of simulations presently operational at the facility which were developed using the AFSF's method. The philosophy of developing a simulation before flight test allows the most to be learned about the aircraft before testing begins. The test smarter approach taken at the AFFTC requires that aircraft simulations be built quickly and be used to make flight testing more efficient and safer. The method for verifying and validating simulations used at the AFSF assures that these requirements are fulfilled. Author

N87-23655# National Aerospace Lab., Amsterdam (Netherlands).

CORRELATION BETWEEN FLIGHT SIMULATION AND PROCESSING OF FLIGHT TESTS BASED ON INERTIAL MEASUREMENTS

A. M. H. NIEUWPOORT, J. H. BREEMAN, L. J. J. ERKELENS, and P. J. J. VANDERGEEST *In* AGARD Flight Simulation 18 p (SEE N87-23633 17-09) Sep. 1986 Previously announced as N87-10863 (AGARD-CP-408) Avail: NTIS HC A16/MF A01

Flight tests and simulations were performed using conventional and dynamic techniques based on inertial measurements. The use of inertial sensors in flight testing implies that specific forces and body rates are determined which are directly employed in the flight path reconstruction procedure. This procedure uses the equations of motion governing flight. After this step, aerodynamics model identification can take place. In flight simulation, the opposite process occurs. From the available aerodynamic and engine model, specific forces and angular accelerations can be computed. Then the equations of motion can be integrated in order to determine the flight path. Consequently there is a strong similarity in the way flight test results are processed and reduced in order to obtain aerodynamic information and the way simulations are executed using a given model. Author

N87-23656# Calspan Advanced Technology Center, Buffalo, NY.

UNUSUAL AIRBORNE SIMULATOR APPLICATIONS

PHILIP A. REYNOLDS *In* AGARD Flight Simulation 14 p (SEE N87-23633 17-09) Sep. 1986 (AGARD-CP-408) Avail: NTIS HC A16/MF A01

Airborne simulation was conceived as a general purpose flying qualities research technique. Many diverse uses, forecast for the Total In-Flight Simulator (TIFS) while it was being developed, have come to pass, but diversity of application has exceeded even the most imaginative predictions. Some of the most unusual TIFS projects since it became active in 1971 are described. The objective is to help define and illustrate the role of airborne simulation in aerospace research and development as it interfaces with analysis, ground simulation, and flight test. Author

N87-23657# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.

DFVLR IN-FLIGHT SIMULATORS ATTAS AND ATTHES FOR FLYING QUALITIES AND FLIGHT CONTROL RESEARCH

DIETRICH HANKE and GERD BOUWER *In* AGARD Flight Simulation 13 p (SEE N87-23633 17-09) Sep. 1986

(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Two new in-flight simulators have been developed by DFVLR in recent years. These are the advanced airborne simulator Advanced Technologies Testing Aircraft System (ATTAS) based on a modified VFW-614 jet transport aircraft which will be operational in 1986, and the helicopter silulator ATTHeS (Advanced Technologies Testing Helicopter System) based on a BO 105 helicopter, which has operated since 198x. The application potential, the design requirements, the vehicle modifications, the overall system performance and the simulation capabilities as well as the used model-following-control methods, showing that good simulation fidelity could be achieved are among the types *discussed.* Author

N87-23658# Royal Aircraft Establishment, Bedford (England) FS(B)1 Div.

DEVELOPMENT OF IN-FLIGHT SIMULATION AIRCRAFT FOR RESEARCH AND TRAINING APPLICATIONS IN UK

O. P. NICHOLAS, J. A. GILES, and D. A. WILLIAMS (Cranfield Inst. of Tech., Bedford, England.) *In* AGARD Flight Simulation 13 p (SEE N87-23633 17-09) Sep. 1986

(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The objectives and the aircraft experimental system for the Vectored thrust Aircraft Advanced Flight Control (VAAC) research program are discussed. The VAAC program studies control laws, displays and cockpit controls for advanced STOL aircraft. The objective is to develop concepts and design and assessment techniques through ground based piloted simulation, mathematical studies, and flight in a two-seat fly-by-wire research Harrier aircraft. This work seeks to free the designer from some of the traditioned stability and control constraints and to maximise operational effectiveness throughout the flight envelope VSTOL aircraft. Author

N87-23659# National Aeronautical Establishment, Ottawa (Ontario). Airborne Simulation Facility.

AIRBORNE SIMULATION AT THE NATIONAL AERONAUTICAL ESTABLISHMENT OF CANADA

J. M. MORGAN. *In* AGARD Flight Simulation 16 p (SEE N87-23633 17-09) Sep. 1986. Sponsored in part by the Canadian Department of National Defence.

(AGARD-CP-408) Avail: NTIS HC A16/MF A01

The present Airborne Simulator operated by the Flight Research Laboratory (FRL) of the National Aeronautical Establishment (NAE), is based on a Bell 205A-1 host vehicle, and is the third generation of such simulators at the laboratory, the previous two being based on Bell 47 models. This aircraft was acquired by the NAE in 1969, first saw service in the simulation of variable stability role in 1971, and since then has undergone and is still undergoing a process of evolutionary development. This paper will concentrate on the operational aspects of airborne simulation using this aircraft, specifically addressing its limitations and the flight safety implications of operating in a single channel fly-by-wire mode in close proximity to the surface and obstacles. The implications of such operations, encompassing such flight phases as landing and Nap of the Earth (NCE) flight on future generations of airborne simualtion are also mentioned. Recent trends in flight mechanics research at the FRL have tended to remove emphasis from classical handling qualities experiments to a more system oriented field, and following this the Airborne Simulator has, of late, been used for investigations of the inherent aspects of fly-by-wire systems and as a general research tool in the investigation of various aspects of the glass cockpit and high technology pilot/machine interfacing. Author

N87-23660# Systems Technology, Inc., Hawthorne, CA.

COLLECTED FLIGHT AND SIMULATION COMPARISONS AND CONSIDERATIONS

IRVING L. ASHKENAS *In* AGARD Flight Simulation 34 p (SEE N87-23633 17-09) Sep. 1986

(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Government-sponsored research at Systems Technology, Inc. dealing with simulation fidelity and utility is reviewed, starting with some generic effects of motion and vision system characteristics and computational artifacts. Diagnostic methods and tools useful in discovering and delineating significant qualitative and quantitative differences between simulation and flight are then exposed and illustrated. Finally, examples of both fixed and moving simulation successes and shortcomings are reviewed and examined as to root causes of either. The research-simulator equipment involved in the above comparisons ranges from modern large-scale motion systems and computer-generated imagery to fixed-base with simple CRT-generated displays.

N87-24480# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Div.

DEVELOPMENT OF INTAKE SWIRL GENERATORS FOR TURBO JET ENGINE TESTING

H. P. GENSSLER, W. MEYER, and L. FOTTNER (Technische Univ., Munich, West Germany.) *In* AGARD Engine Response to Distorted Inflow Conditions 21 p (SEE N87-24464 18-07) Mar. 1987. Sponsored in part by the German Bundesministerium der Verteidigung.

(AGARD-CP-400) Avail: NTIS HC A14/MF A01

The main objective of this investigation is to assess the influence of different types and magnitudes of swirl on the performance and compatibility of turbojet engines. The generation of intake swirl, typical for many supersonic combat aircraft, is described. Essentially two basic types, i.e., twin swirl and bulk swirl of varying strength and also combinations thereof, were selected in order to simulate these swirl patterns by subscale generators in a model wind tunnel. The swirl patterns measured behind these generators show good agreement with the target patterns selected at the beginning. The small scale swirl generators are being rebuilt at full scale for subsequent testing in front of the Larzac engine under static conditions with a bellmouth inlet at the engine test facility of the Jet Propulsion Institute at the Universitaet der Bundeswehr Muenchen. Author

N87-24946# Rome Air Development Center, Griffiss AFB, NY.

ADVANCED SENSOR EXPLOITATION

JOSEPH ANTONIK and LEONARD E. CONVERSE, JR. *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 5 p (SEE N87-24940 18-66) Feb. 1987

(AGARD-CP-404) Avail: NTIS HC A07/MF A01

The Advanced Sensor Exploitation Testbed developed by the Rome Air Development Center for the purpose of evaluating and testing advanced techniques in the area of multisensor multidiscipline correlation is described. The testbed consists of three subsystems: the scenario generation subsystem, the sensor simulation subsystem, and the correlation and exploitation algorithms. The scenario generation subsystem, referred to as Dynamic Ground Target Simulator, is a computer automated system for the development of ground truth. Ground truth is any activity that occurs in the battlefield in relation to movement or emission of opposing ground forces. The sensor simulation subsystem consists of generic moving target indicator, radio detection/location, radar detection/location and imaging type sensors that act as filters for the ground truth. The correlation and exploitation algorithms are resident within the Advanced Sensor Exploitation Element and provide such data as military unit identification, the identification and tracking of high priority/critical targets, threat alerts, and activity level indications. The Advanced Sensor Exploitation Testbed along with built-in evaluation routines allow for the development, test, and evaluation of automated correlation and identification algorithms in as a realistic environment as possible. Author

N88-11655# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich *(Germany, F.R.)*.
MBB SIMULATION FACILITIES APPLIED FOR ROTORCRAFT RESEARCH
PETER KRAUSEP, JAMES VANGAASBEEK, and HORST BORCHERT *In* AGARD, Rotorcraft Design for Operations 17 p (SEE N88-11649 03-05) Jun. 1987
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The increasing pilot workload and environmental conditions of modern military helicopters necessitate detailed assessment of cockpit designs with regard to controls and displays. The optimization must be performed at the initialization of the concept to insure a harmonic design with minimum pilot workload. The status of the MBB Munich flight simulation facility is examined closely in light of these challenging requirements. Projections of the future development of the simulation center components are depicted, as well as priorities. Author

N88-11656# Centre d'Essais en Vol, Istres (France).
RESEARCH SIMULATORS FOR HELICOPTERS [SIMULATEURS D'ETUDES POUR HELICOPTERES]
D. JEROME *In* AGARD, Rotorcraft Design for Operations 12 p (SEE N88-11649 03-05) Jun. 1987 In FRENCH
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

The helicopter simulation facilities of the Centre d'Essais en Vol at Istres are described. The simulator cabins, imaging techniques motion simulator methods, and related computer equipment are described. In addition, the Center's research objectives in the areas of vehicle and systems design, crew station organization, and vehicle performance evaluation are outlined. M.G

N88-11667# Societe de Fabrication d'Instruments de Mesure, Massy (France).
HELICOPTER FIRE CONTROL: ADVANTAGES OF AN AUTOMATIC TARGET TRACKER [CONDUITE DE TIR HELICOPTERE INTERETS D'UNE POURSUITE AUTOMATIQUE DE CIBLE]
B. CERUTTI *In* AGARD, Rotorcraft Design for Operations 5 p (SEE N88-11649 03-05) Jun. 1987 In FRENCH
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

Several advantages of target tracking as applied to helicopter fire control are discussed. The principle elements involved in fire control (sighting, armaments and computers) and their respective roles in target acquisition are briefly described. The benefits of automatic target tracking with image processing are examined in terms of operator workload, improvement in tracking rate and noise, and improvement in target kinetic information (precision, noise) for fire control. Finally, the various criteria for control des[illegible] presented G.

N88-13220# Calspan Corp., Buffalo, NY.
A SURVEY OF EXISTING HYPERSONIC GROUND TEST FACILITIES: NORTH AMERICA
C. E. WITTLIFF *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 17 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

In the past several years there was a significant increase in the number of programs involving hypersonic vehicles, resulting in a resurgance of interest in experimental testing in hypersonic wind tunnels. Unfortunately, there are far fewer such facilities operating now than there were 10 or 15 years ago. The primary purpose is to survey the current status of hypersonic wind tunnels in North America and to describe their performance characteristics. As a part of this survey a comparison is drawn to the number and type of hypersonic wind tunnels that were active in the 1960's and 1970's relative to the current situation. Emphasis is placed on hypersonic aerodynamic and aerothermal testing and related areas. In surveying the hypersonic wind tunnels that are active in North America, all but one are located in the USA. There is a gun tunnel in Canada that will be reactivated this year. Author

N88-13221# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
EUROPEAN HYPERSONIC WIND TUNNELS
J. F. WENDT *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 24 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Although the hypersonic flow regime will probably be the first to be dominated by computational techniques due to serious experimental simulation problems, the next generation of lifting reentry vehicles will still rely on wind tunnels not only for design validation but also to verify computer codes through benchmark test cases. Evidence for this statement is the proposal to utilize European hypersonic tunnels for upwards of 2000 occupancy days from 1986 to 1993 on the Hermes project. Basic research in hypersonics required for the post-Hermes era will also rely heavily on wind tunnels and their associated instrumentation. Thus, it is appropriate to review the present statue of hypersonic tunnels. The requirements for flow simulation in the hypersonic regime are briefly discussed, and the present situation summarized. Gaps are identified and suggestions for improvements are put forward. Author

N88-13223# Queensland Univ., Brisbane (Australia). Dept. of Mechanical Engineering.
SHOCK TUNNELS FOR REAL GAS HYPERSONICS
R. J. STALKER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 10 p (SEE N88-13219 05-02) Nov. 1987
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

The application of free piston shock tunnels to the simulation of real gas effects in hypersonic flight is discussed. It is pointed out that the primary simulation variables for this purpose are the stagnation enthalpy and the binary scaling parameter. The free piston reflected shock tunnel is considered first, and it is shown how test time limitations play a major role in determining the limiting stagnation enthalpy for a given model size. Nevertheless, flight values of the two simulation variables, for vehicles similar to the Space Shuttle Orbiter, can be matched by an existing free piston shock tunnel up to speeds of 1 km/s. Experiments performed in this shock tunnel are used to demonstrate real gas effects in model flow. Radiative energy loss limits the maximum stagnation enthalpy available with reflected shock tunnels. Fortunately, operation in the nonreflected mode circumvents this limitation, and in addition, allows higher values of the binary scaling parameter; although it also leads to greatly reduced test times. The use of the prior steady flow technique to enable high enthalpy nonreflected shock tunnel operation is described, and examples of experiments performed in the facility are used to demonstrate that short test times do not preclude worthwhile experimentation. A variant of the free piston shock tunnel, which is intended for propulsion research at high velocities, also is briefly described. Author

N88-23126*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
WATER FACILITIES IN RETROSPECT AND PROSPECT: AN ILLUMINATING TOOL FOR VEHICLE DESIGN
GARY E. ERICKSON, DAVID J. PEAKE, JOHN DELFRATE, ANDREW M. SKOW, and GERALD N. MALCOLM (Eidetics International, Inc., Torrance, Calif.) *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 28 p (SEE N88-23125 16-34) Jun. 1987 Previously announced as N87-13403
(AGARD-CP-413) Avail: NTIS HC A20/MF A01 CSCL 14B

Water facilities play a fundamental role in the design of air, ground, and marine vehicles by providing a qualitative, and sometimes quantitative, description of complex flow phenomena. Water tunnels, channels, and tow tanks used as flow-diagnostic tools have experienced a renaissance in recent years in response to the increased complexity of designs suitable for advanced technology vehicles. These vehicles are frequently characterized by large regions of steady and unsteady 3-D flow separation and ensuing vortical flows. The visualization and interpretation of the complicated fluid motions about isolated vehicle components and complete configurations in a time and cost effective manner in hydrodynamic test facilities is a key element in the development of flow control concepts, and, hence, improved vehicle designs. A historical perspective of the role of water facilities in the vehicle design process is presented. The application of water facilities to specific aerodynamic and hydrodynamic flow problems is discussed.

and the strengths and limitations of these important experimental tools are emphasized. Author

N88-23128# Societe Bertin et Cie, Plaisir (France).
QUALIFICATION OF A WATER TUNNEL FOR FORCE MEASUREMENTS ON AERONAUTICAL MODELS [QUALIFICATION DUN TUNNEL HYDRODYNAMIQUE POUR DES PESEES DE MAQUETTES AERONAUTIQUES]
B. CHEZLEPRETRE and Y. BROCARD. *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 15 p (SEE N88-23125 16-34) Jun. 1987. In FRENCH; ENGLISH summary
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Bertin and Company maintains a water tunnel where flow visualization, and velocity and force measurements are performed. Recently, force measurements were done on a wing-canard model which was also tested in a wind tunnel at ONERA. This paper focuses on the presentation of the facility (including its laser anemometer and the computerized data acquisition system) and on the satisfactory comparison of the balance measurements obtained in both water and wind tunnels. Author

N88-23132# National Research Council of Canada, Ottawa (Ontario). Low Speed Aerodynamics Lab.
THE USE OF THE NRC/NAE WATER FACILITIES IN CANADIAN AERONAUTICAL RESEARCH AND DEVELOPMENT
R. H. WICKENS and N. E. JEFFREYS. *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 20 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Described are some of the hydrodynamic facilities of the National Research Council in Ottawa and St. John's, Newfoundland. The NAE water tunnel, in particular, contributed to the understanding of the aerodynamics of various VSTOL concepts, and complex flows containing strong elements of vorticity and unsteadiness. Several projects are described in which fundamental flow observations were made, and from which data was obtained in support of theoretical investigations. The past and future potential of several water facilities of the NRC for pursuing aeronautical and marine research are described. Author

N88-23133# MATRA Service Aerodynamique, Velizy-Villacoublay (France).
DESCRIPTION OF A WATER TANK FACILITY: STUDY OF A MISSILE AT HIGH INCIDENCE [PRESENTATION DUN BASSIN HYDRODYNAMIQUE: ETUDE DUN MISSILE AUX GRANDES INCIDENCES]
J. PERINELLE and A. LUPIERI. *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 20 p (SEE N88-23125 16-34) Jun. 1987. In FRENCH; ENGLISH summary
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

The water tank facility at Matra in which measurements are done of flows past missiles and other related research performed, is described. To assess the experimental techniques used, comparisons are made with wind tunnel test results. In terms of flow visualization, the phenomenon of vortex breakdown on a delta wing at incidence is checked against those of other installations. In addition, the characteristics of a simplified missile configuration are considered in subsonic flow at large incidences. The emphasis here is on two aspects. (1) the occurrence of side forces for angles of attack beyond a certain value, and how it is possible to correlate wind tunnel tests with the visualization of such flows, and (2) using wind tunnel data obtained with an instrumented model with a wing mounted on a balance compared with three other wings fixed to the body, a new correlation between measurements and visualization is made, indicating the strong dependency of wing lift on missile roll angle attitude. Author

N88-23150# Stuttgart Univ. (Germany, F.R.). Inst. fuer Aerodynamik und Gasdynamik.
A NEW LAMINAR WATER TUNNEL TO STUDY THE TRANSITION PROCESS IN A BLASIUS LAYER AND IN A SEPARATION BUBBLE AND A NEW TOOL FOR INDUSTRIAL AERODYNAMICS AND HYDRODYNAMIC RESEARCH
M. STRUNZ and J. F. SPETH. *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 5 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Two new watertunnels of the Institute for Aerodynamics and Gas Dynamics of the University of Stuttgart are presented. The first is especially designed to study the stability of a laminar boundary layer. The second was built to solve problems in industrial aero- and hydrodynamics. Both tunnels are constructed of corrosion-resistant materials, i.e. fiberglass/reinforced plastic technology. Technical data and the first applications are discussed. Author

N88-28858# Potter (J. Leith), Nashville, TN.
MISSILES, FUSELAGE AND SIMILAR BODIES
J. LEITH POTTER. *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 5-20 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

A review of current practices for coping with the simulation deficiency when tests of elongated bodies are conducted at Reynolds numbers appreciably lower than full-scale values is presented. High subsonic, transonic, and low-supersonic ranges of Mach number are covered; hypersonic conditions are excluded although much of the discussion is also relevant to high Mach number flows. Because the flows considered may or may not have supersonic regions and shock waves, it is important to remain alert to the differences that shock-boundary layer interaction may impose upon any conclusions that are based upon shock-free flows. Drag and side force variations generated by changes in Reynolds number receive the principal attention. The working premise is that the higher Reynolds number simulation goal implies also that a turbulent boundary layer is desired and that it has to be established by artificial means. Author

N88-28859*# National Aeronautics and Space Administration Langley Research Center, Hampton, VA.
HIGH-ASPECT-RATIO WINGS
JOHN B. PETERSON, JR. *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 21-29 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01. CSCL 14B

High-aspect-ratio aircraft include most transport aircraft such as commercial and military transports, business aircraft, and cargo aircraft. Generally, these types of aircraft are designed to cruise over a narrow range of lift coefficients and Mach numbers in the performance of their mission. Emphasis is therefore placed on the cruise performance of transport aircraft and every effort is made to obtain accurate wind-tunnel data to use as a basis for prediction of full-scale cruise performance. However, off-cruise performance is also important and methods were developed for extrapolating wind-tunnel data on buffet and flutter at transonic speed. Transport-type aircraft were tested extensively in various wind tunnels around the world and many different test techniques were developed to simulate higher Reynolds numbers. Methods developed for one tunnel may not be applicable to another tunnel because of differences in size, Reynolds number capability, running time, and test objectives. Many of the methods of boundary-layer control developed in two-dimensional airfoil testing can be applied in tests of transport configurations, but sometimes the three-dimensional flow fields that develop on tranpsort aircraft can make application of the two-dimensional methods difficult or impossible. The discussion is intended to be a representative, but not exhaustive, survey of the various methods of high Reynolds number simulation in the testing of high-aspect-ratio aircraft. Author

N88-28861# British Aerospace Public Ltd Co., Weybridge (England) Aircraft Group.
COMPLEX CONFIGURATIONS
A. G. T. CROSS *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 50-67 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The practice of simulating high flight Reynolds number behavior in a low Reynolds number facility is well known. However the problems now encountered at transonic speeds are considerable and vary for different model designs such that it is difficult to predict with real confidence the actual flight conditions. In two dimensions these scale effects become more apparent as the degree of supercritical flow is increased and in particular with rearward movement of shocks. In three dimensions the problems are more severe particularly when wing sweep is high due to vortex and turbulent attachment line flows, both of which are Reynolds number dependent and when complex configurations are considered the potential for scale sensitive effects is considerable owing to the many regions where flow separation can occur. The designer will often seek to avoid scale sensitive flow separations in model tests and this amounts to designing for low Reynolds number with a reduction in the potential gains to be had for design for full scale. By furthering the understanding of scale effects more realiable use can be made of Reynolds number simulation techniques, so enabling design for conditions closer to full scale with significant gains in flight performance. The current practice with regard to high Reynolds number simulation in transonic wind tunnels for industrial standards of testing relating to complex aircraft configurations is reviewed. Author

N88-28862# National Aerospace Lab., Amsterdam (Netherlands).
REYNOLDS NUMBER EFFECTS AND THE WIND TUNNEL ENVIRONMENT
A. ELSENAAR *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 68-79 (SEE N88-28857 23-01) Apr. 1988
Previously announced as N87-18546
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

Pseudo Reynolds number effects on wind tunnel test results are discussed. It is shown that many phenomena can be avoided or reduced. However, the natural transition position appears to be critically dependent on a large number of variables: pressure distribution, tunnel noise and turbulence, temperature non-equilibrium, surface roughness, and Reynolds number. For that reason differences in transition location between wind tunnel and flight are likely to occur for other reasons than Reynolds number differences. It remains good practice to either artificially fix the boundary layer or to measure the transition location. ESA

N88-28863# Napoli Univ. (Italy). Experimental Gasdynamics
TECHNIQUES FOR BOUNDARY LAYER TRIPPING AND CONTROL
G. P. RUSSO *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 80-90 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The most used techniques in industrial practice to provoke transition at the desired location on the model rely on narrow strips of sparsely distributed ballotini or carborundum grains. Carborundum is preferred for its sharp irregular shape giving rise to a superior effectiveness in tripping; ballotini are preferred for their closer dimensional control. A new technique trying to combine these two desirable features was proposed which make use of coronets produced with a sewing machine on thin metal strips. Another recently proposed technique makes use of transfer characters (Letraset) build up in layers of the desired thickness. Methods based on the increase of the turbulence level of the stream ahead of the model are to be considered not sufficiently reliable. The two most used techniques to detect transition on 3-D models are both based on surface visualization: the first one makes use of sublimating substances, acenaphtene in high subsonic and transonic tests, the second one makes use of fluorescent oil + ultra-violet light. An alternative technique, promising for its reversibility, is the visualization of temperature distribution on the surface with an infra-red camera (thermography) or with a temperature-sensitive paint. For 2-D or axially-symmetrical models more conventional techniques can be used as measurements of velocity profiles with pitot tubes, boundary layer thickness with optical methods, turbulence levels with hot-wire or Laser-Doppler anemometers. Author

N88-28864# Aircraft Research Association Ltd., Bedford (England).
EXPERIMENTAL TOOLS: THE TUNNEL AND THE MODEL
A. B. HAINES and A. ELSENAAR *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 111-114 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The aim of the report is to draw attention to experimental factors that can have a significant impact on the details of the methodology to adopt for a particular test program in a particular tunnel. First and foremost, the methodology and in particular, the choice of approach to the in-depth study of the viscous effects is likely to depend on the test Reynolds number and on whether it is possible to vary the Reynolds number by changing the tunnel stagnation pressure (or temperature). If the tests are being made in a variable density tunnel, Reynolds-number sweeps will tend to be the preferred option; if the tests are being made in an atmospheric tunnel, manipulation of the boundary layer to produce a closer representation of the full-scale boundary behavior will be the only possible approach unless one is prepared to test more than one model to a different scale. Whenever possible, both approaches should be practised but nevertheless, the type of tunnel will dictate the preference. Reynolds number, is however, not the only significant parameter. The stream turbulence and noise level are also important. The required standards of tunnel flow quality and data accuracy were set out in the report of an earlier sub-committee of the AGARD Fluid Dynamics Panel. For convenience, however, the main issues that can affect the success of applying either approach to the study of the viscous effects are summarized. Author

N88-28865# National Research Council of Canada, Ottawa (Ontario).
COMPUTATIONAL TOOLS FOR SIMULATION METHODOLOGIES
Y. Y. CHAN *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 115-131 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

In the brief review of the computational capabilities for viscous flows, it was shown that the methods of solution of the governing equations were well developed. Turbulence modeling is adequate for simple flows, though further verification and developments are still needed for complex flows. Interactions of viscous and inviscid flows, which are basic characteristics of transonic flows are properly formulated and analyzed. Attached flows can be predicted accurately for a wide range of Reynolds numbers. Flows with moderate separations near the leading or trailing edges and the shock wave-boundary layer interactions can be treated by the interactive methods. Methods for two-dimensional flows are better developed while three-dimensional and unsteady flow methods are showing rapid progress. In general, computations can be applied to simple configurations or components of a complex configuration. The interaction of computational simulations with wind tunnel test programs has effectively augmented the capabilities of these tests. The information provided by computations is now essential for design and checking of the test and for interpretation and extrapolation of the results. Due to strict requirement of accuracy in aerodynamic tests, applications of computation are limited, at present, to stimulation of attached flows. For complex flow simulations, especially with flow separation, further development is needed in better understanding the physical nature of the flow and its modeling. Author

N88-28866# National Aerospace Lab., Amsterdam (Netherlands)
EMPIRICAL TOOLS FOR SIMULATION METHODOLOGIES
A. ELSENAAR and A. B. HAINES (Aircraft Research Association Ltd., Bedford, England) *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 132-138 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

For the application of a simulation/extrapolation methodology a detailed understanding of the relevant viscous effects is essential. The most sophisticated computational methods today cannot describe all aspects of the flow development. This is particularly

true for details of the flow development that involve boundary layer transition and/or separation. For that reason an attempt is made to describe the empirical tools that can be used to supplement the theoretical calculations or the experimental information. The principle of the method is briefly indicated. Also, *in many cases, alternative relations can and will be used depending* on existing practice and experience of a particular design team. Where possible, in addition to a simple method a more sophisticated method was specified. In some cases the more sophisticated method is almost identical to a complete numerical simulation. In that respect the present set of empirical tools is open-ended. On the one hand, new experimental information will become available in the future to refine or extend the empirical tools as used at present. On the other hand, the ever increasing sophistication in flow modeling through computational methods will eventually supercede most empiricism. Author

N88-29742# British Aerospace Public Ltd. Co., Preston (England).
THE ROLE OF SIMULATION IN FLYING QUALITIES AND FLIGHT CONTROL SYSTEM RELATED DEVELOPMENT
A. G. BARNES *In* AGARD, Advances in Flying Qualities 21 p (SEE N88-29735 24-01) May 1988
(AGARD-LS-157) Avail: NTIS HC A09/MF A01

Flight simulation makes a vital contribution to the understanding of flying quality requirements and to the clearance of modern aircraft flight controls. The background to the use of simulators, both airborne and ground based is presented, and the experimental techniques, including validation and hardware requirements are discussed. The limitations which equipments can impose are presented, and examples are given of the use of flight simulation *in flying qualities research. Finally, the techniques required for the* clearance of current designs are highlighted, and a direction for future research is indicated. Author

N89-10054# Boeing Aerospace Co., Seattle, WA.
RANGE DELAY TECHNIQUES FOR RADAR TARGET SIMULATORS
LELAND C. BUSE *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 9 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

It was recognized that the Radar Guided Seeker and countermeasure development using flight tests as a primary evaluation tool is costly and insecure from interception of signal and telemetry emenations. Radar Target Simulators were developed which provide the capability both to evaluate actual radar guided seeker hardware and software and to evaluate countermeasures against the actual seeker hardware in a secure environment. Experience with these simulators has demonstrated that with adequate simulator hardware, valid closed-loop performance evaluations can be conducted which will accurately reflect flight test performance. A critical issue in the implementation of such systems is the simulation of radar pulse range delay. This must be accomplished with sufficient fidelity to represent a range-delayed target of ECM signal credible to modern seeker signal processors. Various range delay techniques as applied to *Radar Target Simulators are presented. In particular, a digital* approach to the solution of the range delay problem is developed from basic concepts through actual hardware implementation. Author

N89-16846# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING
Jul. 1988 516 p In ENGLISH and FRENCH Symposium held in Naples, Italy, 28 Sep. - 1 Oct. 1988
(AGARD-CP-429; ISBN-92-835-0469-0; AD-A202496) Avail: NTIS HC A22/MF A01

The wind tunnel is the main instrument for providing experimental aerodynamic data to the aerospace industry and researcher for the purpose of load and performance evaluation and for verification of theoretical results. In both cases, it is imperative that the user has confidence in the quality of the results, which means that he must have information on what accuracy to attach to the data. The quality of wind tunnel results depends upon both the accuracy of measurements and the imperfections provided by the wind tunnel environment. Great strides have been made on measurement accuracy and as a rule this need no longer be of much concern if properly attended to. However, imperfections provided by the wind tunnel are still extant and these *are the main sources affecting the quality and accuracy of* aerodynamic wind tunnel data. The capabilities of wind tunnels are compared with the demands of the user. For individual titles, see N89-16847 through N89-16880.

N89-16848# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).
EXPRIMENTS ON THE DFVLR-F4 WING BODY CONFIGURATION IN SEVERAL EUROPEAN WINDTUNNELS
G. REDEKER, R. MUELLER, P. R. ASHILL, A. ELSENAAR, and V. SCHMITT (Office National d'Etudes et de Recherches Aeronautiques, Paris, France) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 15 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Attempts are made to improve design methods for three-dimensional configurations in transonic flow and to increase the confidence in wind tunnel data. The selected configuration was the DFVLR-F4 wing-body combination incorporating a transonic wing of high aspect ratio and a fuselage of Airbus type. The experimental part of the exercise is examined, where the same model of the wing-body configuration was tested in three European Transonic wind tunnels. The tests followed an agreed test program comprised of force and moment measurement as well as measurements of pressure distribution on wing and fuselage. Selected test results from the three wind tunnel tests are compared, the main emphasis being placed on the comparison of results from different wind tunnels on physically the same model. The results show that the data of the three wind tunnels are in reasonable agreement, although the severe accuracy requirements of industry for judging performance data from different wind tunnels could not be met. Author

N89-16851# Calspan Field Services, Inc., Arnold AFS, TN. Aerodynamics Sect.
HIERARCHY OF UNCERTAINTY SOURCES IN TRANSONIC WIND TUNNEL TESTING
JAMES M. WHORIC and RANDY W. HOBBS *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 13 p (SEE N89-16846 09-09) Jul. 1988 Prepared in cooperation with Arnold Engineering Development Center, Arnold Air Force Station, TN
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

A numerical perturbation technique was employed to compute the aerodynamic coefficient uncertainties attributable to uncertainty sources associated with transonic wind tunnel testing. A force accounting system which included data from an aerodynamic reference system, a nozzle afterbody test, and an inlet test was established to develop a system of equations by which to compute nominal flight values of lift, drag, and pitching moment coefficient uncertainties. Uncertainty estimates included standard instrumentation uncertainties for such sources as wall interference, specific humidity, and viscous simulation which were based on combinations of CFD calculations and experimental data. Author

N89-16852# Naval Air Systems Command, Washington, DC. Aerodynamics and Flight Controls.
WIND TUNNEL PREDICTED AIR VEHICLE PERFORMANCE: A REVIEW OF LESSONS LEARNED
E. C. ROONEY and R. F. LAUER, JR. (Calspan Field Services, Inc., Arnold AFS, TN.) *In* AGARD, Aerodynamic Data Accuracy *and Quality: Requirements and Capabilities in Wind Tunnel Testing* 11 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Air vehicle development programs continue to experience difficulty in preformacne prediction of new aircraft configurations. Advances in the state-of-the-art in wind tunnel simulation techniques, flight performance measurements and computational fluid dynamics have provided the basis for investigating the accuracy of the aerodynamic element used in the performance prediction process. The force accounting procedures, model and wind tunnel simulation techniques and correction procedures are reviewed, along with full scale adjustments used to predict the

performance of air vehicles. The lesson learned in this review should enhance the capability to predict aircraft performance for future air vehicle development programs. Author

N89-16855# Royal Aircraft Establishment, Bedford (England).
THE ACCURATE MEASUREMENT OF DRAG IN THE 8 FT X 8 FT TUNNEL
M. N. WOOD and D. S. CAPPS *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 9 p (SEE N89-16846 09-09) Jul. 1988 Previously announced as X88-72373
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The techniques currently adopted in the 8 ft by 8 ft wind tunnel at RAE for the accurate measurement of drag are described in detail. Data are presented from three series of tests on a model of the A-310 aircraft and these demonstrate the level of accuracy which can be achieved. Author

N89-16856# British Aerospace Public Ltd. Co., Preston (England).
ACCURATE DRAG ESTIMATION USING A SINGLE COMPONENT DRAG MODEL TECHNIQUE
A. M. CASSIE *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The design, development and operation of an advance afterbody drag rig at the high speed wind tunnel at Warton is reviewed. The rig has been extensively used over a 16 year period for minimization of modern combat aircraft afterbody drag. Accurate incremental drag data is produced by measurement of the axial force on a fully representative metric afterbody section. A full description of the rig is given along with techniques for data correction and presentation of typical data. Author

N89-16857# Aircraft Research Association Ltd., Bedford (England).
DEVELOPMENT OF TESTING TECHNIQUES IN A LARGE TRANSONIC WIND TUNNEL TO ACHIEVE A REQUIRED DRAG ACCURACY AND FLOW STANDARDS FOR MODERN CIVIL TRANSPORTS
E. C. CARTER and K. C. PALLISTER *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 20 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Experience and results obtained in the ARA 9 ft by 8 ft transonic wind tunnel are used to address the questions of measurement and flow quality, data accuracy and achieved performance. The discussions relate primarily to experience with civil transports for which accurate drag prediction and efficient drag reduction through reliable experimental techniques is of major importance. The quality of results is studied via the definition of the problem areas, the correction methods and analysis of dynamics of the flow and the associated measurements. Techniques specific to a large development transonic tunnel are discussed in detail with a constant awareness of the cost and efficiency in relation to the required accuracy and repeatability standards. Author

N89-16859# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Berlin (Germany, F.R.).
FLOW UNSTEADINESS IN THREE LOW-SPEED WIND TUNNELS
U. MICHEL and E. FROEBEL *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 10 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The velocity unsteadiness in 6 test sections of 3 low speed wind tunnels is discussed. Large differences of the root-mean-square velocity or turbulence levels are observed in these tunnels. It is shown that these differences can be explained with the two independent contributions to the velocity unsteadiness in a wind tunnel: (1) vorticity which is convected into the test section from upstream, and (2) pressure waves which have many origins but the important ones for low speed wind tunnels are the free shear layers of open test sections and slotted wall test sections. It is further shown that the turbulence level is not sufficient to describe the effect of velocity unsteadiness on the quality of data measured in a wind tunnel and it is demonstrated with the example of boundary layer transition that the distribution of the fluctuating energy in the frequency domain is more important. Author

N89-16860# DSMA International, Inc., Toronto (Ontario).
IMPACT OF NOZZLE DESIGN CONSTRAINTS ON TEST SECTION FLOW QUALITY
D. VANEVERY, S. RAIMONDO, and G. M. ELFSTROM *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 11 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

A procedure is described which allows the design of relatively short adjustable nozzles without resorting to the assumption of radial flow upstream of the nozzle inflection point. This design procedure is used to generate a number of fully flexible nozzle designs for a design Mach number of 1.4. Flexible nozzle parameters such as pressure loading, number of actuators and nozzle length are varied in order that the influence of these parameters on test section flow quality may be evaluated. The influence of nozzle actuator setting accuracy is also estimated. The parametric study shows that high flow quality can be achieved for the shortest nozzle considered. The examination of jack setting errors shows that for well designed nozzles, jack setting error will be a significant source of test section flow nonuniformities. Author

N89-16861# McDonnell Aircraft Co., Saint Louis, MO. Aerodynamics and Propulsion Labs.
TRANSONIC WIND TUNNEL BOUNDARY INTERFERENCE: A CORRECTION PROCEDURE
R. C. CRITES *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

An effort to develop a transonic wind tunnel boundary correction procedure is examined. The goal is a boundary correction procedure applicable to ventilated test sections from subsonic through transonic Mach numbers. Boundary correction is distinguished from wall correction. Boundary corrections contain wall corrections, but also contain model support, and other tunnel dependent corrections. The approach taken uses computational fluid dynamics with measured boundary conditions to provide corrections at a few points in the test envelope. Conventional similarity principles and regression techniques are used to extend these corrections over the full test range. To provide experimental data needed for development and validation, a wind tunnel test program was initiated. A set of 4 wing-body model were built. Model size was varied while maintaining precise geometric similarity. The 3 smallest models were tested from Mach 0.5 to 1.2 in a small transonic tunnel. Preliminary testing of 2 of the largest models was made in a larger tunnel. Extensive boundary pressure data were measured in both tunnels. Typical results of these tests are reviewed. Author

N89-16862# Aircraft Research Association Ltd., Bedford (England).
THE USE OF COMPUTATIONAL FLUID DYNAMIC METHODS TO ASSESS THE EFFECTS OF MODEL SUPPORT SYSTEMS AND WORKING SECTION MODIFICATIONS ON THE FLOW AROUND WIND TUNNEL MODELS
D. R. STANNILAND *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The continuing development of computer codes and power means that computational fluid dynamic methods can be used, in conjunction with test techniques, to provide a more thorough knowledge of measured flow phenomena. The use of various programs is demonstated to evaluate the magnitude of the interference due to model support and flow measurement installations and to guide the design of an acoustic liner for the ARA transonic wind tunnel. Various simplifications are necessary to permit the representation of the complex geometry within the constraints imposed by the programs, and hence, care is needed in using the computed results. Within this limitation, the methods can provide a valuable aid to the interpretation of experimental results and to guide the design of wind tunnel installations.

Calculations are described using various theoretical methods, carried out in support of tests on five different wind tunnel installations. Author

N89-16863# National Aerospace Lab., Amsterdam (Netherlands).
ACCURACY OF VARIOUS WALL-CORRECTION METHODS FOR 3D SUBSONIC WIND-TUNNEL TESTING
R. A. MAARSINGH, TH. E. LABRUJERE, and J. SMITH *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 13 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

On the basis of wind-tunnel measurements on a (simple, unpowered, but complete) transport aircraft model in a small and a very large solid-wall test section the accuracy of four measured-boundary-condition (MEC) methods, as well as two classical methods, was analyzed at low-speed conditions. Large reductions in the amount of in situ measured data are shown to be possible, yet yielding results which match almost with those of calculations using multiples of input data. Classical methods need not be abandoned at once in low-speed solid-wall testing. Higher priority should be given to the well-known interpretation problem: the determination of the actual model reaction upon the wall-induced flow field. Author

N89-16864*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WIND TUNNEL-SIDEWALL-BOUNDARY-LAYER EFFECTS IN TRANSONIC AIRFOIL TESTING-SOME CORRECTABLE, BUT SOME NOT
F. T. LYNCH (Douglas Aircraft Co., Inc., Long Beach, CA.) and C. B. JOHNSON *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01 CSCL 14B

The need to correct transonic airfoil wind tunnel test data for the influence of the tunnel sidewall boundary layers, in addition to the wall accepted corrections for the analytical investigation was carried out in order to evaluate sidewall boundary layer effects on transonic airfoil characteristics, and to validate proposed correction and the limit to their applications. This investigation involved testing of modern airfoil configurations in two different transonic airfoil test facilities, the 15 x 60 inch two-dimensional insert of the National Aeronautical Establishment (NAE) 5 foot tunnel in Ottawa, Canada, and the two-dimensional test section of the NASA Langley 0.3 m Transonic Cryogenic Tunnel (TCT). Results presented included effects of variations in sidewall-boundary layer bleed in both facilities, different sidewall boundary layer correction procedures, tunnel-to-tunnel comparisons of corrected results, and flow conditions with and without separation. Author

N89-16865# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle Stroemungsmechanik.
PHYSICAL ASPECTS OF VISCOUS SIMULATION AND ASSOCIATED RESEARCH REQUIREMENTS Summary Report
E. STANEWSKY *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Boundary layer development and transition; nonequilibrium boundary layers; shock boundary layer interaction; classical separation, trailing edge flow and buffet; vortex flows; environmental effects on the boundary layer development and transition; and boundary layer manipulation are examined. Some selected results are presented and summarized with respect to the dominant viscous and outer inviscid flow parameters and most urgently needed research. B.G.

N89-16867# Case Western Reserve Univ., Cleveland, OH.
A PROPOSED BOUNDARY LAYER SIMULATION METHODOLOGY FOR WIND TUNNEL TESTING
ELI RESHOTKO, C. ARMAND, Y. Y. CHAN, A. ELSENAAR, A. B. HAINES, J. L. POTTER, and GIUSEPPE P. RUSSO *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 12 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

While wind tunnels were used for about a century to obtain performance data for vehicles to be used in atmospheric flight, these are still numerous uncertainties and ambiguities in the interpretation of the data and in reliably extrapolating them to flight conditions. These issues were recently addressed. The development of a boundary layer simulation/extrapolation methodology is examined. Author

N89-16870# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).
ACCURACY REQUIREMENTS FOR HIGH-SPEED TEST WITH ENGINE SIMULATION ON TRANSPORT AIRCRAFT MODELS IN THE NLR-HST
W. BURGSMUELLER, J. W. KOOI, and K. MOELLER, W. (National Aerospace Lab., Amsterdam, Netherlands.) *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 16 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Air-driven turbine-powered simulators, so-called TPS units, are being used in wind tunnel testing to simulate the engine flow for an aircraft model. These simulators provide substantial improvement in testing as compared to simple through-flow nacelles used earlier. In order to fully explore the improvement potential in aerodynamic simulation it is mandatory to assure a high level of accuracy or in case of increment testing a good repeatability because the effects of engine interference drag are of the order of a few counts. For increment testing a repeatability of at least + or - 1 drag count must be achieved. The efforts made to demonstrate that this repeatability can be achieved in the NLR high speed wind tunnel (HST) for a half model with a wing-mounted TPS engine are described. The test was performed in a joint program of NLR and MBB-UT, where MBB delivered the model and TPS unit with engine cowlings, while NLR was responsible for engine calibration, wind tunnel instrumentation, and the test. To obtain the desired quality of the final test results the investigation was subdivided into several steps. These steps and the technical problems and questions encountered will be described in detail.
Author

N89-16871# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.).
ENGINE SIMULATOR TESTS: COMPARISON OF CALIBRATION AND WIND TUNNEL RESULTS
W. BAUMERT, B. BINDER, and W. STAEGER *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 11 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

A turbine powered simulator (TPS) was tested with a bellmouth inlet in the calibration tank and with a flight inlet in the low speed wind tunnel at DFVLR Gottingen. Local Mach number distribution shows good agreement in both facilities. The Pitot pressure distribution behind the fan however is different. This is probably due to the different inlet configurations. The nozzle coefficients obtained in the calibration tank are used to calculate the thrust of the simulator in the wind tunnel. The comparison with the thrust measured in the wind tunnel shows that additional corrections have to be applied when evaluating wind tunnel measurements with TPS. Author

N89-16872# Office National d'Etudes et de Recherches Aerospatiales, Modane (France).
INSTANTANEOUS FORCE MEASUREMENT ON A MODEL SUBJECTED TO RAPID CONTROL VARIATIONS
J. P. DREVER and M. ROBERT *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 20 p (SEE N89-16846 09-09) Jul. 1988 In FRENCH; ENGLISH summary Original language document was announced in IAA as A88-22599
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The development of a wind-tunnel model using a lateral-jet system to enact rapid control variations is discussed, and the results of instantaneous force measurements obtained with the model without wind in the supersonic test section of the ONERA S2MA facility are reported. The range of frequencies to be avoided in controlling the generator are identified, and a mathematical model for calculating the model motion is developed. Torsion applied to the model is measured with a precision of + or - 5 percent in roll and + or - 10 percent in pitch and yaw over a range of frequencies from 0 to 60 Hz. Good correlation is found between the applied and measured forces. Author

N89-16873# Technische Univ., Darmstadt (Germany, F.R.).
BALANCE ACCURACY AND REPEATABILITY AS A LIMITING PARAMETER IN AIRCRAFT DEVELOPMENT FORCE MEASUREMENTS IN CONVENTIONAL AND CRYOGENIC WIND TUNNELS
B. EWALD *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 12 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The success of a commercial transport development is heavily influenced by the accuracy of drag measurements during the aerodynamic development in the wind tunnel. It is shown, that the internal balance in one limiting factor of accuracy. The accuracy standard of modern internal balances is compared to the accuracy and repeatability requirement of the aerodynamicist. The comparison with high precision single component load cells promises a large improvement potential in multi-component balance design and calibration. The following fields of improvement are discussed: balance design, balance material selection and treatment, calibration methods, calibration software, and thermal effects. Perfect correction of the thermal effects is the key to the successful use of cryogenic tunnels. An approach for the crucial problem of balance body distortion due to temperature gradients is demonstrated. Author

N89-16874# Arnold Engineering Development Center, Arnold Air Force Station, TN.
CHARACTERIZATION OF HYPERSONIC WIND TUNNEL FLOW FIELDS FOR IMPROVED DATA ACCURACY
ALBERT H. BOUDREAU *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 9 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Hypersonic test facilities produce flow fields which are difficult to characterize. In the past, many hypersonic facilities were reputed to produce test data of inferior quality, when, in fact, it was poor characterization of the flow field principally at fault. With the renaissance in hypersonics at hand, experimentalists face anew the challenge of accurately characterizing flow fields. The U.S. Air Force's Arnold Engineering Development Center has faced these complex problems and developed techniques to accurately determine free-stream conditions. Those tools of characterization are highlighted and a standard by which all hypersonic wind tunnels should be compared. Author

N89-16877# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).
ACCURACY PROBLEMS IN WIND TUNNELS DURING TRANSPORT AIRCRAFT DEVELOPMENT
GUENTER KRENZ *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 9 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

Wind tunnel test data accuracy requirements for transport aircraft are derived. Airline performance guarantees, model and tunnel test techniques available and the quality of prediction methods used form the concept for wind tunnel test programs and set accuracy requirements for test data. Procedures which were followed in high speed cruise and low speed takeoff and landing are described. The accuracy of the wind tunnel tests is limited by several parameters, the most important being flow quality, model and model suspension quality, and balance accuracy. Problems which occurred during the test with small models in the transonic regime led to the concepts presented: the use of large models on a specific suspension with a range-limited balance and the improvement of small model test techniques in connection with the requirements for measurements in cryogenic facilities. Low speed tests are ambitious and extensive due to the many configurations at takeoff and landing. Furthermore, the work is complicated by the many details like closing plates and shutters, which can have a strong effect on the performance data. Some examples are presented. Author

N89-16878# National Aerospace Lab., Amsterdam (Netherlands).
REQUIREMENTS AND CAPABILITIES IN UNSTEADY WINDTUNNEL TESTING
R. D. DENBOER, R. HOUWINK, and R. J. ZWAAN *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 18 p (SEE N89-16846 09-09) Jul. 1988
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

The accuracy required for aeroelastic applications concerning full-scale aircraft is discussed, after which the accuracy in current unsteady wind tunnel testing is considered. Author

N89-16879# Institut de Mecanique des Fluides de Lille (France).
PARTICULAR FLIGHT MECHANICS SPECIFICATIONS RELATED TO WIND TUNNEL TEST RESULTS [SPECIFICATIONS PARTICULIERES CONCERNANT LES RESULTATS DES ESSAIS EN SOUFFLERIE POUR LA MECANIQUE DU VOL]
MARC PIANKO *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 19 p (SEE N89-16846 09-09) Jul. 1988 In FRENCH
Original language document was announced in IAA as A88-28859
(AGARD-CP-429) Avail: NTIS HC A22/MF A01

A flight mechanics analysis of requirements and recommendations for the quality and precision of wind tunnel measurements is presented. The effect of imprecision in modeling flight behavior is examined in order to determine the sensitivity of the individual aerodynamic coefficients. Problems in the characterization of flight at large angles of incidence and sideslip, where unsteady phenomena and perturbations play a large role, are considered. Difficulties in the use of the wind tunnel for aircraft design are also reviewed. Author

N89-16880*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
WIND TUNNEL REQUIREMENTS FOR COMPUTATIONAL FLUID DYNAMICS CODE VERIFICATION
JOSEPH G. MARVIN *In* AGARD, Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing 13 p (SEE N89-16846 09-09) Jul. 1988 Previously announced as N87-27150
(AGARD-CP-429) Avail: NTIS HC A22/MF A01 CSCL 14B

The role of experiment in the development of computational fluid dynamics (CFD), as an aerodynamic flow field prediction is discussed. Requirements for verification from two sources that pace the development of CFD are described for: (1) development of adequate flow modeling, and (2) establishment of confidence in the use of CFD to predict complex flows. The types of data needed and their accuracy differs in detail and scope and leads to definite wind tunnel requirements. Examples of testing to assess and develop turbulence models, and to verify code development, are used to establish future wind tunnel testing requirements. Versatility, appropriate scale and speed range, accessibility for nonintrusive instrumentation, computerized data systems, and dedicated use for verification were among the more important requirements identified. Author

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GROUND SUPPORT SYSTEMS AND FACILITIES (SPACE)

Includes launch complexes, research and production facilities; ground support equipment, e.g., mobile transporters; and simulators.

N87-24489# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
ROCKET ALTITUDE TEST FACILITIES REGISTER
P. DUCASSE Mar. 1987 84 p
(AGARD-AG-297; AGARDOGRAPH-297; ISBN-92-835-0404-6; AD-A181679) Avail: NTIS HC A05/MF A01

In 1982, the Propulsion and Energetics Panel Working Group 17 endeavored to investigate test techniques applied to solid rocket motors with metallized propellants. It was stated that there is a large number of related test facilities in existence with a large variety of technologies applied and test possibilities offered. It was decided to compile a register showing the major altitude test facilities with their characteristic data. Emphasis was put on facilities capable of performing research and development tests. Author

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LAUNCH VEHICLES AND SPACE VEHICLES

Includes boosters; operating problems of launch/space vehicle systems, and reusable vehicles.

N87-16000# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
GUIDANCE, CONTROL AND POSITIONING OF FUTURE PRECISION GUIDED STAND-OFF WEAPONS SYSTEMS
Jun. 1986 263 p In ENGLISH and FRENCH Symposium held in Ottawa, Ontario, 8-11 Oct. 1985
(AGARD-CP-388; ISBN-92-835-0390-2; AD-A173353) Avail: NTIS HC A12/MF A01

Topics addressed include: tactical operational requirements; weapon systems concepts; design criteria and integration issues; tactical mission planning and management, communication; sensor aspects for guidance and control, position, and navigation; computational techniques and data processing; and system demonstrations. For individual titles see N87-16001 through N87-16011.

N87-16003# Singer Co., Wayne, NJ. Kearfott Div.
DESIGN/DEVELOPMENT TRADEOFFS TO ACHIEVE A MISSION EFFECTIVE SOW GUIDANCE SYSTEM
ALBERT J. SHAPIRO *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems (date) 14 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

The increasing role of Precision Guided Standoff Weapons (PGSOW) places special requirements on the navigation systems conventionally provided to this class of vehicles. The standoff mission requires innovative system concepts altogether different from the conventional system configurations that have become almost a standard approach to fighter and bomber navigation systems. This need for innovation is even more necessary if the SOW navigation system is to be affordable and mission effective in the context of these small relatively low cost vehicles. The navigation requirements are developed and reviewed. A trade-off of the alternatives as a function of guidance effectiveness are identified and performed. From the spectrum of navigation system alternatives, the specifics of a multiple sensor self-contined system is developed showing the benefits to be derived by optimum integration of low cost sensors. The key elements of this integrated multiple sensor navigation system are described. Author

N87-16005# System Dynamics, Inc., Gainesville, FL.
MIDCOURSE GUIDANCE FOR THE US ARMY'S LOW COST FIBER OPTIC GUIDED MISSILE
WILLIAM BOYKIN and PAUL JACOBS (Army Missile Lab., Redstone Arsenal, Ala.) *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 17 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

A method for achieving midcourse guidance using a digital correlator and known white rocks, or positions of objects that appear in the seeker video is analyzed. A variety of filtering techniques and filter mechanizations are analyzed and the results presented. Algorithms are developed which use updates from the ensemble of white rocks or waypoints to correct the missile attitude at each waypoint and predict time or range to go to the target area. Models for the system dynamics and the measurement process were formulated and six extended Kalman filter designs were developed and tested for state estimation accuracy and efficiency. Work was also performed to improve the efficiencies of the algorithms so that the estimates are available in a timely manner for midcourse navigation and to aid the operator. B.G.

N87-16007# Laboratoire de Recherches Balistiques et Aerodynamiques, Vernon (France).
COLLISION PROBABILITY OF CRUISE MISSILES FLYING IN FORMATION [PROBABILITE DE COLLISION DE MISSILES DE CROISIERE VOLANT EN FORMATION]
MICHEL FERRAND and PHILIPPE RIOT *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 8 p (SEE N87-16000 08-15) Oct. 1985 In FRENCH
(AGARD-CP-388) Avail: NTIS HC A01/MF A01

A collision rule for Cruise missiles flying in formation at the same altitude is established mathematically. The mean rate of loss for a multi-missile mission with a trajectory including several segments is then determined. The presentation concludes with a numerical application. B.G.

N87-16008# Societe Nationale Industrielle Aerospatiale, Paris (France). Div. Engins Tactiques.
STRAPDOWN INERTIAL SYSTEMS APPLICATIONS FOR TACTICAL MISSILES (STAND-OFF MISSILES)
PUECH *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 16 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

Strapdown Inertial Systems (SDIS) are particularly well suited for tactical standoff missile applications. This certainty was made clear by several years of theoretical design work and trials. Initial theoretical work made wide use of parameters giving detailed definition of missile trajectories and motions as obtained from measurements made on weapon systems then in development or production. Sensors (principally gyroscopes) were laboratory tested. These preliminary design efforts led to selection of various technologies such as the laser gyro and the mechanical gyro, each being adapted to the weapon system in question. Share-out of functions between various equipment items was defined. Comparison of the advantages and disadvantages of these technologies shows that today the laser gyro is principally retained for high and medium range levels of precision, with the mechanical (spin-stabilized) gyro serving in the medium and low precision range. Since requirements are ever increasing in the fields of dynamic performance and robustness, it is here that most progress is expected. Author

N87-16010# Rockwell International Corp., Duluth, GA. Missile Systems Div.
PRECISION DELIVERY OF UNGUIDED SUBMUNITIONS FROM A TACTICAL STANDOFF MISSILE
R. D. EHRICH and J. R. BEATY *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems) 17 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

The extension of a low cost tactical weapon to missions involving area targets requires the accurate dispensing of unguided submunitions. For a terminally guided weapon, proportional navigation can no longer be used, since it cannot compensate for the ballistics of the submunition. A terminal guidance algorithm

was developed to control the weapon trajectory between the midcourse flight path and the point of dispense. The algorithm incorporates submunition drag characteristics to assure high accuracy. The algorithm also assures adequate arming time for the submunitions and adequate time for the pattern to develop. The second element of accurate submunition delivery is the dispensing or expulsion mechanism, which ejects the payload out of the canister. The ejection mechanism must provide the desired pattern size, shape, and density. Air bag technology is employed to assure satisfactory ejection forces with adequate repeatability. The current study is theoretical in nature, relying on digital simulation to substantiate conclusions on patterns and accuracy. Author

N87-29482# Rheinmetall G.m.b.H. Duesseldorf (Germany, F.R.). Guided Munition Dept.

JET REACTION CONTROL SYSTEM FOR AUTONOMOUS PRECISION MUNITION

H. PELLER and S. BUECHELE-BUECHER *In* AGARD, Advances in Guidance and Control Systems and Technology 18 p (SEE N87-29474 24-04) Jul. 1987 Original contains color illustrations

(AGARD-CP-411) Avail: NTIS HC A07/MF A01

The essential differences between missile and projectile application which are very important for actuations system designs are featured. A short trade study compares two methods of steering missiles and projectiles using aerodynamic or impulsive control, where the last mentioned one will be presented more exactly. The described hot gas reaction jet control actuation block is mounted in a submunition called EPHRAM which stands for terminal guided artillery munition. In this actuation system the gases produced by a gas generator are controlled by four individual thrusters. All these important and necessary components of a jet reaction control are explained and demonstrated by photographs and figures. Results of computer computation and simulation will finally verify that jet reaction control is the ideal application for such a cannon-launched guided projectile. Author

N87-29483# Naval Surface Weapons Center, Dahlgren, VA. Weapons Systems Dept.

APPLICATION OF OPTIMAL ESTIMATION AND CONTROL CONCEPTS TO A BANK-TO-TURN MISSILE

E. J. OHLMEYER *In* AGARD, Advances in Guidance and Control Systems and Technology 12 p (SEE N87-29474 24-04) Jul. 1987

(AGARD-CP-411) Avail: NTIS HC A07/MF A01

The design and evaluation of optimal estimators and optimal control laws for application to bank-to-turn missiles was addressed. Two guidance laws, one based on modern control theory and the other on an augmented form of proportional navigation, were compared to the classical implementation of proportional navigation. The former two control laws require the use of a state estimator. An extended Kalman filter was devised for that purpose. Performance of the three guidance laws was compared on the basis of average miss distance achieved for a number of engagement scenarios. Author

N88-19553# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

ADVANCES IN AIR-LAUNCHED WEAPON GUIDANCE AND CONTROL

Dec. 1987 118 p In ENGLISH and FRENCH Symposium held in Athens, Greece, 5-8 May 1987

(AGARD-CP-431; ISBN-92-835-0439-9; AD-A194648) Avail: NTIS HC A06/MF A01

Air to air and air to surface missile systems are discussed with an emphasis upon guidance and control technology advances and guidance impacts from other areas. For individual titles, see N88-19554 through N88-19562.

N88-19554# British Aerospace Public Ltd. Co., Stevenage (England). Precision Products Group.

A PROTOTYPE FIBRE OPTIC GYROSCOPE FOR MISSILE GUIDANCE APPLICATIONS

C. J. KAY *In* AGARD. Advances in Air-Launched Weapon Guidance and Control 13 p (SEE N88-19553 12-15) Dec. 1987 (AGARD-CP-431) Avail: NTIS HC A06/MF A01

The design of a prototype fiber optic gyro intended for missile guidance operations is discussed. Important design constraints for the next generation of missiles are wide dynamic range, rapid switch-on, extreme ruggedness, low cost, and digital operation. These features are all embodied in the design described, which employs optical phase modulation in an integrated optical waveguide device. A Y-branch beam splitter is also incorporated into the design. Serrodyne phase ramps are impressed on the light propagating around the fiber optic sensor coil connected to the integrated optics chip. Rotation rate is measured by the serrodyne frequency needed to null the rotation induced Sagnac phase shift. The gyro performance (drift and random walk) and errors up to 1000 degrees per second are presented. Author

N88-19555# Defence Research Establishment Valcartier (Quebec).

AN INVESTIGATION OF STEEP DESCENT GUIDANCE FOR TERMINALLY-GUIDED SUB-MUNITIONS

G. TROTTIER *In* AGARD. Advances in Air-Launched Weapon Guidance and Control 16 p (SEE N88-19553 12-15) Dec. 1987 (AGARD-CP-431) Avail: NTIS HC A06/MF A01

The lateral acceleration requirement of a hit-to-kill terminally-guided sub-munition (TGSM) aimed at hitting tanks near the top is examined. An analytic development of proportional navigation against stationary targets shows that a TGSM flying level at 150 m above the ground can hit a target 150 m in front of it with near vertical impact and without acceleration saturation if it can pull an initial 13.6 g. With acceleration saturation, a hit is theoretically possible with 6.8 g. TGSM configurations capable of hitting stationary and moving targets are then defined and tested with a nonlinear 6-DOF computer simulation. The footprint of a selected configuration is selected to hit most stationary and moving tanks likely to be found on the battlefield with impact angles above 60 degrees and reasonable angles of attack. Author

N88-19556# Naval Weapons Center, China Lake, CA. Research Dept.

EFFECTS OF CLOSING SPEED UNCERTAINTY ON OPTIMAL GUIDANCE

W. W. WILLMAN *In* AGARD. Advances in Air-Launched Weapon Guidance and Control 8 p (SEE N88-19553 12-15) Dec. 1987 (AGARD-CP-431) Avail: NTIS HC A06/MF A01

An idealized planar intercept is analyzed in which an air-to-air homing missile has singular measurements of the line of sight to a randomly maneuvering target and seeks to use a guidance law which optimizes a specific performance criteria. If the closing speed were known precisely, the optimal guidance law for this case would be proportional navigation with a certain navigation gain. There is uncertainty in the closing speed because of the target maneuvers and lack of range measurements. The effect of this uncertainty on the optimal guidance law is to increase the nominal value of the navigation gain and to add a rapid weaving component if the fractional uncertainty in the inverse target range exceeds a certain level. Author

N88-19557# Avions Marcel Dassault, Saint-Cloud (France).

GUIDANCE AND CONTROL OF AIR-LAUNCHED ARMAMENTS: AN AEROENGINEER'S PERSPECTIVE [GUIDAGE ET PILOTAGE DES ARMEMENTS TIRES D'AVION: POINT DE VUE DE L'AVIONNEUR]

P. PAGNIEZ and F. CHIVOT *In* AGARD. Advances in Air-Launched Weapon Guidance and Control 6 p (SEE N88-19553 12-15) Dec. 1987 In FRENCH

(AGARD-CP-431) Avail: NTIS HC A06/MF A01

Aircraft armament engineers conceive and develop products of higher and higher sophistication. However, obtaining a total operational manner which results in the optimal performance of these arms is a consequence of the homogeneity of the aircraft-aircrew-weapons association. The engineer is faced with the task of solving an increasing number of problems whose severity increases with weapon sophistication. The aeroengineer

must therefore make increasingly complex decisions regarding the compromise among weapon requirements, aircraft vulnerability, and crew workloads. The various constraints relating to the design and development of air/air missiles with passive, active and semi-active homing are examined along with specific design considerations for air/sea and air/ground missiles. Author

N88-19560# Standard Elektrik Lorenz A.G., Stuttgart (Germany, F.R.).
A FIBER OPTIC GYRO STRAPDOWN REFERENCE SYSTEM FOR GUIDED WEAPONS
D. RAHLFS, W. AUCH, O. GLASER, and D. RUPPERT *In* AGARD, Advances in Air-Launched Weapon Guidance and Control 11 p (SEE N88-19553 12-15) Dec. 1987
(AGARD-CP-431) Avail: NTIS HC A06/MF A01

Simulations based on the error behavior of the phase modulated fiber optic gyro have shown that this kind of rate sensor is becoming a serious competitor in the field of strapdown system sensors. Potential applications include missile attitude reference systems and high quality line-of-sight stabilization systems for high dynamic environments. These features encourage the development of integrated concepts where attitude reference system and line-of-sight stabilization system are merged into one simple strapdown sensing and controlling unit. Author

N88-19561# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Unternehmensbereich Apparate.
SPEED CONTROL OF A MISSILE WITH THROTTLEABLE DUCTED ROCKET PROPULSION
DIETER THOMAIER *In* AGARD, Advances in Air-Launched Weapon Guidance and Control 15 p (SEE N88-19553 12-15) Dec. 1987
(AGARD-CP-431) Avail: NTIS HC A06/MF A01

The Mach number controller computes the suitable nominal value for gas generator pressure while accounting for the pertinent gas generator dynamics. This procedure requires the knowledge of the pressure sensitive burning rate with adequate narrow tolerance limits. In the case of high-g flight maneuvers, the system can optionally switch over to a simple command for the pressure nominal value. An adaptive controller is nested within the Mach number loop to keep the gas generator pressure in closed loop control. Thus, an open loop control of the mass flow rate is provided. This loop is controlled by the flight Mach number loop, its value being derived from flight data. The installation of prototype engines on test stands in a hardware-in-the-loop configuration and the required additional simulation procedure is described. Test results are given. Author

N88-19562# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
THE USE OF HARDWARE-IN-THE-LOOP-TECHNIQUES IN THE DEVELOPMENT OF A MODERN AIR-TO-SURFACE MISSILE SYSTEM
THOMAS KUESTNER *In* AGARD, Advances in Air-Launched Weapon Guidance and Control 6 p (SEE N88-19553 12-15) Dec. 1987
(AGARD-CP-431) Avail: NTIS HC A06/MF A01

Because of their increasing requirements, modern guided missiles have a very high degree of complexity. To improve cost effectiveness and reduce risk and uncertainty, new test concepts are necessary. Realtime simulations like Software-in-the Loop (SIL) and Hardware-in-the-Loop (HIL) represent such new concepts. This means closed loop simulation with actual missile components in a laboratory environment where the physical environment is simulated and controlled by special computer equipment. After a definition of SIL/HIL simulation, the configuration of such test equipment is presented. Author

N89-17605# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
GUIDANCE AND CONTROL OF PRECISION GUIDED WEAPONS
Nov. 1988 81 p In ENGLISH and FRENCH Symposium held in Geilo, Norway, 3-6 May 1988
(AGARD-CP-435; ISBN-92-835-0486-0; AD-A203595) Avail: NTIS HC A05/MF A01

Topics relative to the guidance and control of guided missiles are discussed. Operational requirements and considerations; guidance sensors and components; guidance and control techniques and signal processing; system effectiveness and evaluation; and systems demonstration are among the topics considered. For individual titles, see N89-17606 through N89-17611.

N89-17607# Societe Francaise d'Equipments pour la Navigation Aerienne, Chatellerault (France).
AQM: ACCELEROMETER FOR PRECISION-GUIDED WEAPONS [LAQM: ACCELEROMETRE POUR MUNITIONS DE PRECISION]
A. BOURA, O. AUJAY, and J. L. BOST *In* AGARD, Guidance and Control of Precision Guided Weapons 8 p (SEE N89-17605 10-15) Nov. 1988 In FRENCH
(AGARD-CP-435) Avail: NTIS HC A05/MF A01

Pendular, monolithic accelerometer structures with surface areas of a few millimeters have been designed, fabricated and tested. The results support the possibility of applying this technology to homing weapons and projectile drift correction. Around these small monolithic structures it is possible to construct accelerometers which occupy a volume of between 1 and 4 cu cm. Certain prototypes have shown resistance to shocks up to 20,000 G, while others exhibit a static measuring range greater than 100 G. Recent experimental results and the extrapolations that can be deduced with regard to usable sensors for precision-guided weapons are discussed. Author

N89-17609# Prins Maurits Lab. TNO, Rijswijk (Netherlands).
DEMONSTRATION OF FOG-M (FIBRE OPTIC GUIDED MISSILE) CAPABILITIES BY MEANS OF SIMULATION AND EFFECTS OF PROPRIOCEPTIVE FEEDBACK ON THE CONTROL
B. J. DAMEN, R. N. H. W. VANGENT, and H. SCHUFFEL (Institute for Perception RVO-TNO, Soesterberg, Netherlands) *In* AGARD, Guidance and Control of Precision Guided Weapons 16 p (SEE N89-17605 10-15) Nov. 1988
(AGARD-CP-435) Avail: NTIS HC A05/MF A01

A simulated scenario with the Fiber Optic Guided Missile (FOG-M) with the aid of a 6 degree of freedom simulation model for investigating maneuverability and footprint areas against stationary and moving ground targets is described. The performance against moving helicopters is discussed. A simulator built for research on the FOG-M system, including man-in-the-loop control, is described. Demonstration studies indicated some problem areas, such as the manual control characteristics. A study was started concerning which type of joystick system would enhance the performance of persons with minimal experience. It was shown that providing the operator with proprioceptive feedback on the maneuverability would enhance control performance. Author

N89-17610# Norwegian Defence Research Establishment, Kjeller.
APPLICATIONS OF IMAGE ANALYSIS IN PRECISION GUIDED WEAPONS
S. GRINAKER *In* AGARD, Guidance and Control of Precision Guided Weapons 17 p (SEE N89-17605 10-15) Nov. 1988
(AGARD-CP-435) Avail: NTIS HC A05/MF A01

An autonomous fire and forget weapon will have to automatically navigate from the launch site to the target area, detect and recognize the target, home on to it, and select an aim-point in the terminal phase. All of these tasks can be performed by using an imaging seeker-head. Image based target acquisition and tracking are well established ideas and implemented in weapons in operation or under development. A brief survey of the involved image processing techniques are provided, including a few examples of state-of-the-art algorithms. The basic ideas of image based navigation and aim-point selection are introduced and

accompanied by examples, and the possibility of replacing the gyro stabilization by image processing is discussed. Finally, the problems concerning the implementation of image analysis for real time processing are addressed, and some principles for system design are provided. Author

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SPACE TRANSPORTATION

Includes passenger and cargo space transportation, e.g., shuttle operations; and space rescue techniques.

N87-20369# British Aerospace Public Ltd. Co., Stevenage (England). Space and Communications Div.
INFLUENCE CO-EFFICIENT TESTING AS A SUBSTITUTE FOR MODAL SURVEY TESTING OF LARGE SPACE STRUCTURES
T. F. KEATES *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

The American Space Transportation System is capable of placing large payload into low earth orbit. Since the presence of the payload has a significant effect on the behavior of the Shuttle under the low frequency and transient loading during launch and return, a flight loads analysis is performed using a mathematical model of the payload coupled to that of the Shuttle. The process of clearing a payload for launch involves performing this coupled analysis with a validated mathematical model of the payload. This validation usually includes modal survey testing on a structurally representative model which may also be used for static load testing. The advantages and disadvantages of modal survey testing (either fixed base or free/free) and of Static Influence Co-efficient (Flexibility) Testing are discussed. It is concluded that for parts of certain types of payload the latter is a cheaper and sufficient alternative to modal survey testing. Author

N87-20370# National Aeronautical Establishment, Ottawa (Ontario).
USE OF A VIDEO-PHOTOGRAMMETRY SYSTEM FOR THE MEASUREMENT OF THE DYNAMIC RESPONSE OF THE SHUTTLE REMOTE MANIPULATOR ARM
G. L. BASSO and R. B. KULCHYSKI *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 12 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

A video-photogrammetry system was used to obtain the dynamic response of the Canadian developed, space transportation system remote manipulator arm from video tape recordings of two space based test events - specifically, an auto-trajectory and a backup mode test sequence. The application of this system to this task represented a non-generic use in that no pre-launch preparations were made for implementing this technique. The procedures used to extract the response information from the video tapes are outlined. The stated resolution of the video-photogrammetry system is 1 part in 5000 (1 sigma) - typically, 0.03mm for a 12.5mm image plane size. Within this capability, the amplitude of the response for the auto-trajectory sequence was obtained with an estimated resolution of 1mm with a camera-to-object spacing of 2.18m, and for the backup mode, 3mm at a spacing of 13.78m. In both instances, dynamic parameters such as frequency and damping were readily derived from the response measurements. Author

N87-26962# Air Force Geophysics Lab., Hanscom AFB, MA
POLAR-AURORAL CHARGING OF THE SPACE SHUTTLE AND EVA ASTRONAUT
WILLIAM N. HALL, PHILIP LEUNG, IRA KATZ, GARY A. JONGEWARD, JOHN R. LILLEY, JR., JOSEPH E. NANEVICZ, JEFFREY S. THAYER, and N. JOHN STEVENS (TRW, Inc., Redondo Beach, Calif.) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 9 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

The evidence indicates that an astronaut carrying out extra-vehicular activity (EVA) in the Shuttle wake in polar orbit could have his EVA equipment charge up to significant voltages if an intense aurora is encountered. Arc discharges are expected to occur that are similar to those that have caused system upsets and failures in geosynchronous orbits. The possibility of hazard to the astronauts must be evaluated quickly, since polar orbit Shuttle launches will soon begin. Author

18

SPACECRAFT DESIGN, TESTING AND PERFORMANCE

Includes satellites; space platforms; space stations; spacecraft systems and components such as thermal and environmental controls; and attitude controls

N87-20355# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
MECHANICAL QUALIFICATION OF LARGE FLEXIBLE SPACECRAFT STRUCTURES
Jul. 1986 269 p In ENGLISH and FRENCH Meeting held in Oberammergau, West Germany, 9-13 Sep. 1985
(AD-A175529; AGARD-CP-397; ISBN-92-835-0396-1) Avail: NTIS HC A12/MF A01

An account is given of Conference Proceedings of a Specialists' Meeting held by the Structures and Materials Panel in Oberammergau in the Fall of 1985. The problems associated with the mechanical qualification of flexible spacecraft are discussed, and details of relevant methods and techniques are given. The final discussion highlights the difficulties associated with advanced methods of experimental and theoretical dynamic analysis and the handling of larger and larger amounts of data. For individual titles see N87-20356 through N87-20374.

N87-20356*# National Aeronautics and Space Administration, Washington, DC. Materials and Structures Div.
FUTURE TRENDS IN SPACECRAFT DESIGN AND QUALIFICATION
SAMUEL L. VENNERI, BRANTLEY R. HANKS (National Aeronautics and Space Administration, Langley Research Center, Hampton, Va.), and LARRY D. PINSON *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01 CSCL 22A

Material and structures issues that must be resolved in order to develop the technology data base needed to design and qualify the next generation of large flexible spacecraft are discussed. This invoves the development of new ground test and analysis methods and the conduct of appropriate instrumented in-space flight experiments for final verification. A review of present understanding of material behavior in the space environment and identification of future needs is presented. The dynamic verification and subsequent qualification of a spacecraft structure currently rely heavily on ground-based tests, coupled with the verified analysis model. Future space structures, such as large antennas, Space Station and other large platforms, will be of sizes difficult to test using current ground test methods. In addition to size, other complex factors, such as low natural frequencies, lightweight construction and many structural joints, will also contribute significant problems to the test and qualification process in an Earth-gravity environment. These large spacecraft will also require

new technology for controlling the configuration and dynamic deformations of the structures. Future trend in large flexible structures will also involve long-life design missions (10 to 20 years). In low earth orbit (LEO), materials will be subjected to repeated thermal cycles, ultraviolet radiation, atomic oxygen and vacuum. For high orbits such as geo-synchronous earth orbit (GEO), the materials will also be subjected to large doses of high energy electrons and protons. Understanding degradation and material stability over long-mission time periods will confront the designer with many issues that are unresolved today.

N87-20357# Messerschmitt-Boelkow-Blohm/Entwicklungspring Nord, Bremen (Germany, F.R.).
RECENT DEVELOPMENTS AND FUTURE TRENDS IN STRUCTURAL DYNAMIC DESIGN VERIFICATION AND QUALIFICATION OF LARGE FLEXIBLE SPACECRAFT
E. HORNUNG, E. BREITBACH (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany.), and H. OERY (Technische Univ., Aachen, West Germany.) *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 43 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

A comprehensive dynamic verification concept is proposed, focusing on a multi-axis transient qualification test to be performed on the primary structure or on modular segments of it, respectively. First, practical experiences and development areas identified are addressed. Former existing barriers preventing the practical performance of this verification concepts are no longer relevant because of the extended analytical capabilities due to the positive developments in computer techniques and software and because of the availability of large multi-axis vibration simulators. A vital prerequisite for the applicability of this verification concept is the ability for analytical flightload identification and identification of the true dynamic characteristics on a high quality and reliability level. For this a comparative discussion is presented about the suitability of analytical methods for flightload predictions (shock spectra versus transient methods). The state of the art of design identification tests and of updating methods on mathematical models is summarized and discussed with respect to necessary development areas and the implementation into the proposed structure verification concept. First experience with this new *verification cycle was made on a real satellite structure. The results* and open development areas identified are discussed. Author

N87-20358# Societe Nationale Industrielle Aerospatiale, Cannes (France).
DYNAMIC MODELING AND OPTIMAL CONTROL DESIGN FOR LARGE FLEXIBLE SPACE STRUCTURES
L. PASSERON, CH. GARNIER, and B. SEVENNEC *In* AGARD *Mechanical Qualification of Large Flexible Spacecraft Structures* 14 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

Some advanced results in dynamic modeling and control areas are unifyingly reviewed. Dynamic modeling for complex assemblies of interconnected, rigid or flexible bodies subject to wide relative motions is achieved through a Lagrangian formulation using quasi-coordinates. Lagrange multipliers are explicitly eliminated by way of singular value decomposition resulting in a minimized set of equations. An original software program using element shape functions interfaces the dynamic model with NASTRAN-performed individual substructure analyses. Section 3 summarizes the now classical results in optimal control, while section 4 gives a comprehensive coverage of robustness aspects. Last section is devoted to model order reduction. The Internal Balancing Approach is generalized to systems with rigid body modes. Moreover, an error bound between full order and reduced order transfer function is evidenced, which bridges truncation and robustness. Author

N87-20360# Societe Nationale Industrielle Aerospatiale, Cannes (France)
DYNAMIC ANALYSIS OF DIRECT TELEVISION SATELLITE TV-SAT/TDF.1
Y. PLUMAT *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 8 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

An application of the methods of analysis for the structural behavior of spacecraft whose bottom is affected by a vibrational environment is discussed. The application concerns the Direct Broadcast satellites TV-SAT and TDF.1, for which sine vibration qualification and acceptance are achieved through combination of the theoritical analysis (finite element method and frequential response) and of the experimental (sine vibrations test) verification of some subsystems and system assembles. This procedure requires highly detailed mathematical models, which are validated by way of in depth correlation between the test predictions and test dynamic results. TV-SAT and TDF.1 satellites are a specially worthwhile illustration for the said type of studies as they are a pair of large, wholly European built spacecrafts whose structures *are made up of several major subassemblies, namely: main body,* propellant tanks. Antenna module complete with reflectors, solar array. Author

N87-20361*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STRUCTURAL QUALIFICATION OF LARGE SPACECRAFT
BEN K. WADA *In* AGARD Mechanical Qualification of Large *Flexible Spacecraft Structures* 19 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01 CSCL 22A

Over the past twenty-five (25) years of the space program, the major challenge in the structural qualification of the primary structure has shifted from conducting a test that simulated the environment to accurately predicting the structural member loads in flight. Once the flight loads are available, a number of different test methods are used to qualify the structure by subjecting it to the proper loads. The qualification challenge for future large spacecraft will be to adequately predict its dynamic characteristic in space to assure that it can be controlled to meet the mission objectives. A new test concept that may allow acquisition of modal data by ground tests for verification of mathematical models of large flexible space structures which can't be ground tested by conventional methods is discussed. Author

N87-20362# Rome Univ. (Italy). Dipt. Aerospaziale
EFFECT OF MODAL DAMPING IN MODAL SYNTHESIS OF SPACECRAFT STRUCTURES
LUIGI PALIS CREMA and ANTONIO CASTELLANI *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 11 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

In the modal synthesis of a large space structure, by a substructuring approach, a focal point is in the evaluation of the modal characteristics of the single components. As a matter of fact it is required to get the non-diagonal terms of the damping substructure matrix to acquire an efficient estimate of the damping characteristics of the whole structure. In this work it has been considered important to understand and to predict the physical *causes of complex modes also in an elementary substructure* as a sandwich carbon fiber plate. The results of the experimental work indicate that the modal analysis has to be gained in a very tight frequency range, with many averaged data, and the possibility of complex modes is increasing with the increase of the mode order. Author

N87-20363# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. of Aeroelasticity.
DYNAMIC QUALIFICATION OF SPACECRAFT BY MEANS OF MODAL SYNTHESIS
A. BERTRAM and P. CONRAD (Messerschmitt-Boelkow-Blohm Entwicklungspring Nord, Bremen, West Germany.) *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 11 p (SEE N87-20355 13-18) Jul. 1986 Sponsored in part by ESA-ESTC
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

The dynamic qualification process is essentially based on tests verification tests and qualification tests. In order to render ground testing feasible, the structure has to be subdivided into modules. After performing tests on the module level, the dynamic behavior of the entire structure is obtained by modal synthesis. The experience gained in applying modal synthesis concepts to simple models and spacecraft-type structures is discussed. It is shown that the success of a modal synthesis approach is considerably dependent on the input data, i.e., the results of the modal survey tests. Accordingly, test data requirements are outlined. Finally, the discussion includes the way in which the coupling analyses can

be improved by precise consideration of the coupling conditions in substructure tests and calculations. Author

N87-20364# Centre National d'Etudes Spatiales, Toulouse (France).
LOW FREQUENCY VIBRATION TESTING ON SATELLITES
A. GIRARD, A. MAMODE, and F. MERCIER *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p (SEE N87-20355 13-18) Jul. 1986 In FRENCH; ENGLISH summary and title
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

Except the well known POGO phenomenon, the low frequency dynamic flight environment for a satellite consists of transient vibrations, mainly thrust transients. The qualification is generally achieved by a sine sweep on a shaker according to contractual specifications. Far from the POGO frequencies and near the main resonant frequencies of the satellite, notchings based on quasi static load criteria or launch vehicle/satellite coupled analysis results are applied to avoid overtesting. However this approach becomes unsatisfactory for complex structures with large appendages, where the initial specifications are widely modified, disturbing the qualification of secondary structures. In order to improve the representativity of these tests, transient vibration testing has been recently investigated. The feasability of such tests on electrodynamic shakers using digital control techniques was demonstrated several years ago and the main problem remaining prior to their operational use has been the definition of an adequate specification for satellite qualification purposes. Several approaches are presented, including shock synthesis, production of a specified transient, and simulation of the launch vehicle impedance. Author

N87-20365# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. of Aeroelasticity
MODAL-SURVEY TESTING FOR SYSTEM IDENTIFICATION AND DYNAMIC QUALIFICATION OF SPACECRAFT STRUCTURES
N. NIEDBAL and H. HUENERS *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 13 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

Modal-survey testing is an increasingly common part of the qualification procedure for spacecraft structures, since it offers an experimental verification of normal mode parameters determined by dynamic finite-element anlaysis. Moreover, it permits identification of structural damping, knowledge of which is essential for reliable flight-load calculations. A state of the art survey of modern modal-survey testing is given here, covering the phase-resonance method and various phase-separation methods. The use of modal-survey results in the dynamic qualification of spacecraft structures is discussed, emphasizing the correlation of analytical and experimental modal data. This aspect has attracted growing interest in recent years, due to the obvious need for convenient tools that allow finite-element models to be updated with measured modal data. Author

N87-20366# Spar Aerospace Ltd., Weston (Ontario).
MODAL TESTING OF THE OLYMPUS DEVELOPMENT MODEL STOWED SOLAR ARRAY
C. ORAISEY, M. ELZEKI, A. S. JONES, and G. MARKS *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 14 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

The modal testing portion of the structural verification of the stowed solar array configuration of the Olympus S/C, a high powered communication satellite is discussed. The Olympus S/C was designed for both Ariane and Shuttle launches. This versatility of launch configurations requires an emphasis on the ability to accurately predict loads and structural performance. The stowed array is comprised of: release mechanisms, a tip tensioning mechanism, a stowed astromast and a folded flexible blanket to which solar cells have been mounted. The blanket is held in place between a pallet and pressure plate. The prediction of accurate structural response for such a complicated arrangement from analytical data only would be difficult. Over the past few years Spar has undertaken several development studies in the area of modal analysis. Within these studies a technique, using base excitation of the structure has been established. The use of base input as the excitation for a modal test has provided an economical means of incorporating a modal test into a structural acceptance test procedure Author

N87-20367# Politecnico di Milano (Italy). Dipt. di Ingegneria Aerospaziale
ACTIVE STRUCTURAL CONTROLLERS EMULATING STRUCTURAL ELEMENTS BY ICUS
AMALIA ERCOLI FINZI, MASSIMILIANO LANZ, and PAOLO MANTEGAZZA *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 13 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

An approach is presented to the active control design of Large Space Structures that is based on the adoption of decentralized control units. These control units use colocated sensors and actuators and adopt a control law that generates forces proportional to local motions in order to emulate real structural elements, discrete tuning masses and grounding spring-damper combinations. Some numerical examples are used to demonstrate the application of the Independent Control Unit (ICU) concept to a beam and a plate for which the active structure controls are obtained by using a suboptimal design procedure. It is shown how the use of this type of control unit allows the development of an intrinsic fail-safe design. The results obtained with the application of the concepts developed here are demonstrated by their application to an experiment in which a thin beam, suspended from the ceiling, is controlled by different combinations of the independent analog control units making use of a velocity trasducer, an integrator and an electrodynamic actuator. Author

N87-20368# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.). Modal Testing Sect.
SPACECRAFT QUALIFICATION USING ADVANCED VIBRATION AND MODAL TESTING TECHNIQUES
K. MUEHLBAUER and U. SCHILDT *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

The classical single-shaker vibration test has played a dominant role in the mechanical qualification of flexible spacecraft. Due to the substantially increased payload capacity of modern carrier vehicles the existing test facilities have reached their limits in terms of test article mass and size. These limits are being extended by implementing multi-shaker systems for uni-axial testing. At the same time digital data acquisition and analysis techniques are employed to get a better understanding of the test results and of the test article itself. An alternative approach which overcomes the limitations imposed by the test article size is the analytical qualification. Besides static testing this is in particular supported by modal testing accomplished on system or on sub-system level. For modal testing a broad spectrum of computerized or computer-based techniques is now available which are capable of meeting manifold requirements. The dynamic testing techniques mentioned here are outlined and illustrated using actual examples of installations and applications. Author

N87-20371# Martin Marietta Aerospace, Denver, CO.
BENEFITS OF PASSIVE DAMPING AS APPLIED TO ACTIVE CONTROL OF LARGE SPACE STRUCTURES
R. N. GEHLING, H. W. HARCROW, and G. MOROSOW *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 8 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

Active vibration and shape control of large space structures (LSS) has received a great deal of attention recently, while passive damping measures have been somewhat neglected. However, benefits may be derived from simultaneously considering both passive and active control measures to achieve certain performance requirements. Presented are results of a preliminary study of the role passive damping plays in the design and performance of active vibration control strategies. Passive dampers were incorporated into a representative LSS and their effect on candidate active control laws was investigated. Viscous dampers were implemented in time simulations with direct velocity feedback and optimal quadratic regulator control laws. The impact of passive damping on overall closed-loop performance, control system spill over and robustness, and active control requirements was

evaluated. Numerical results are presented for a representative model. The merit of designing a LSS to incorporate discrete passive dampers in the overall approach to vibration suppression is demonstrated through a reduction in demands placed upon an active control system.

N87-20373# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.). Abteilung Maschinenbau und Fahrzeuge.

MULTI-AXIS VIBRATION TESTS ON SPACECRAFT USING HYDRAULIC EXCITERS

H. HAHN and W. RAASCH. *In* AGARD, Mechanical Qualification of Large Flexible Spacecraft Structures, 23 p (SEE N87-20355 13-18), Jul. 1986.

(AGARD-CP-397). Avail: NTIS HC A12/MF A01.

Based on performance data that are specified for a spacecraft multi-axis hydraulic vibration test facility by ESA, the feasibility of such a test facility is investigated. Technical problems and possible solutions concerning test table stiffness, elasticity of actuator oil columns, actuator joints, and oil consumption are discussed. More sophisticated problems may arise concerning the control and safety systems. The designed solutions include controllers for each individual actuator, controllers for a coordinated control of the multiple actuator system, and a safety and monitoring system. The control system has to be based on a control strategy using a combination of analog fixed algorithm controllers and a digital variable algorithm controller, both together performing individual degree of freedom control including suitable decoupling procedures. The safety system has to be based on a triple redundancy concept for critical system components. It is recommended to built it by a digital multi-processor system. The investigations lead to the statement that multi-axis vibration tests of spacecrafts are realizable with respect to the necessary test equipment. Author

N87-20374# Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.

DEVELOPMENT OF PRECISION STRUCTURAL JOINTS FOR LARGE SPACE STRUCTURES

HAROLD C. CROOP and ANDREW R. ROBERTSON (General Dynamics Corp., San Diego, Calif.). *In* AGARD, Mechanical Qualification of Large Flexible Spacecraft Structures, 7 p (SEE N87-20355 13-18), Jul. 1986.

(AGARD-CP-397). Avail: NTIS HC A12/MF A01.

Many anticipated future space systems will employ deployable structural assemblies to meet the packaging constraints of the Space Transporatation System. Recent developments in deployable structures are described relative to the use of advanced composite materials in the joint designs of such systems. Specific design requirements of interest are dimensional stability, zero free play, minimum weight, and thermal/electrical conductivity through the joints. Several design approaches are presented, along with results of material characterization tests. Author

N87-26937# Advisory Group for Aerospace Research and Development, Neuilly Sur Seine (France). Electromagnetic Wave Propagation Panel.

THE AEROSPACE ENVIRONMENT AT HIGH ALTITUDES AND ITS IMPLICATIONS FOR SPACECRAFT CHARGING AND COMMUNICATIONS

May 1987, 286 p. In ENGLISH and FRENCH. Symposium held in The Hague, Netherlands, 2-5 Jun. 1986.

(AGARD-CP-406; ISBN-92-835-0418-6; AD-A185880). Avail: NTIS HC A13/MF A01; CSCL 22B.

The symposium examined how the magnetosphere and polar plasmas vary as a result of natural causes and man-made perturbations, and the implications of these variations for the charging and differential charging of spacecraft with their effects in turn on spacecraft systems and communications. A better understanding of these phenomena can help to design of spacecraft systems and subsystems to minimize the effects of these disturbances. For individual titles, see N87-26938 through N87-26962.

N87-26944*# California Univ., San Diego, La Jolla. Center for Astrophysics and Space Sciences.

HIGH SPACECRAFT POTENTIALS ON ISEE-1 IN SUNLIGHT

E. C. WHIPPLE, JR. and R. C. OLSEN (Alabama Univ., Huntsville). *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications, 10 p (SEE N87-26937 21-18), May 1987.

(Contract NAG-320).

(AGARD-CP-406). Avail: NTIS HC A13/MF A01; CSCL 22B.

Data from two electric field experiments and from the plasma composition experiment on ISEE-1 show that the spacecraft charged to close to -70 V in sunlight at about 0700 UT on March 17, 1978. Data from the electron spectrometer experiment show that there was a potential barrier of some -10 to -20 V about the spacecraft during this event. The potential barrier was effective in turning back emitted photoelectrons to the spacecraft. Potential barriers can be formed by differential charging on the spacecraft or by the presence of space charge. The stringent electrostatic cleanliness specifications imposed on ISEE made the presence of differential charging seem unlikely, if these precautions were effective. Modeling of the event to determine if the barrier was produced by the presence of space charge suggested that this could not explain the observed barrier. The angular shape of the distribution could be successfully modeled as a product of differential charging on the solar arrays. This implies that the conductive coating was not completely effective in preventing differential charging, and that differential charging did occur. Author

N87-26945*# Utah State Univ., Logan.

ACTIVE VEHICLE CHARGING MEASUREMENTS IN SOUNDING ROCKET AND SPACE SHUTTLE ORBITER ENVIRONMENTS AT LOW EARTH ORBIT (LEO) ALTITUDE

W. J. RAITT, J. V. ECCLES, N. B. MYERS, D. C. THOMPSON, P. M. BANKS, P. R. WILLIAMSON, R. I. BUSH, J. HAWKINS, S. SASAKI, K.-I. OYAMA (Tokyo Univ., Japan) et al. *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications, 16 p (SEE N87-26937 21-18), May 1987.

(Contract NAS8-36011, F19628-86-K-0015).

(AGARD-CP-406). Avail: NTIS HC A13/MF A01; CSCL 22B.

It was concluded that for electron beam emission up to 100mA, vehicle charging is not a significant problem with the Space Shuttle Orbiter. Similarly, sounding rocket payloads have no serious charging problems up to this level of beam current, provided that the maximum amount of the rocket skin is available to collect ionospheric electrons from the LEO altitude range. However, sounding rockets are marginal in their collecting area capability, and other effects may occur to balance the beam current when operated at lower altitudes during the night. Author

N87-26946*# Alabama Univ., Huntsville. Dept. of Physics.

ELECTRON BEAM EXPERIMENTS AT HIGH ALTITUDES

R. C. OLSEN. *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications, 8 p (SEE N87-26937 21-18), May 1987.

(Contract NAG3-620).

(AGARD-CP-406). Avail: NTIS HC A13/MF A01; CSCL 22B.

Experiments with the electron gun on the SCATHA satellite produced evidence of beam-plasma interactions, and heating of the low energy electrons around the satellite. These experiments were conducted near geosynchronous orbit, in the dusk bulge and plasma sheet with one short operation in the lobe regions, providing a range of ambient plasma densities. The electron gun was operated at 50 ev, with beam currents of 1, 10, and 100 micro-A. Data from electrostatic analyzers and the dc electric field experiment show that the satellite charged to near the beam energy in sunlight, if the beam current was sufficient. Higher ambient densities required higher beam currents. The electrostatic analyzers showed distribution functions which had peaks or plateaus at energies greater than the satellite potential. These measurements indicate heating of the ambient plasma at several Debye lengths from the satellite, with the heated plasma then accelerated into the satellite. It is likely that the ambient plasma is in fact the photoelectron sheath generated by the satellite. Author

N87-26947*# Physikalisch-Technische Studien G.m.b.H., Freiburg (Germany, F.R.).
GIOTTO-SPACECRAFT CHARGING DUE TO IMPACT GENERATED PLASMA IN THE PRESENCE OF DIELECTRIC MATERIALS
H. THIEMANN, R. W. SCHUNK, N. SINGH, and R. GRARD (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands.) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 7 p (SEE N87-26937 21-18) May 1987
(Contract NAGW-77; NSF ATM-84-17880)
(AGARD-CP-406) Avail: NTIS HC A13/MF A01 CSCL 22B

The charging effects of a conducting/dielectric model spacecraft *in the impact induced plasma environment are contrasted.* The results of dynamic model calculations indicate larger charging times and higher positive spacecraft potentials for a conducting/dielectric spacecraft. The potential and particle distributions around the spacecraft differ quantitatively and qualitatively in both cases.
Author

N87-26948# Air Force Geophysics Lab., Hanscom AFB, MA.
COMPUTER MODELS OF THE SPACECRAFT WAKE
M. HEINEMANN, A. RUBIN, M. TAUTZ, and D. COOKE (RADEX, Inc., Carlisle, Mass.) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 9 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

The Mesothermal Auroral Charging (MACH) code, an inside-out particle tracking code, was developed for the purpose of validating the physics of the Potential Of Large Spacecraft in the Auroral Regions (POLAR) code in regimes where there can be no comprehensive theoretical or experimental results. While the *spacecraft that can be treated by MACH are restricted to simple* geometries, the methodology is more fundamental than POLAR. MACH generates self-consistent solutions within the context of quasisteady Vlasov plasma flow and achieves Debye ratios previously unobtainable. POLAR and MACH solutions are shown for the particle and electrostatic potential structure of the wake of a charged disk in a low altitude flow for Mach numbers 4, 5, and 8. The results of the codes are compared to each other and to simple analytic approximations as part of an effort to compute the nature of the spacecraft wake and to establish the validity of the codes.
Author

N87-26949# York Univ., Toronto (Ontario). Dept. of Physics.
SPACECRAFT CHARGING IN THE AURORAL PLASMA: PROGRESS TOWARD UNDERSTANDING THE PHYSICAL EFFECTS INVOLVED
J. G. LAFRAMBOISE and L. W. PARKER (Parker, Lee W., Inc., Concord, Mass.) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 16 p (SEE N87-26937 21-18) May 1987
(Contract F19628-83-K-0028)
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

The main differences between the plasma environments in geostationary orbit and low polar orbit with respect to high-voltage charging situations are reviewed. Results are presented from a calculation of secondary electron escape currents from negatively charged spacecraft surfaces having various orientations relative to the local magnetic field direction. A simple rough estimate of the required conditions for high-voltage auroral-zone charging is developed. The results suggest that for any given spacecraft, surface potentials are likely to depend more strongly on the ratio of ambient flux of high-energy electrons to that of all ions, than any other environmental parameter. Preliminary results of simulation *work directed toward testing this hypothesis are presented.*
Author

N87-26950*# National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.
SECONDARY ELECTRON GENERATION, EMISSION AND TRANSPORT: EFFECTS ON SPACECRAFT CHARGING AND NASCAP MODELS
IRA KATZ, MYRON MANDELL (Systems Science and Software, La Jolla, Calif.), JAMES C. ROCHE, and CAROLYN PURVIS *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 12 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01 CSCL 22B

Secondary electrons control a spacecraft's response to a plasma environment. To accurately simulate spacecraft charging, the NASA Charging Analyzer Program (NASCAP) has mathematical *models of the generation, emission and transport of secondary* electrons. The importance of each of the processes and the physical basis for each of the NASCAP models are discussed. Calculations are presented which show that the NASCAP formulations are in good agreement with both laboratory and space experiments.
Author

N87-26951# University Coll., London (England). Space Science Lab.
SPACECRAFT CHARGING: METEOSAT EXPERIENCE
G. L. WRENN and A. D. JOHNSTONE *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 14 p (SEE N87-26937 21-13) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

Operational problems with Meteosat 1 led to a collaborative effort to furnish subsequent spacecraft with simple charging *monitors and to study the geosynchronous environment in an* attempt to better understand the charging process. The electron spectrometer on Meteosat 2 has yielded a continuous 3-year data set which has clarified the role of plasma sheet electrons in the detailed current balance which controls spacecraft potentials. Continual observation of eclipse and partial shadowing features has illuminated the dominant role of photoelectrons and demonstrated that the safe clamping of differential voltages can be obtained. An electron albedo index has been developed as an aid to assessing spacecraft liability to charging. The majority of anomalies experienced by Meteosat 2 are not directly caused by charging, an alternative natural cause has not been found.
Author

N87-26952# Toronto Univ. (Ontario). Dept. of Electrical Engineering.
ARC PROPAGATION, EMISSION AND DAMAGE ON SPACECRAFT DIELECTRICS
K. G. BALMAIN *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 7 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

A review is given of the literature on the subject of arc discharges on spacecraft dielectric materials which have become charged by energetic electrons and ions. Arcs resulting from the charging of spacecraft dielectrics can be very strong because the charge over a large area is mobilized through the phenomenon of arc propagation. The resultant damage patterns on the dielectric are shown to be related to arc patterns, and to the optical anisotropy and crystallinity of the material. The evidence for dielectric melting is suggestive of likely contamination of nearby *surfaces. The effectiveness of arc barriers sheds light on arc* propagation mechanisms.
Author

N8 26953# Centre d'Etudes et de Recherches, Toulouse (France). Dept. Technologie Spatiale.
ON THE POSSIBILITY OF A SEVERAL-KILOVOLT DIFFERENTIAL CHARGE IN THE DAY SECTOR OF A GEOSYNCHRONOUS ORBIT [SUR LA POSSIBILITE DE CHARGE DIFFERENTIELLE DE PLUSIEURS KILOVOLTS DANS LE SECTEUR JOUR DE L'ORBITE GEOSYNCHRONE]
L. LEVY, D. SARRAIL, J. P. PHILIPPON, J. P. CATANI, and J. M. FOUROUET (MATRA Service Aerodynamique, Toulouse, France) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 12 p (SEE N87-26937 21-18) May 1987 In FRENCH
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

Day-sector charging events detected with the Telecom 1-A satellite were analyzed. The temporal distribution of the events, seasonal variations, and correlations with geomagnetic activity are discussed. In addition, several covering materials were subjected to quasi-monoenergetic electron bombardment in a simulation chamber. It was found that floating metallic surfaces, although small, produced enduring discharges with short rise times. M.G.

N87-26956# Societe Nationale Industrielle Aerospatiale, Cannes (France).
SPACECRAFT PROTECTION AGAINST ELECTROSTATIC DISCHARGE APPLICATION TO THE ARABSAT SPACECRAFT
LAURENT BROIHANNE *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 11 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

The protections against electrostatic discharge (ESD) phenomena effects which were implemented on the ARABSAT spacecraft are summarized. The origins of ESD phenomena on geostationary spacecraft are recalled. The basic design rules concerning ESD which were applied to ARABSAT are given
Author

N87-26957# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Community Satellites Dept.
ELECTROSTATIC IMMUNITY OF GEOSTATIONARY SATELLITES
HORST G. LECHTE *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 8 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

It is demonstrated that electrostatic immunity of telecommunication satellites can be achieved to a large extent by relatively simple means. Those means include the selection of antistatic external materials and the desensitization of electronic actuators and memories regarding fast transients. The dual approach is considered necessary because not all external surfaces can be made antistatic. Protection of operationally critical circuitries against single event upsets is achieved by the same means
Author

N87-26958# Telesat Canada, Ottawa (Ontario). Satellite Engineering Group.
THE EFFECTS OF ELECTROSTATIC DISCHARGE PHENOMENA ON TELESAT'S DOMESTIC COMMUNICATIONS SATELLITES
P. N. WADHAM *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 10 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

A number of anomalies believed to have been caused by electrostatic discharges are discussed. In particular, an unusually severe event which resulted in a temporary loss of control and a consequent loss of fuel is discussed. Each class of satellite is covered in sequence by launch date. Mention is made of the configuration of the thermal blankets because they are considered to be the prime cause of electrostatic discharges. Author

N87-26960# Air Force Geophysics Lab., Hanscom AFB, MA.
AUTOMATIC CHARGE CONTROL SYSTEM FOR GEOSYNCHRONOUS SATELLITES
B. M. SHUMAN, H. A. COHEN, J. HYMAN, R. R. ROBSON, J. SANTORU, and W. S. WILLIAMSON (Hughes Research Labs., Malibu, Calif.) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 17 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

An autonomous system to detect both absolute and differential spacecraft charging aboard high altitude satellites and to reduce those potentials before hazardous arcing levels are reached is being developed. The principle of safely reducing spacecraft charging levels by the emission of a low energy neutral plasma, effectively shorting the spacecraft and charged dielectric surfaces to the ambient space plasma, was demonstrated. The Charge Control System will utilize a xenon-based plasma source capable of igniting within one second, and capable of emitting a quasi-neutral plasma containing more than 1 mA of ions. Author

N87-26961# Aerospace Corp., Los Angeles, CA. Space Sciences Lab.
THICK DIELECTRIC CHARGING ON HIGH ALTITUDE SPACECRAFT
A. L. VAMPOLA *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 7 p (SEE N87-26937 21-18) May 1987
Previously announced as N87-13480
(Contract F04701-82-C-83)
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

Thick dielectric charging, in which energetic electrons embed within bulk dielectrics and build up to potentials in excess of the breakdown potential of the dielectric, is shown to be a causitive factor in the anomalous operation of high altitude satellites. Results of laboratory studies are reviewed and a table of maximum expected electron fluxes orbits of various altitudes is presented. The combination of maximum expected electron fluxes and the small energy associated with a bulk dielectric breakdown permits the elimination of bulk charging as a spacecraft problem through the minimum shielding (400 mg/sq cm) of all cables and circuit boards otherwise exposed to the environment, and through the desensitizing of digital logic inputs that are serviced by cables.
Author

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SPACECRAFT PROPULSION AND POWER

Includes main propulsion systems and components, e.g., rocket engines; and spacecraft auxiliary power sources.

N87-18610# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
PERFORMANCE OF ROCKET MOTORS WITH METALLIZED PROPELLANTS
D. REYDELLET, ed. Sep. 1986 84 p
(AGARD-AR-230; ISBN-92-835-1534-X; AD-A175565) Avail: NTIS HC A05/MF A01

Different methods were used to calculate and predict the performance of solid rocket motors with metallized propellants. An AGARD Working Group was formed in order to compare the different prediction methods, to investigate the sources of inaccuracy and to make recommendations for future applications. The Working Group performed calculations and predictions with different methods for two test cases and compared the results with each other and with the results of experimental investigations. Finally, the Working Group came up with some conclusions and the recommendations for the application of a simplified semi-empirical method for a specific impulse prediction accuracy of 1 percent. Author

N87-28589# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

DESIGN METHODS IN SOLID ROCKET MOTORS

Mar. 1987 239 p In ENGLISH and FRENCH Lectures held in Rijswijk, Netherlands, 6-7 Apr. 1987; in Athens, Greece, 9-10 Apr. 1987; in Ankara, Turkey, 13-14 Apr. 1987; and in Lancaster, Calif., 23-24 Apr. 1987

(AGARD-LS-150; ISBN-92-835-0415-1; AD-A184476) Avail: NTIS HC A11/MF A01

A compilation of lectures summarizing the current state-of-the-art in designing solid rocket motors and and their components is presented. The experience of several countries in the use of new technologies and methods is represented. Specific sessions address propellant grains, cases, nozzles, internal thermal insulation, and the general optimization of solid rocket motor designs. For individual titles, see N87-28590 through N87-28599.

N87-28590# Air Force Rocket Propulsion Lab., Edwards AFB, CA.

ADVANCES IN SOLID ROCKET NOZZLE DESIGN AND ANALYSIS TECHNOLOGY IN THE UNITED STATES SINCE 1970

JOSEPH H. HILDRETH *In* AGARD, Design Methods in Solid Rocket Motors 15 p (SEE N87-28589 23-20) Mar. 1987

(AGARD-LS-150) Avail: NTIS HC A11/MF A01

The evolution of solid rocket nozzle design and analysis in the United States over the past decade is examined. Generalized design requirements are briefly summarized and the evolution from tungsten and graphite based designs to the current carbon-carbon designs is discussed. The main causes for the incorporation of new technologies are identified. The analysis processes employed in the design cycle are described. The portions of the analysis activities where advanced technologies have been incorporated are identified as well as the current trends for improved capabilities. Finally, activities directed towards the verification of analysis technology are summarized. These activities include code versus code comparisons as well as code versus laboratory measurement efforts. The code versus measurement efforts include investigations into threaded interfaces between the throat and exit cone parts and the behavior of carbon-carbon involute exit cones subjected to multiaxial loads. Author

N87-28591# Societe Europeene de Propulsion, Saint-Medard-en-Jalles (France).

DESIGN AND SIZING OF SOLID ROCKET NOZZLES [CONCEPTION ET DIMENSION'EMENT DES TUYERES DE PROPULSEURS A POUDRE]

ANDRE TRUCHOT *In* AGARD, Design Methods in Solid Rocket Motors 27 p (SEE N87-28589 23-20) Mar. 1987 In FRENCH

(AGARD-LS-150) Avail: NTIS HC A11/MF A01

Design and sizing of solid propellant rocket nozzles is discussed and examples from the field of tactical propulsion systems are given. The principle specifications and parameters necessary for the analysis of nozzles (pressure, time, throat diameter, over-all dimensions, etc.) are outlined. The various design stages are detailed: nozzle configuration analysis, section profiling, selection and pre-sizing of section and insulation materials, and structural components design. The different systems utilized for thrust vector control (nozzle movement, fluid injection, etc.) are then discussed. Finally, the various stages of nozzle sizing are examined. For every phase (aerodynamic, thermal or thermomechanical), the computation codes utilized are described. M.G.

N87-28592# Hercules, Inc., Rocket Center, WV. Aerospace Products Group.

COMPOSITE MOTOR CASE DESIGN

P. R. EVANS *In* AGARD, Design Methods in Solid Rocket Motors 11 p (SEE N87-28589 23-20) Mar. 1987

(AGARD-LS-150) Avail: NTIS HC A11/MF A01

Information is presented on the design of composite cases for rocket motors. Typical design requirements are discussed, including pressure, axial and bending loads and thermal loading. Material technology discussed includes filament winding resins and glass, Kevlar and graphite fibers. Design features discussed include the pressure vessel body, skirts, polar adapters and other attachments. Typical qualification testing and inspection techniques are presented. Author

N87-28593# Societe Nationale Industrielle Aerospatiale, Saint-Medard-en-Jalles (France). Program for Filament-Wound Structures.

DESIGN OF FILAMENT-WOUND ROCKET CASES

J. P. DENOST *In* AGARD, Design Methods in Solid Rocket Motors 44 p (SEE N87-28589 23-20) Mar. 1987

(AGARD-LS-150) Avail: NTIS HC A11/MF A01

The methods of design and justification of filament wound rocket cases are described. A critical analysis of rapid light-weight design methods and computer aided design methods is presented and the complementary utilization of the techniques is illustrated. Consideration is also given to materials, their implementation and performance, and to the major principles of fabrication of this type of structure. Author

N87-28594# IMI Summerfield, Kidderminster (England). Rocket Motor Design and Development.

CONSIDERATIONS FOR DESIGNERS OF CASES FOR SMALL SOLID PROPELLANT ROCKET MOTORS

H. BADHAM and G. P. THORP *In* AGARD, Design Methods in Solid Rocket Motors 20 p (SEE N87-28589 23-20) Mar. 1987

(AGARD-LS-150) Avail: NTIS HC A11/MF A01

When manufacturing the initial design of the case or load bearing components for a solid propellant rocket motor a number of possible solutions may be apparent and many factors need consideration before the design of the individual components can be finalized. The process of optimization involves consideration of material properties, methods of manufacturing, inspection and proof as well as interactions with other rocket motor and missile components. The various factors are considered and indications are given of the interactions to be taken into account. Particular emphasis is given to the design of metallic motor cases. Both homogeneous and non-homogeneous body structures are considered, the latter being fiber overwound metallic and strip laminate structures. The relatively recent requirement of munitions insensitivity (resistance to fragment attack and fuel fire) is also discussed in relation to body construction. Author

N89-16815*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

SPACE SHUTTLE MAIN ENGINE MONITORING EXPERIENCE AND ADVANCED MONITORING SYSTEMS DEVELOPMENT

HARRY A. CIKANEK *In* AGARD, Engine Condition Monitoring: Technology and Experience 20 p (SEE N89-16780 09-06) Oct. 1988

(AGARD-CP-448) Avail: NTIS HC A20/MF A01 CSCL 21H

Advanced space transportation systems must provide improved availability, reliability, safety, and reduced cost in order to make a new, more vigorous level of space activity economically feasible. Earth-to-Orbit (ETO) propulsion monitoring systems are a major factor in progress toward these improvements, and in the success of current systems. Operational experience with the Space Shuttle Main Engine (SSME), the first reusable ETO rocket engine, is valuable for examining current rocket engine monitoring capability and technology developments. Here, Space Shuttle Main Engine (SSME) monitoring practice and experience are surveyed. Unique aspects of rocket engine mission requirements are highlighted to provide improved understanding of engine monitoring practices and technology needs. Current ETO engine transportation systems mission needs are outlined. With this foundation, the techniques and components addressed within current technology programs are discussed to complete a picture of ETO propulsion monitoring status and development. Author

N89-16816*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

PLUME SPECTROMETRY FOR LIQUID ROCKET ENGINE HEALTH MONITORING

WILLIAM T. POWERS, F. G. SHERRELL, J. H. BRIDGES, III, and T. W. BRATCHER (Sverdrup Technology, Inc., Arnold Air Force Station, TN.) *In* AGARD, Engine Condition Monitoring: Technology and Experience 10 p (SEE N89-16780 09-06) Oct. 1988

(AGARD-CP-448) Avail: NTIS HC A20/MF A01 CSCL 21H

An investigation of Space Shuttle Main Engine (SSME) testing failures identified optical events which appeared to be precursors of those failures. A program was therefore undertaken to detect plume trace phenomena characteristic of the engine and to design a monitoring system, responsive to excessive activity in the plume,

capable of delivering a warning of an anomalous condition. By sensing the amount of extraneous material entrained in the plume and considering engine history, it may be possible to identify wearing of failing components in time for a safe shutdown and thus prevent a catastrophic event. To investigate the possibilities of safe shutdown and thus prevent a monitor to initiate the shutdown procedure, a large amount of plume data were taken from SSME firings using laboratory instrumentation. Those data were used to design a more specialized instrument dedicated to rocket plume diagnostics. The spectral wavelength range of the baseline data was about 220 nanometers (nm) to 15 microns with special attention given to visible and near UV. The data indicates that a satisfactory design will include a polychromator covering the range of 250nM to 1000nM, along with a continuous coverage spectrometer, each having a resolution of at least 5A degrees. The concurrent requirements for high resolution and broad coverage are normally at odds with one another in commercial instruments, therefore necessitating the development of special instrumentation. The design of a polychromator is reviewed herein, with a detailed discussion of the continuous coverage spectrometer delayed to a later forum. The program also requires the development of applications software providing detection, variable background discrimination, noise reduction, filtering, and decision making based on varying historical data. Author

N89-16906# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

DESIGN METHODS IN SOLID ROCKET MOTORS

Apr. 1988 243 p In ENGLISH and FRENCH Lecture series held in London, United Kingdom, 18-19 Apr. 1988, in Saint-Aubin de Medoc, France, 21-22 Apr. 1988, in Neubiberg, Fed. Republic of Germany, 25-26 Apr. 1988, and in Rome, Italy, 28-29 Apr. 1988 Revised

(AGARD-LS-150-REV; ISBN-92-835-0454-2; AD-A199356) Avail: NTIS HC A11/MF A01

The current state of the art in designing solid rocket motors and their components are summarized. The aim is to collect the experience of several countries in using new technologies and new methods which have been developed over the past ten years. Specific sessions dealt with propellant grain, cases, nozzles, internal thermal insulations. The question of the general optimization of a solid rocket motor is emphasized. For individual titles, see N89-16907 through N89-16916.

N89-16907# Air Force Rocket Propulsion Lab., Edwards AFB, CA.

ADVANCES IN SOLID ROCKET NOZZLE DESIGN AND ANALYSIS TECHNOLOGY IN THE UNITED STATES SINCE 1970

JOSEPH H. HILDRATH *In* AGARD, Design Methods in Solid Rocket Motors 15 p (SEE N89-16906 09-20) Apr. 1988

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

The evolution of the nozzle design and analysis in the U.S. in the past decade is examined. A brief summary is given of generalized design requirements along with a description of the design evolution from tungsten and graphite based designs to the current carbon-carbon designs. The main caused for the incorporation of new technologies in the design are identified. A technical description of the analysis processes that are employed in the design cycle is given. The verification of the analysis procedure is a vital aspect of improving the analysis capabilities. A description is also given of some of the activities which have occurred to demonstrate the validity of the new analysis technology. These activities include code vs. code comparisons as well as code vs. lab measurement efforts. The code vs. measurement efforts include investigations into threaded interfaces between the throat and exit cone parts and the behavior of carbon-carbon involute exit cones subjected to mulitaxial loads. Author

N89-16908# European Space Agency, Paris (France).

DESIGN AND ANALYSIS OF SOLID ROCKET MOTOR NOZZLE

A. TRUCHOT *In* AGARD, Design Methods in Solid Rocket Motors 22 p (SEE N89-16906 09-20) Apr. 1988

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

The different methods are presented which are used to design and analyze solid rocket motor nozzles. In a preliminary phase, the typical requirements and parameters required to design a nozzle are discussed. Afterwards, the general process of the design is detailed: nozzle configuration, aerodynamic contour design, selection and sizing of liners and insulators, etc. In a second step, the different systems used to control the motor thrust or to improve the performance, such as extendible exit cones, are presented. For each step (aerodynamic, thermal and structural) the different computer programs used are presented. Author

N89-16909# Hercules, Inc., Rocket Center, WV. Aerospace Products Group.

COMPOSITE MOTOR CASE DESIGN

P. R. EVANS *In* AGARD, Design Methods in Solid Rocket Motors 11 p (SEE N89-16906 09-20) Apr. 1988 Previously announced as N87-28592

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

Information is presented on the design of composite cases for rocket motors. Typical design requirements are discussed, including pressure, axial and bending loads and thermal loading. Material technology discussed include filament winding resins and glass, Kevlar and graphite fibers. Design features discussed include the pressure vessel body, skirts, polar adapters and other attachments. Typical qualification testing and inspection techniques are presented. Author

N89-16910# Societe Nationale Industrielle Aerospatiale, Saint-Medard-en-Jalles (France). Programs for Filament-Wound Structures.

DESIGN OF FILAMENT-WOUND ROCKET CASES

J. P. DENOST *In* AGARD, Design Methods in Solid Rocket Motors 22 p (SEE N89-16906 09-20) Apr. 1988

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

Aerospatiale began developing methods for design and sizing of filament-wound rocket cases in the early 1970's. Such methods have since evolved to the extent that rapid design and precise verification means are now available. These two approaches are outlined, criticized, and their complementarity is determined. The principle rules are outlined. The theory is completed by considerations relating to materials, their implementation and performances, and by a description of the major principles of fabrication of this type of structure. Author

N89-16911# IMI Summerfield, Kidderminster (England). Rocket Motor Design and Development.

CONSIDERATIONS FOR DESIGNERS OF CASES FOR SMALL SOLID PROPELLANT ROCKET MOTORS

H. BADHAM and G. P. THORP *In* AGARD, Design Methods in Solid Rocket Motors 20 p (SEE N89-16906 09-20) Apr. 1988 Previously announced as N87-28594

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

When manufacturing the initial design of the case or load bearing components for a solid propellant rocket motor, a number of possible solutions may be apparent and many factors need consideration before the design of the individual components can be finalized. The process of optimization involves consideration of material properties, methods of manufacturing, inspection and proof as well as interactions with other rocket motor and missile components. The various factors are considered and indications are given of the interactions to be taken into account. Particular emphasis is given to the design of metallic motor cases. Both homogeneous and nonhomogeneous body structures are considered, the latter being fiber overwound metallic and strip laminate structures. The relatively recent requirement of munitions insensitivity (resistance to fragment attack and fuel fire) is also discussed in relation to body construction. Author

N89-16915# European Space Agency, Paris (France).

DESIGN AND ANALYSIS OF SOLID ROCKET MOTOR INTERNAL INSULATION

A. TRUCHOT *In* AGARD, Design Methods in Solid Rocket Motors 13 p (SEE N89-16906 09-20) Apr. 1988

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

The main purpose of internal insulation is to protect the motor case from the thermal environment of propellant combustion products. Several secondary objectives must also be met. Internal insulation must bond to propellant and case, transmit case strain into propellant and sometimes seal the case. In the first step, the general process of internal insulation is presented: evaluation of thermal environment, selection of material, thermal and structural

analyses. For each phase, the different analysis methods are described: aerodynamic, thermal and structural. Also the different phases of internal insulation fabrication are presented: elastomer formulation, fabrication of parts and integration into the motor case. Author

N89-16916# European Space Agency, Paris (France).
OVERALL OPTIMIZATION OF SOLID ROCKET MOTOR
A. TRUCHOT *In* AGARD, Design Methods in Solid Rocket Motors 10 p (SEE N89-16906 09-20) Apr. 1988
(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

The overall optimization of a solid rocket motor consists of determining the most efficient configuration of the motor in terms of range or payload of the vehicle. After a presentation of the general requirements of a solid rocket motor, the different design parameters are detailed: operating conditions, geometric parameters and technologies used for each component. In order to achieve parametric studies, a computer program was developed by SEP. The principle and main characteristics of this program are presented and two examples of application are given in order to illustrate the possibilities of the program. Author

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COMPOSITE MATERIALS

Includes physical, chemical, and mechanical properties of laminates and other composite materials.

N86-27425# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
IMPACT DAMAGE TO COMPOSITE STRUCTURES
Feb. 1986 40 p
(AGARD-R-729; ISBN-92-835-1517-X; AD-A167594) Avail: NTIS HC A03/MF A01

The impact of ballistic penetrators in fuel filled tanks generates high dynamic pressure loading. This damage process is generally *referred to as hydraulic ram. Hydraulic ram in aircraft fuel tanks* results in large damage of structural components, which in turn can lead to fuel loss or ingestion into the engines, fire and explosion. To determine the effect of hydraulic ram to an integral fuselage fuel tank with carbon/epoxy skin, a firing program was established. Plane carbon/epoxy plates, bolted to an impact box, were impacted with single cuboid fragments. Different shock-absorbing materials used to reduce hydraulic ram pressures on the impact plate, were investigated to prevent propagation of the shock wave. Multiple fragments were projected against the simulated fuel tank sections with carbon/epoxy skins and sandwich design at a hit density of 25 fragments per square meter. Author

N87-20178# *Societe Nationale Industrielle Aerospatiale, Toulouse* (France). Composite Structure Design Dept.
A.T.R. 42 CARBON FIBRE FLAP REPAIR DESIGN AND INSPECTION
GUY HELLARD *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 9 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

The new commuter aircraft known as ATR.42 developed jointly by Aerospatiale and Aeritalia is the first aircraft of its category to be equipped with carbon fabric flaps. All the airlines which have placed orders for this aircraft are not equipped with the heavy installations required for working on the composite materials. Repair schemes using a simple technology have therefore to be developed. Partial or complete tests have shown that a perfect understanding of the structural ability to withstand the different types of damage was required beforehand. Repair methods using in situ pre-impregnation of dry fabrics have been developed with the relevant method. The mechanical strength of the various repairs and the effects of inadequate damage repairs have been investigated through tests. Author

N88-20190# British Aerospace Aircraft Group, Warton (England). Structural Engineering.
STRUCTURAL MATERIALS: THE CHANGING SCENE
R. I. HARESCEUGH *In* AGARD, Flight Vehicle Development Time and Cost Reduction 6 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Structural materials for use on aircraft have, in the main, evolved by minor development from a previously existing base. These developments, which have been by small increments, have taken place at a fairly leisurely pace. The major exception to this in the last two decades has been the introduction of fiber composites which, while achieving a revolutionary change, has been effected against a protracted time scale. Developments are currently under way, or anticipated, which will require other revolutionary materials to be introduced but to much tighter time scales and against *aircraft project requirements. Examples are identified where this* development should be directed and action is proposed necessary to ensure that the materials are developed to a common requirement in the required time scale. Author

N89-17696# Royal Armament Research and Development Establishment, Christchurch (England).
TEST SPECIMENS FOR BEARING AND BY-PASS STRESS INTERACTION IN CARBON FIBRE REINFORCED PLASTIC LAMINATES
M. B. SNELL and G. P. BURKITT *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 21 p (SEE N89-17685 10-31) Mar. 1988 Original document contains color illustrations
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

Compact test specimens for measuring the strength interaction behaviour of bolted joints subject to combined bearing and by-pass stresses have been studied. Multi-bolt specimens which have been successfully used to study these effects in aluminum alloy were found to be unsatisfactory because of the uncertainty in load transfer, and a new specimen based on parallel plates was developed. Bearing load at the holes is achieved through load transfer from the central carbon fiber reinforced plastic (CFRP) coupon to the parallel plates. The maximum ratio of bearing to bypass loads is limited by the initial fit of the bolt and by subsequent bolt/hole deformation under load. However the specimens recommended are capable of applying a wide range of bearing/bypass load ratios. Sample strength interaction envelopes were produced for a Hercules IM6 fiber and Ciba-Geigy Fibredux 6376 resin laminate of typical wing skin lay-up, 5.5 mm thick. Both tension and compression quadrants were studied, with two hole sizes, in both double shear and single shear. The interaction behavior was similar in both tension and compression for 6.35 mm holes in double shear, but in the case of 9.5 mm bolts there was less interaction in compression than in tension. Countersunk fasteners in tension appeared to suffer little reduction in net strength due to bearing stresses. Author

N89-17699# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.
THE STATIC STRENGTH OF BOLTED JOINTS IN FIBRE *REINFORCED PLASTICS*
F. L. MATTHEWS *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 9 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

Joints in glass fiber reinforced plastics (GFRP) and Kevlar fiber reinforced plastics (KFRP) laminates show similar characteristics to those in carbon fiber reinforced plastics (CFRP) but with differences brought about by the low elastic modulus of glass fibers, and the low compressive strength of Kevlar fibers. Data is presented for GFRP laminates manufactured from layers of unidirectional fiber prepreg, and for KFRP laminates manufactured from layers of balanced, bi-directional, woven fabric prepreg. Comparative data for CFRP is also given. As far as GFRP is concerned, test on single-hole joints show that the effects of width, end distance, hole size, bolt clamping pressure and stacking sequence are similar to those in CFRP. In general, strength levels for GFRP are about 20 pct below those for CFRP. A stronger interaction between failure modes is found for GFRP, which also shows a greater tendency to delaminate rather than showing in-plane shear or tensile cracking. Due to the nature of the prepreg

the range of possible lay-ups for KFRP is restricted. Bearing strengths are generally in the range 50 to 600 MN/sq m. Overall behavior is found to be similar to other FRP although the ultimate failure mode is almost invariably tensile. There is evidence that the inherent compressive characteristics of Kevlar fiber contribute to the low bearing strength. Surprisingly, although very large hole distortions are seen at failure, there is very little evidence of resin cracking. Author

N89-17701# *Aeritalia S.p.A., Naples (Italy).*
JOINING OF CARBON FIBER COMPOSITE WITH FASTENERS
SALVATORE PAGLIUSO *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 5 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

This paper deals with the Aeritalia experience on drilling techniques and fastener selection for advanced composite assembly. Details are provided on fabrication techniques. Information is given on corrosion prevention. Author

N89-17702# Avions Marcel Dassault, Saint-Cloud (France).
BOLTED SCARF JOINTS IN CARBON COMPOSITE MATERIALS. COMPARISON BETWEEN ASSEMBLIES WITH AN INTERFERENCE FIT AND THOSE WITH PLAY [ENTURES BOULONNEES EN MATERIAUX COMPOSITE CARBONE COMPARAISON ENTRE MONTAGES A INTERFERENCE ET MONTAGE A JEU]
DANIEL CHAUMETTE *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 10 p (SEE N89-17685 10-31) Mar. 1988 In FRENCH
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

Experimental results on the behavior of carbon assemblies with mechanical fasteners mounted with and without interference are presented. Interference tests have been conducted for the cases of unstressed joints and scarf joints. In contrast to the predictions of elastic stress theory, interference fit is not found to have a significant influence on the static strength of test specimens, even after fatigue loading. The present results can be explained by the fracture mode of the drilled composite parts which leads to delamination. Author

N89-17705# National Aeronautical Establishment, Ottawa (Ontario). Structures and Materials Lab.
BEHAVIOUR OF MECHANICALLY FASTENED JOINTS IN ADVANCED COMPOSITES
C. POON and R. GOULD *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 14 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

Experimental results obtained to date from an on-going test program are presented. The purpose of this program is to evaluate the performance of mechanical fastener systems in Narmco IM6/5245C, a high strain/tough resin composite identified as a promising material system for new aircraft designs. Preliminary results obtained from tensile tests on open-hole specimens and double-lap joints were used to characterize the notch strength and the bearing strength as influenced by the effect of design parameters involving geometric ratios, hole size and fastener torque. A constant amplitude tension-compression ($R \approx -1$) fatigue test was performed on a double-lap composite joint to assess a simple and effective technique based on hysteresis measurements for monitoring progressive elongation by as much as 26 pct at the end of the fatigue test. This was explained by the observation that graphite particles formed during the fatigue test reduce the clearance between the hole and the pin. Single-shear composite/titanium joints were tested to evaluate three fastener systems designed specifically for composite applications. Four single-shear joints were tested to date to the ultimate tensile strength. Author

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INORGANIC AND PHYSICAL CHEMISTRY

Includes chemical analysis, e.g., chromatography; combustion theory; electrochemistry; and photochemistry.

N87-21171# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Inst. fuer Physikalische Chemie der Verbrennung.
SIMULTANEOUS TEMPERATURE MEASUREMENTS WITH RAMAN AND CARS IN LAMINAR FLAMES
W. STRICKER, W. KREUTNER, and TH. JUST *In* AGARD Advanced Instrumentation for Aero Engine Components 11 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Spatially resolved temperature measurements in laminar premixed flames were made using Coherent Anti-Stokes Raman Scattering (CARS) and spontaneous Raman spectroscopy. In the case of narrowband (scanning) CARS, the experimental arrangement allows the performance of simultaneous temperature measurements with both techniques. For broadband (multiplex) CARS the measurements have to be made successively. Three different Raman linewidth models were used for CARS data evaluation. The results were compared with the independently recorded rotational Raman temperatures. Temperature differences up to 10% were observed, depending on the linewidth model used. For two, more complicated linewidth models the CARS and Raman temperatures are in good agreement. Author

N87-21172# United Kingdom Atomic Energy Authority, Harwell (England). Combustion Centre.
CARS THERMOMETRY FOR LOW AND HIGH PRESSURE COMBUSTION SYSTEMS
DOUGLAS A. GREENHALGH *In* AGARD Advanced Instrumentation for Aero Engine Components 26 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The theory and application of broadband Coherent Anti-Styles Raman Spectroscopy (CARS) for ambient (low) and high pressure combustion thermometry is discussed. The accuracy of broadband CARS is assessed from 300 to 3500 Kelvin for pressures around 1 bar, and from 300 to 700 Kelvin for pressures from 1 to 20 bar. The use of CARS thermometry for both average and instantaneous measurements is discussed. Systematic accuracy strongly depends on the quality of the spectral model used in the CARS data analysis step. CARS spectral modelling methods are discussed with particular reference to important recent developments. Instantaneous CARS accuracy is importantly influenced by noise arising in both the broadband dye laser and the multichannel detector. Both of these factors, and their relative influences are assessed. The application of CARS thermometry is illustrated by application to both in-cylinder studies of an operating production i.c. petrol engine and to turbulent combustion in an oil-fired 30 kilowatt furnace. Author

N87-21173# Sandia National Labs., Albuquerque, NM. Combustion Research Facility.
ACCURATE MEASUREMENTS OF COMBUSTION SPECIES CONCENTRATIONS USING CARS
R. L. FARROW *In* AGARD Advanced Instrumentation for Aero Engine Components 16 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Results are given of research at the Combustion Research Facility, Sandia National Laboratories, on improving the capabilities of Coherent Anti-Stokes Raman Spectroscopy (CARS) for species concentration measurements in combustion gases. Scanning CARS experiments based on single- and multi-mode Nd:YAG lasers, and on pulse-amplified and conventional pulsed dye lasers have been used to evaluate an in situ normalization technique, to measure Raman linewidths in flames, and to determine nonresonant electronic susceptibilities. Experimental and theoretical considerations affecting concentration measurement accuracy are discussed. Author

N87-21174# Defence Research Establishment Ottawa, (Ontario).
NONLINEARITY AND SINGLE SHOT NOISE PROBLEMS IN CARS SPECTROSCOPY
D. R. SNELLING, G. J. SMALLWOOD, R. A. SAWCHUK, and T. PARAMESWARAN In AGARD Advanced Instrumentation for Aero Engine Components 19 p (SEE N87-21170 14-31) Nov. 1986 (AGARD-CP-399) Avail: NTIS HC A24/MF A01

The design and operation of a Coherent Anti-Stokes Raman Spectroscopy (CARS) spectrometer and its use to perform accurate temperature measurements in a simple laboratory flat-flame burner are discussed. Instrumental sources of systematic error and noise in CARS temperature measurements are discussed. An analysis of the system noise is presented and the use of the measured noise to perform weighted least mean squares fits of experimental and theoretical CARS spectra is discussed. The use of a weighted fit is shown to markedly improve the precision of single pulse CARS temperature measurements. Finally, the incorporation of some recent advances in CARS theory which have resulted in more computationally efficient algorithms for calculating theoretical CARS spectra and their effect on the accuracy of temperature measurements are discussed. Author

N87-21175# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
APPLICATION OF CARS THERMOMETRY TO A TURBULENT FLAME [APPLICATION DE LA METHODE DRASC A LA MESURE DE LA TEMPERATURE DANS UNE FLAMME TURBULENTE]
PHILIPPE MAGRE, PIERRE MOREAU, GERARD COLLIN, and MICHEL PEALAT *In* AGARD Advanced Instrumentation for Aero Engine Components 19 p (SEE N87-21170 14-31) Nov. 1986 In FRENCH; ENGLISH summary
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The good spatial and temporal resolution of broad-band Coherent Anti-Stokes Raman Spectroscopy (CARS) diagnostic is suitable for turbulent flows and allows instantaneous temperature measurements in the reaction zone. From these instantaneous values, temperature probability density functions (PDF) are built. CARS thermometry is applied to a high velocity premixed flame. The combustion of an air-methane flow (u approx. equal to 55 m/s, T approx. equal to 560 K, equivalence ratio = 0,8) in the combustor is ignited and stabilized by a parallel flow of hot gases (u approx. equal to 110 m/s, T approx. equal to 2000 K). The mixing of the two flows without combustion (equivalence ratio = 0) is also studied as well as combustion stabilized by a step replacing the hot gases. Author

N88-29910# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
COMBUSTION AND FUELS IN GAS TURBINE ENGINES
Jun. 1988 515 p In ENGLISH and FRENCH Symposium held in Chania, Greece, 19-23 Oct. 1987
(AGARD-CP-422; ISBN-92-835-0465-8; AD-A202495) Avail: NTIS HC A22/MF A01

The attention of combustor designers and researchers has focused upon two main factors: the identification of the significance of fuel degradation upon combustion design and performance, and the potential prizes to be gained by the development of better design techniques. The aim of the conference was to review progress made in these areas under four main subject headings: namely, alternative fuels and fuel injection, combustor development, soot and radiation, and the development of mathematical models for the design of gas turbine combustors. For individual titles, see N88-29911 through N88-29951.

N88-29912# Illinois Univ., Urbana-Champaign. Dept. of Mechanical and Industrial Engineering.
ALTERNATIVE FUEL SPRAY BEHAVIOR
J. P. ASHEIM and J. E. PETERS *In* AGARD, Combustion and Fuels in Gas Turbine Engines 16 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The effects of alternative fuels on the combustion characteristics of a liquid fuel sprays were examined. Fuel properties were systematically varied and the effects of these variations on the structure of the spray flames were calculated. In addition, a comparison was made of the differences in two spray flames fueled by the standard NATO F-40 fuel and a proposed alternative fuel, the AGARD Research Fuel. The calculations were performed using a reacting, two phase, two-dimensional flow code which utilizes a Lagrangian calculation of droplet trajectories and an Eulerian approach for the gas phase flow field. Interactions between the drops and the gas phase were accomplished through the particle in cell technique with exchange of mass, momentum and energy between the two phases. A global reaction scheme was used with the reaction rate determined by the minimum of either an Arrhenius rate or mixing rate. Fuel property changes which affect droplet size and volatility were shown to have significant effects on droplet trajectory patterns. However, for the flow field examined, these trajectory changes only moderately modify the fuel vaporization pattern within the spray. Author

N88-29913# Purdue Univ., West Lafayette, IN. School of Mechanical Engineering.
ATOMIZATION OF ALTERNATIVE FUELS
ARTHUR H. LEFEBVRE *In* AGARD, Combustion and Fuels in Gas Turbine Engines 14 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The influence of atomization quality on several key aspects of combustion performance is reviewed. The performance parameters considered include combustion efficiency, lean blowout, and lean lightup, and also the pollutant emissions of carbon monoxide, unburned hydrocarbons, oxides of nitrogen, and smoke. The fuel properties of importance are described and equations are presented for estimating the effects of changes in fuel properties on spray characteristics for the main types of fuel nozzle employed in aero gas turbines, namely plain orifice, pressure swirl, and airblast atomizers. The anticipated effects on atomization of changes from conventional to alternative fuels is discussed. Author

N88-29914# Centre d'Etudes et de Recherches, Toulouse (France).
SIMULATION STUDY OF SPRAYING, STREAMING AND VAPORIZATION PHENOMENA ASSOCIATED WITH FUEL INJECTION [ETUDE PAR SIMULATION DES PHENOMENES DE PULVERISATION, DE RUISSELEMENT ET DE VAPORISATION LIES A L'INJECTION DE CARBURANT]
P. HEBRARD and G. LAVERGNE *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p (SEE N88-29910 24-25) Jun. 1988 In FRENCH
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Combustion modeling requires a knowledge of the limit conditions and the physical models that can often be provided only through experience. Such an experimentally-based approach for studying injection-associated phenomena, involving simulation starting from experimental measurements, is presented. An evaluation of the performances of the different types of injectors used in the combustion chambers is carried out through particle size analysis: local distribution of size, the Sauter mean diameter, and measurements of drop concentration. Models describing the phenomena of evaporation, acceleration and impact of drops on a hot wall were tested experimentally. The modeling of premixed fuel injection with a prevaporization type injector is discussed as an example of a modeling approach using experimental results. Author

N88-29915# Karlsruhe Univ. (Germany, F.R.). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.
TURBULENCE EFFECTS ON THE DROPLET DISTRIBUTION BEHIND AIRBLAST ATOMIZERS
S. WITTIG, W. KLAUSMANN, and B. NOLL *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p (SEE N88-29910 24-25) Jun. 1988 Sponsored in part by the Forschunbsvereinigung Verbrennungskraftmaschinen, e.V., and German National Science Foundation, Fed. Republic of Germany
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Turbulent fluctuations of the airflow in gas turbine combustion chambers have decisive influence on the mixing of fuel droplets and air both in premixing regions and primary zones. Detailed measurements in a recirculating, droplet charged airflow in a combustor model are conducted with an optical diffraction type particle sizer. These investigations yield information about the local fuel concentrations as well as the local concentration weighted diameter distributions under cold and hot airflow conditions. The spray is produced by a prefilming airblast nozzle, which is built

into the combustor model. The calculation of the above mentioned quantities using a new computational model shows that in considering turbulence fluctuations significant improvement of the results is obtained and excellent agreement between predicted and measured values is achieved. Therefore, the results indicate that turbulence can be one of the major influencing parameters on droplet distribution. Author

N88-29916# United Technologies Research Center, East Hartford, CT.
NOZZLE AIRFLOW INFLUENCES ON FUEL PATTERNATION
T. J. ROSFJORD and W. A. ECKERLE (Clarkson Univ., Potsdam, N.Y.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 12 p (SEE N88-29910 24-25) Jun. 1988 Previously announced in IAA as A88-44765
(Contract F33615-85-C-2515)
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The velocity and turbulence levels downstream of eight variations of a model gas turbine, aerating, fuel nozzle were measured. The nozzle configurations were assemblies which purposefully altered the airflow in a swirler or contouring swirl vane trailing edges. Data were acquired by a traversing, two component laser velocimeter in planes 0.060 in. or 2.50 in. downstream from the nozzle exit. Analyses of these data indicated that very symmetric flow fields can be produced. Such control was easier to achieve for the airflow than the fuel, supporting the position that nozzle patternation quality was more dependent on the fuel distribution in the nozzle. The presence of swirler wakes could always be discerned at the nozzle exit; the extreme variations imposed by coarse swirlers could dominate the flow. Such airflow influences were not apparent in the velocity profiles at downstream locations. However, their influence in convecting a higher fuel mass flux persisted from the nozzle exit and produced extreme variations in the spray pattern. Author

N88-29917# National Research Council of Canada, Ottawa (Ontario). Div. of Mechanical Engineering.
MULTIPLE SCATTERING EFFECTS IN DROP SIZING OF DENSE FUEL SPRAYS BY LASER DIFFRACTION
OEMER L. GUELDER *In* AGARD, Combustion and Fuels in Gas Turbine Engines 15 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Practical schemes to correct the effect of multiple scattering in a dense drop field on the measured distribution parameters by laser light scattering based spray sizing techniques are presented. An experimental study, involving multi-modal distributions and drop field which can not be adequately described by single mode two parameter distribution, is described. Data from the experimental program were employed to develop empirical expressions to correct the measured spray parameters at high obscuration levels. Accuracies of the proposed expressions are acceptable for engineering applications, and comparable to the accuracies involved in conversion of light scattering data to drop size information. Author

N88-29918# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
INFLUENCE OF OPERATING CONDITIONS ON THE ATOMIZATION AND DISTRIBUTION OF FUEL BY AIR BLAST ATOMIZERS
M. CAO, H. EICKHOFF, F. JOOS, and B. SIMON (Technische Univ., Munich, West Germany) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 8 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by the Federal German Ministry of Research and Technology, Berlin
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The performance of a gas turbine combustion chamber depends essentially on the distribution of the fuel in the primary zone. Ignition, stability of combustion, wall temperatures, and smoke and pollutant emission are all affected. Maintaining a fixed geometry, the droplet size and spray angle under variation of the air pressure drop at constant temperature were measured using two test liquids in an air blast atomizer system. Correlation equations were provided for both variables. Known correlations were confirmed for the droplet size. The spray angle is pressure related, increasing very rapidly with increasing pressure. Author

N88-29919# Cranfield Inst. of Tech., Bedford (England). School of Mechanical Engineering.
SPRAY PERFORMANCE OF A VAPORIZING FUEL INJECTOR
A. K. JASUJA and H. C. LOW (Rolls-Royce Ltd., Bristol, England) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The spray performance of a vaporizer fuel injector of a type that has accumulated extensive service experience in sub- and super-sonic commercial and military aircraft applications is examined. Spray performance data covers a wide range of operating conditions including the effects of fuel quality as well as the atomizing air temperature. The objective is to further not only the current level of understanding regarding the fundamental functional aspects of vaporizer technology but also the data base for future designs. Author

N88-29920# Laval Univ. (Quebec). Dept. du Genie Mecanique.
THE CHARACTERIZATION OF COMBUSTION BY FUEL COMPOSITION: MEASUREMENTS IN A SMALL CONVENTIONAL COMBUSTOR
D. KRETSCHMER and J. ODGERS *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by National Defence Canada
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

In a continuing program on the effects of fuel properties on combustion, some 20 pure hydrocarbons and synthesized fuels were tested at atmospheric conditions in a one third scale version of an aircraft type combustor. This combustor used a Simplex type pressure jet atomizer. Each fuel was burned over a range of air-fuel ratios, and at each condition, a full exhaust gas analysis was done, exhaust temperature distribution was measured, as also weak extinction. The results and their implications are discussed. Author

N88-29921# Office National d'Etudes et de Recherches Aerospatiales, Palaiseau (France).
FLAME STABILIZATION IN A REHEAT COMBUSTOR
A. CADIOU *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p (SEE N88-29910 24-25) Jun. 1988 In FRENCH; ENGLISH summary
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

In a reheat burner, combustion is stabilized with flameholders. The stabilization depends on the following parameters: Mach number, temperature, pressure and equivalence ratio of the flow, flameholder geometry. Many experimental measurements have allowed the calculation of a correlating parameter including the Mach number and the temperature. For the geometry, studies on linear stabilizers in two-dimensional flows have shown that the height of the stabilizer is a convenient parameter. An accurate experimental study of the recirculation zone downstream annular flameholders in a axisymmetric flow have pointed out the effect of another geometrical parameter, the diameter of the flameholder. The experimental results have improved the knowledge of the flame stabilization mechanism downstream annular flameholders. Author

N88-29922# Rolls-Royce Ltd., Bristol (England)
HIGH PERFORMANCE TURBOFAN AFTERBURNER SYSTEMS
A. SOTHERAN *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The modern turbofan afterburner is characterized by its high boost and efficiency and by its compact geometry which is achieved by locating the flameholding baffles immediately downstream of the turbine exhaust plane of the engine core and bypass gas stream. At the confluence, the stream divider may be a simple cylinder or it may be of lobed configuration to encourage mixing between the two gas streams in the downstream jet pipe in order to improve the unboosted thrust of the engine. The geometry of the afterburner hardware must be adapted to suit the choice of mixed or unmixed configurations. In flight, selection of the afterburner must be fast and reliable under all flight conditions with times to full thrust of the order of only a second or two. Both the light up and the subsequent acceleration to full thrust are expected to be smooth with no excessive initial thrust jump. Synchronization and matching of the afterburner fuel with the variable final nozzle must be accurate at all times to maintain the

engine turbomachinery on its required running lines. The afterburner must always be free of combustion driven pressure oscillations which can occur either in cross stream modes or in longitudinal modes, both of which can be mechanically damaging and, in some cases, cause fan surge and other intolerable effects in the engine. The afterburner must incorporate appropriate measures to avoid various potential thermal problems including fuel boiling and gumming in the supply manifolds and excessive heat transfer to the jet pipe and aircraft engine bay. Author

N88-29923# Technische Univ., Munich (Germany, F.R.). MTU Motoren- und Turbinen-Union.
COMPARISON OF THE PERFORMANCE OF A REVERSE FLOW ANNULAR COMBUSTION CHAMBER UNDER LOW AND HIGH PRESSURE CONDITIONS
F. JOOS and B. SIMON *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by the Federal German Ministry of Research and Development, Berlin
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Combustor development testing is usually carried out under different pressure conditions; low pressure burning test for the optimization of the fuel distribution inside the combustor and high pressure tests for demonstrating the desired performance. Comparison of the results under these two test conditions often reveal discrepancies, especially in wall temperatures and exit temperature patterns, which cannot be attributed simply to the greater flame radiation and heat release rate associated with the tests at high pressure. Another cause, in particular, lies in differences in the fuel distribution in the primary zone as a function of pressure conditions. This phenomenon is demonstrated by measurements and 3-D 2-phase flow field calculations. Author

N88-29924# Imperial Coll. of Science and Technology, London (England). Fluids Section.
FLOW CHARACTERISTICS OF A MODEL ANNULAR COMBUSTOR
A. F. BICEN, D. TSE, and J. H. WHITELAW *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by Rolls Royce Plc and the Ministry of Defence, United Kingdom
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Measurements are reported of the velocity and passive scalar characteristics of the isothermal flow in a model combustor which comprises a T-vaporizer and two rectangular sectors of an annular combustor similar to one used in small gas turbine engines. Mean temperatures were also obtained in a reacting flow with an overall equivalence ratio similar to that of takeoff conditions. The results were obtained with a combination of laser velocimetry, thermocouples and probe techniques and quantify the effects of flow asymmetries in the vaporizer fuel arrangement and of different alignments of the primary holes with respect to the vaporizer position. Flow visualization results are also included to indicate the general features of the combustor flow. Author

N88-29925# Southwest Research Inst., San Antonio, TX.
FUEL EFFECTS ON FLAME RADIATION AND HOT-SECTION DURABILITY
C. A. MOSES and P. A. KARPOVICH (Naval Air Propulsion Test Center, Trenton, N.J.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 16 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The results of combustor experiments relating to fuel effects on combustor durability are summarized and analyzed with respect to Navy aircraft operations and maintenance. By combining life ratio models with data on mission profiles, models were developed that predict the impact of flying an aircraft on a fuel of reduced hydrogen content in terms of the combustor life lost in flying a typical mission. To determine the effect of decreasing hydrogen content on maintenance requirements, the life ratio models were combined with data obtained from maintenance depots on combustor life along with information on the importance of combustor life in determining engine overhaul schedules. From this, it was possible to identify which engines or aircraft would be most affected by decreases in hydrogen content, and at what point increases in maintenance requirements are likely to be realized. Author

N88-29926# California Univ., Irvine. Combustion Lab.
THE PERFORMANCE OF A SURROGATE BLEND IN SIMULATING JP-4 IN A SPRAY-FUELED COMBUSTOR
G. S. SAMUELSEN and C. P. WOOD *In* AGARD, Combustion and Fuels in Gas Turbine Engines 6 p (SEE N88-29910 24-25) Jun. 1988 Sponsored in part by the Naval Air Propulsion Center
(Contract F08635-86-C-0309)
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

A surrogate fuel was developed to simulate the atomization and combustor performance of a practical distillate JP-4. The surrogate is comprised of 14 pure hydrocarbons and formulated based on the distillation curve and compound of the distillate parent. In previous work, the atomization performance (evaluated in terms of the atomization quality in an isothermal chamber), and the combustor performance (evaluated in terms of the velocity and thermal fields in a spray fueled combustor) were found to be equivalent for the parent and surrogate JP-4. The sooting performance of the two fuels is addressed, as well as two reference fuels (a JP-5 and isooctane) of purposefully disparate properties. The sooting performance of the parent and surrogate JP-4 are nearly identical, and distinctly different from that of either the JP-5 or the isooctane. The surrogate represents, as a result, an attractive fuel blend for the study of fuel compositional effects on the sooting performance of petroleum fuels in spray fueled combustor. Author

N88-29927# Michigan Univ., Ann Arbor. Dept. of Aerospace Engineering.
RADIATION FROM SOOT-CONTAINING FLAMES
G. M. FAETH, J. P. GORE, and Y. R. SIVATHANU *In* AGARD, Combustion and Fuels in Gas Turbine Engines 12 p (SEE N88-29910 24-25) Jun. 1988
(Contract NBS-60-NAN-135D-0576)
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The thermal radiation properties of turbulent soot containing diffusion flames are considered, treating: scalar structure, excluding soot; soot properties; and turbulence/radiation interactions. The laminar flamelet concept, implying universal correlations of scalar properties as a function of mixture fraction appears to be effective for estimates of scalar structure needed for analysis of flame radiation. Extension of the laminar flamelet concept to soot volume fractions was also encouraging; however, universality is cruder than for gas properties due to effects of finite rate chemistry. Turbulence/radiation interactions were studied by comparing radiation perdictions based on statistical simulation of scalar properties along a radiation path (stochastic analysis) with conventional results using time averaged properties along the path. Stochastic predictions of spectral radiation intensities are found to be 40 to 100 percent higher than mean property predictions in luminous turbulent diffusion flames, suggesting significant effects of turbulence/radiation interactions. Author

N88-29928# Cranfield Inst. of Tech., Bedford (England). School of Mechanical Engineering.
FLAMELET CHEMISTRY MODELLING OF SOOT FORMATION FOR RADIATION
J. B. MOSS, C. D. STEWART, and K. J. SYED *In* AGARD, Combustion and Fuels in Gas Turbine Engines 12 p (SEE N88-29910 24-25) Jun. 1988 Sponsored in part by Ministry of Defence, Pyestock, United Kingdom, Science and Engineering Research Council and British Gas, United Kingdom
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The development of generalized models for radiative heat transfer in the gas turbine requires the detailed prediction of the turbulent scalar fields, most notably for temperature, the principal gaseous species and particulate soot. Mixing limited descriptions of the turbulent combustion process have proved quite successful in modeling the effects of heat release on the flow field. However, the chemical aspects of the problem, fuel specific features and the multi component composition, are poorly reproduced. Laminar flamelet modeling currently offers the best prospect for incorporating realistic complex chemistry into the computations. A strategy is described to extend laminar flamelet modeling of turbulent non-premixed hydrocarbon combustion to include a simplified mechanism for soot formation. In the absence of a widely applicable multistep kinetic mechanism the formation rate must be inferred from detailed measurement but comparatively comprehensive flow field modeling is necessary to distinguish fluid

mechanic and chemical kinetic effects and hence interpret the observations in model terms. Author

N88-29929# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of mechanical Engineering.
RADIATION TRANSFER IN GAS TURBINE COMBUSTORS
M. G. CARVALHO and P. J. M. COELHO *In* AGARD, Combustion and Fuels in Gas Turbine Engines 22 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by Instituto Nacional de Investigacao Cientifica, Lisbon, Portugal
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The prediction of the local flow, heat transfer and combustion processes inside a three-dimensional can combustor chamber of a gas turbine is presented. A 3-D numerical solution technique is used to solve the governing time averaged partial differential equations and the physical modeling for the turbulence, combustion and thermal radiation. The heat transfer modeling is emphasized. A method to calculate the distribution of temperature, radiative heat flux and total heat flux of the liner is described. The implications of neglecting radiative heat transfer in gas turbine combustion chamber calculations are discussed. The influence of working pressure on the radiative heat transfer is investigated comparing the radiative heat flux and the temperature distribution of the liner for three different working pressures: 5, 15 and 25 bar. Author

N88-29930# Royal Aircraft Establishment, Farnborough (England). Propulsion Dept.
GAS TURBINE SMOKE MEASUREMENT: A SMOKE GENERATOR FOR THE ASSESSMENT OF CURRENT AND FUTURE TECHNIQUES
S. P. GIRLING *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Smoke measurement from gas turbine engines is one instrumentation technique that remains, literally, a black art. Current methods are inaccurate, slow, insensitive and unable to detect transients. A smoke generator was developed capable of generating by pyrolysis of aviation kerosene, stable levels of smoke for prolonged periods, representative of that from engines. Particle size measurements have enabled the comparison of smokes from different sources and provided a greater understanding of the problems of representative sampling using currently approved methods. Several alternative measurement techniques were evaluated using the smoke generator, precluding the need for expensive engine testing. This has promoted research into instrumentation that will give a truer indication of particulate criteria of interest to the engine designer and customer, for example truer visibility and erosiveness. Author

N88-29931# Karlsruhe Univ. (Germany, F.R.). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.
PARTICLE SIZE MEASUREMENTS IN SOOTING COMBUSTION SYSTEMS
S. WITTIGN and H.-J. FELD *In* AGARD, Combustion and Fuels in Gas Turbine Engines 11 p (SEE N88-29910 24-25) Jun. 1988 Sponsored in part by Stiftung Volkswagen AG, Fed. Republic of Germany
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Radiation effects caused by the presence of soot particles are of dominant influence in gas turbine combustors, especially on the stress distribution in the flame tube. In studying the two-phase flow within and after the combustor experimentally, a wide spectrum of soot particle and fuel droplet sizes is to be considered. Two optical measuring techniques were used throughout. First, the dispersion quotient (DQ) technique was applied to determing the size of the early soot particles, i.e., in the small-diameter range. The second method, the well established Multiple-Radio-Single-Particle Counter (MRSPC), was used to measure the larger particle sizes, i.e., fuel droplets and soot. Furthermore, attention was focused on data acquisition- and analysis-techniques. Experimental results were obtained from measurements in a combustor with high concentration of soot particles and in the exhaust gas of a gas turbine. Author

N88-29932# Technische Hochschule, Darmstadt (Germany, F.R.). Inst. fuer Physikalische Chemie.
LARGE IONIC SPECIES IN SOOTING ACETYLENE AND BENZENE FLAMES
PH. GERHARDT, K. H. HOMANN, S. LOEFFLER, and H. WOLF *In* AGARD, Combustion and Fuels in Gas Turbine Engines 11 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by Deutsche Forshcungagemeinschaft and Fonde der Chemischen Industrie, Fed. Republic of Germany
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Ionic species with masses from 24 to 10,000 u were studied in premixed, fuel-rich, low-pressure acetylene and benzene flames by means of a time-of-flight mass spectrometer. Total positive and negative ion concentrations in the flame were also determined by sampling ions from a beam. The mass spectrum of positive poly-yne ions corresponds to two different Poisson distributions for the groups C sub 2nH sub 3(+) and C sub 2n + 1H sub 3(+) respectively. THese ions are not related to soot formation. The growth of polycyclic aromatic hydrocarbon ions, however, could be followed up to a mass of about 2000 u where coagulation started resulting in ions of about 4000 u which then grew further. The relative volume fractions of charged and neutral soot was determined using a method of soot deposition in vacuum. The results can be interpreted by a partial-equilibrium model. Polyhedral carbon ions were detected as a completely new class of flame ions similar to those found in the laser-evaporation of graphite. The C sub 60(+) is the dominant positive ion of this group, while C sub 50(+) and a broad distribution of C sub 2n(-) with 2n up to about 210 are characteristic for the negative polyhedral ions. Author

N88-29933# Leeds Univ. (England). Dept. of Fuel and Energy.
RATES OF FORMATION OF SOOT FROM HYDROCARBON FLAMES AND ITS DESTRUCTION
J. MULLINS, B. SIMMONS, and A. WILLIAMS *In* AGARD, Combustion and Fuels in Gas Turbine Engines 14 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by IEA, Lucas-CAV Ltd, British Gas Plc and SERC, United Kingdom
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The equations that were proposed in the literature to describe the rate of soot formation in hydrocarbon flames are surveyed. Recent work using a shock tube to measure soot formation rates is outlined and the correlation equation proposed compared with that of other workers. Data on the rate of combustion of soot particles are also outlined and combined with recent measurements to give an overall soot oxidation rate expression. The two equations are combined to give an expression suitable to describe soot formation and burn out for gas turbines and tested to a limited degree. Author

N88-29934# Goettingen Univ. (Germany, F.R.). Inst. fuer Physikalische Chemie.
THE INFLUENCE OF PRESSURE ON SOOT FORMATION
H. GG. WAGNER *In* AGARD, Combustion and Fuels in Gas Turbine Engines 11 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The influence of pressure on soot formation was investigated for pyrolysis, premixed flames, and diffusion flames. Detailed kinetic studies are available for the first two. It is shown that the essential steps: particle inception, induction time (tau), coagulation, and surface growth remain similar for different pressures, also the influence of temperature on the maximum amount of soot formed. Tau for pyrolysis depends on the carbon density, strongly on temperature, and only slightly on pressure. The coagulation rate constant decreases slightly towards higher pressures. The amount (f sub v) of soot formed per cubic cm for a given fuel-air mixture increases with pressure P like P sup n, n was found for C(sub 2)H(sub 4)-air up to 3, for other fuels near one, it depends on pressure. Larger (f sub v) means larger soot particles, larger radiation losses and longer oxidation time at a given temperature and therefore higher chance for smoke emission. Author

N88-29935# General Electric Co., Cincinnati, OH. Aircraft Engines.
NUMERICAL MODELS FOR ANALYTICAL PREDICTIONS OF COMBUSTOR AEROTHERMAL PERFORMANCE CHARACTERISTICS
D. L. BURRUS, W. SHYY, and M. E. BRAATEN (General Electric Co., Schenectady, N.Y.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 25 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

An overview of the work performed at GE Aircraft Engines under an ongoing program to develop and improve the sophisticated analytical models for the design and analysis of aircraft turbine engine combustors is presented. This effort has focused on the full three-dimensional (3-D) elliptic combustor internal flow model. The objectives of the program are reviewed. The progress made in the past five years is discussed starting with the initial application and assessment of first generation 3-D combustor models based on cartesian grids, progressing to the development and recent application of an improved second generation 3-D combustor model based on a body fitted generalized curvilinear grid. Finally, a brief review of planned future modeling activities to be conducted under this program will be discussed. Author

N88-29936# General Motors Corp., Indianapolis, IN. Gas Turbine Div.
GAS TURBINE COMBUSTION MODELING Status Report
HUKAM C. MONGIA *In* AGARD, Combustion and Fuels in Gas Turbine Engines 14 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

To effectively use multidimensional models for gas tubine combustor design and development activities, a method is presented to compute aerothermal performance parameters including CO, unburned hydrocarbon, NOx and smoke emissions; lean blowout and ignition fuel/air ratios, and pattern factor. To further improve modeling accuracy, advances are required in numerics and physical submodels of turbulence and spray transport processes. A status report is presented on the ongoing Allison modeling activities. Author

N88-29937# Sheffield Univ. (England). Dept. of Chemical Engineering and Fuel Technology.
THREE-DIMENSIONAL GAS TURBINE COMBUSTOR MODELLING
P. N. WILD, F. BOYSAN, J. SWITHENBANK, and X. LU *In* AGARD, Combustion and Fuels in Gas Turbine Engines 14 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

A mathematical model of the finite difference type is employed to predict the three-dimensional reacting flows within realistic combustor geometries. Both algebraic stress and k-epsilon submodels were employed for turbulence, together with combustion models of the Magnussen type and a detailed fuel spray model. A Lagrangian type model for the calculation of residence time distribution has also proved useful in validating the predicted flow fields. Modeling is carried out for a cylindrical combustor can and for a sector of an annular gas turbine burner. Both of these possess swirl stabilized primary zones. Experimental measurements of gas velocity, combustor resistence time distribution, composition and temperature were employed for model validation and results obtained to date were encouraging. Author

N88-29938# Karlsruhe Univ. (Germany, F.R.). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.
ON THE APPLICATION OF FINITE-DIFFERENCE TECHNIQUES FOR THE COMPUTATION OF THE FLOW FIELD IN GAS TURBINE COMBUSTORS WITH COMPLEX GEOMETRIES
S. WITTIG, H.-J. BAUER, and B. NOLL *In* AGARD, Combustion and Fuels in Gas Turbine Engines 14 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by German National Science Foundation, Fed. Repuulic of Germany
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

A finite-volume method is presented for solving the time-averaged two-dimensional Navier-Stokes equations in non-orthogonal curvilinear coordinates. In contrast to most existing codes, a non-staggered grid is employed for the discretization of the momentum equations avoiding the onset of pressure and velocity ocsillations by additional steps. In a first step, turbulent transport is taken into account by the standard k, -model. As a test-case, the turbulent flow through a model combustor with variable cross-sectional area and dilution air jets is considered. The results of the computations are compared with measurements as well as with finite-difference calculations of other available codes utilizing orthogonal coordinates especially adapted for this geometry. The advantages of the new non-orthogonal approach are demonstrated. It is shown that the proposed mathematical model serves as a powerful tool for the computation of turbulent separated flows in ducts with complex geometries pertinent to modern gas turbine combustors, especially those of the reverse-flow type. Author

N88-29939# Politecnico di Milano (Italy). Dipt. di Energetica.
NUMERICAL MODELING OF COMBUSTION PROCESSES IN GAS TURBINES
L. GALFETTI, M. BELLI, and C. BRUNO (Consiglio Nazionale delle Ricerche, Peschiera Borromeo, Italy) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 14 p (SEE N88-29910 24-25) Jun. 1988 Prepared in cooperation with National Center for Energetics and Propulsion, Peschiera Borromeo, Italy
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The indications coming from fundamental turbulence research were incorporated in combustor modeling without a systematic analysis of their effect on predictions. Comparisons are presented between finite rate (overall) kinetics and equilibrium in their influence on the structure of the recirculation region attached to a disk flame-holder. The effect of including density gradient terms in the k-epsilon turbulence model is also examined. The results indicate that the fluid dynamic field may determine whether equilibrium or kinetics produces higher temperatures, and that the temperature difference predicted with the two approaches tends to become small with increasing pressure. The effect of introducing density gradients has a moderate effect on temperature. Author

N88-29940# Imperial Coll. of Science and Technology, London (England). Fluids Section.
THREE-DIMENSIONAL COMBUSTOR PREDICTORS: A COMPARISON OF EQUILIBRIUM AND LAMINAR FLAMELET CHEMISTRY MODELS
J. J. MCGUIRK *In* AGARD, Combustion and Fuels in Gas Turbine Engines 11 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Numerical calculations are reported for the three-dimensional reacting flow inside a can-type combustor geometry. Several flow features found in current combustor designs are included, a swirl driven primary zone and a single row of radially inward dilution air jets. The particular aspect of the mathematical formulation given special attention concerns the mode for the chemical reaction. Alternative descriptions of the instantaneous thermochemistry are adopted which correspond to either full chemical equilibrium or the laminar flamelet approach. In the latter case the flamelet structure is taken over from published calculations of laminar propane-air diffusion flames. All other aspects of the mathematical model such as numerical discretization and solution algorithm, turbulence model and turbulence/chemistry interaction are common in the predictions obtained (the two k-epsilon model and a beta-probability density function (pdf) were used). The results obtained indicate that the predicted flow patterns are essentially the same for both chemistry models, even though differences of almost 100 percent are observed for the density field. The predictions with both models indicate, however, a deficiency in the representation of CO burn out and it is probable this will require an alternative chemistry description. Finally, although the calculations have used an unstrained laminar flame description, predictions of the mean scalar dissipation rate are presented to assess the likelihood of local quenching due to flame stretching. Author

N88-29941# National Technical Univ., Athens (Greece). Thermal Engineering Section.
THE EFFECT OF PARTICLE PROPERTIES ON RADIATIVE HEAT TRANSFER
EM. KAKARAS, M. FOUNTI, and N. PAPAGEORGIOU *In* AGARD, Combustion and Fuels in Gas Turbine Engines 7 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Radiative heat transfer in combustion chambers is strongly influenced by the presence among the gaseous combustion products of solid particles of various size and chemical composition such as soot, char, and fly-ash. The particle parameters of these products are of great importance for the calculation of radiative heat transfer and insufficient knowledge of their magnitude can often lead to erroneous simplifications. The importance of absorption or scattering phenomena in radiative transfer is also sometimes misinterpreted. It is the aim of this work to provide computational data in order to demonstrate and explain the importance of solid particles, present in the combustion products, on absorption and scattering phenomena occurring in the radiative heat transfer. Author

N88-29942# Centre National de la Recherche Scientifique, Chatenay-Malabry (France).
FLAMELET MODELING OF TURBULENT PREMIXED FLAMES
N. DARABIHA, V. GIOVANGIGLI, A. TROUVE, S. M. CANDEL, and E. ESPOSITO *In* AGARD, Combustion and Fuels in Gas Turbine Engines 17 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by Societe Nationale d'Etude et de Construction de Moteurs d'Aviation and DRET, France Prepared in cooperation with Ecole Centrale des Arts et Manufactures, France
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Some aspects of the effort to analyze turbulent combustion on the basis of an extension of the coherent flame model initially proposed by Marble and Broadwell are described. At this stage the model comprises a local description (flamelets) and a global representation of the turbulent flow-field including a balance equation for the mean flame area per unit volume. The flamelets are non-adiabatic premixed strained flames, a model suggested by Libby, Linan, and Williams. Complex chemistry calculations were carried out for a large number of propane-air flames and a large data-vase of flamelets is being constructed. These calculations provide consumption rates, extinction, and ignition characteristics which are used in the global turbulent calculation to model the mean reaction terms. Numerical results obtained for turbulent premixed flames stabilized in a duct are discussed. Experiments performed on a model combustor provide distributions of the mean heat release rate. These distributions are compared with those determined numerically. This comparison indicates that the coherent flame description accounts for important features found in this experiment. Author

N88-29943# Centre d'Etudes et de Recherches, Toulouse (France).
MODELING THE STABILITY OF A TURBULENT PREMIXED FLAME, DOWNSTREAM FROM A STEP BY A LAGRANGIAN METHOD [MODELISATION DE LA STABILISATION D'UNE FLAMME TURBULENTE PREMELANGEE, EN AVAL D'UNE MARCHE PAR UNE METHODE LAGRANGIENNE]
A. GIOVANNINI *In* AGARD, Combustion and Fuels in Gas Turbine Engines 11 p (SEE N88-29910 24-25) Jun. 1988 In FRENCH
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Calculations are carried out for a backward facing step, by solving numerically the Navier-Stokes equations utilizing a Lagrangian method of singularity type. The combustion of premixed gas is modeled by utilizing the concept of a thin flame separating burning and mixing gases (treated as incompressible). The exothermicity of the reaction is represented with the aid of volumetric sources positioned in front of the flame. The advancement of the later is realized through advection, and normally with the combustion velocity as a function, not only of the thermodynamic mixing state, but also of the local curve of the front and of the front in its entirety. Thus, the combustion aerodynamics can be discussed from the point of view of coherent structures, and the velocities compared with the work of Pitz and Daily with and without chemical reaction. Author

N88-29944# Institut National de Recherche d'Informatique et d'Automatique, Valbonne (France).
NUMERICAL MODELLING OF PREMIXED FLAMES IN GASEOUS MEDIA
B. LARROUTUROU *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Numerical methods and numerical results for the propagation of premixed flame fronts in a two-dimensional gaseous flow are presented. The study is restricted to simple rectangular geometries, and considers both open and closed vessels. The methods use essentially finite-element approximations and adaptive gridding procedures. The results include curved flame propagation, cellular front instabilities and quenching phenomena due to non-adiabatic walls. Author

N88-29945# Centre National de la Recherche Scientifique, Poitiers (France).
GASEOUS PREMIXED FLAMES IN NON-UNIFORM FLOWS
P. CAMBRAY, B. DESHALES, and G. JOULIN *In* AGARD, Combustion and Fuels in Gas Turbine Engines 6 p (SEE N88-29910 24-25) Jun. 1988 Prepared in cooperation with Ecole Nationale Superieure de Mecanique et d'Aerotechnique, Poitiers, France
(Contract DRET-85/130)
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

A theoretical analysis led to an evolution law for a flame front propagating in a nonuniform flow when the scales of the nonuniformity of the flow are much larger than the flame thickness. This law gives the local burning velocity of the flame front as a function of the flame stretch which can be split in two parts, one accounting for the geometry of the front and the other for the nonuniformity of the flow. In such a law, all the physio-chemical properties of the mixture are lumped in only two scale factors. A theoretical determination of one of these two scale factors (i.e., the so-called Markstein length) is developed. An experimental test of the evolution law is presented in different flame and flow configurations, which leads to experimental values for the two scale factors in the case of lean propane-oxygen-nitrogen mixtures. Finally experimental and theoretical values are compared.
Author

N88-29946# Centre National de la Recherche Scientifique, Poitiers (France). Lab. d'Energetique et de Detonique.
MODELING AND EXPERIMENTAL STUDY OF A REACTIVE FLOW CONFINED WITH WELL INJECTION [MODELISATION ET ETUDE EXPERIMENTALE D'UN ECOULEMENT REACTIF CONFINE AVEC INJECTION PARIETALE]
P. BRUEL, M. CHAMPION, M. BOUTOUILI, and J. C. BELLET *In* AGARD, Combustion and Fuels in Gas Turbine Engines 9 p (SEE N88-29910 24-25) Jun. 1988 In FRENCH Prepared in cooperation with Ecole Nationale Superieure de Mecanique et d'Aerotechnique, Poitiers, France
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The combustion of premixed fuel injected into a two-dimensional channel is studied numerically and experimentally. In the case of a high injection rate, a model of turbulent combustion with second-order closure for mass and energy transport is developed taking into account prior results obtained in the case of reactive shear flows in a simpler structure. The corresponding code is tested by comparing one part with the exact solution from the case of a Couette flow, and the other part with the experimental results obtained from the velocity fields in a two-dimensional channel. Author

N88-29947# Racal Defence Electronics (Radar) Ltd., Walton-on-Thames (England).
MODELLING OF CO OXIDATION IN DILUTION JET FLOWS
P. V. CHLEBOUN, K. P. HUBBERT, and C. G. W. SHEPPARD (Leeds Univ., England) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 11 p (SEE N88-29910 24-25) Jun. 1988 Sponsored in part by Rolls-Royce Plc, United Kingdom
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

Existing equilibrium chemistry and laminar flamelet computer codes are inadequate for calculation of post-flame carbon monoxide burn-up in gas turbine combustion chamber dilution zones. The amount of reaction occurring in such zones is small, but significant in terms of CO emissions, especially under low power conditions. A method was developed, based on a small departure from

equilibrium concept, which shows promise in modeling dilution zone carbon monoxide oxidation rate. The procedure, when incorporated into the Rolls-Royce PACE program, still only requires specification of a one-dimensional probability function and entails just one extra conservation equation. Output data were compared with those measured experimentally in an idealized dilution zone. Author

N88-29948# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
INFLUENCE OF THE CONVECTION ON EVAPORATION AND COMBUSTION OF A FUEL DROPLET
DOMINIQUE SCHERRER *In* AGARD, Combustion and Fuels in Gas Turbine Engines 8 p (SEE N88-29910 24-25) Jun. 1988 In FRENCH; ENGLISH summary
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

A numerical model is presented for the combustion of a droplet in a gaseous flow. The method is based on the integration of the unsteady balance equations in the two phases. It uses a finite volumes implicit scheme. The results for the vaporization law are compared with the empirical law of Ranz-Marshall: a good agreement is found only in the case of pure vaporizaton (without combustion) at a sufficient Reynolds number. The other results are the following: the data of the droplet is decreased by the vaporization; the unsteady effects in the gaseous phase become negligible with convection (except those due to finite rate reaction *which are not studied here); and the velocities inside the droplet* are not sufficient to neglect the unsteady effects due to heat tranfer in the liquid phase. Author

N88-29949# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
ANALYSIS OF THE FLOW THROUGH DOUBLE SWIRL AIRBLAST ATOMIZERS
E. BLUEMCKE, H. EICKHOFF, C. HASSA, and J. KOOPMAN *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

The flow field resulting from a counterswirl airblast atomizer was investigated numerically and experimentally. The flow pattern shows the typical features of a swirling flow with an inner recirculation zone. Comparison of calculated results with experimental data shows that general features of the flow can be predicted with reasonable accuracy. The propagation of the spray downstream from the atomizer was investigated theoretically using a deterministic flow model for the liquid phase. The predictions demonstrate the influence of operating conditions on the spray characteristics. Author

N88-29950# Laval Univ. (Quebec). Dept. du Genie Mecanique.
THE BEHAVIOUR OF SYNTHETIC FUELS IN A SMALL TRANSPARENT COMBUSTOR
J. ODGERS and D. KRETSCHMER *In* AGARD, Combustion and Fuels in Gas Turbine Engines 11 p (SEE N88-29910 24-25) Jun. 1988 Sponsored by Canadian National Defence and Canadian National Science and Engineering Research Council
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

In a continuing program on the effects of fuel properties on combustion, some 20 pure hydrocarbons and synthesized fuels were tested at atmospheric conditions in a small transparent combustor. This combustor used a very efficient air assist atomizer, such that droplet size was nearly constant. Each fuel was burned over a range of air/fuel rations, and at each condition, a full exhaust gas analysis was done, exhaust temperature distribution was measured, as also flame radiation and weak extinction. The results and their implications are discussed. Author

N88-29951# KHD Luftfahrttechnik G.m.b.H., Oberursel (Germany, F.R.).
A SMALL ANNULAR COMBUSTOR OF HIGH POWER DENSITY, WIDE OPERATING RANGE AND LOW MANUFACTURING COST
K. H. COLLIN *In* AGARD, Combustion and Fuels in Gas Turbine Engines 12 p (SEE N88-29910 24-25) Jun. 1988
(AGARD-CP-422) Avail: NTIS HC A22/MF A01

A short description will be given of the design and manufacturing philosophy, testing, and optimization of a combustion chamber. The features and design layout of the burner are characterized by the requirements for a low cost propulsion system for an unmanned flight vehicle, such as RPV and drones. Rig test results for the ignition and the performance over a wide operating range will be discussed. Ignition by hot gas from a cartridge as well as experience with testing this combustor in the demonstrator turbojet engine will be described. Author

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METALLIC MATERIALS

Includes physical, chemical, and mechanical properties of metals, e.g., corrosion; and metallurgy.

N86-16374# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AGARD CORROSION HANDBOOK. VOLUME 1: CORROSION, CAUSES AND CASE HISTORIES
W. WALLACE (National Research Council, Ottawa, Canada), D. W. HOEPPNER (Toronto Univ.), and P. V. KANDACHAR (Fokker, Schiphol, Netherlands) Jul. 1985 205 p refs
(AGARD-AG-278-VOL-1; ISBN-92-835-1505-6; AD-A160638)
Avail: NTIS HC A10/MF A01

A need exists to keep aircraft operators and maintenance personnel aware of the science and technology of corrosion as it applies to aircraft structures. Information is provided on the aircraft operating environment, corrosion theory, common airframe materials and their response to corrosion, the detection of corrosion, and methods employed to control corrosion in aircraft structures and materials. Also given are case histories of the deterioration or failure of components in typical aircraft and the means of detection are detailed and the remedical action taken Microbiological corrosion is also discussed. The handbook is intended to assist in the early diagnosis of developing corrosion problems and in the selection of appropriate corrective measures Author

N86-29245# Army Materials and Mechanics Research Center, Watertown, MA. Physical Metallurgy Branch.
DIRECTION OF R AND D AND CURRENT STATUS OF UNDERSTANDING OF ADVANCED GEAR STEELS
P. J. FOPIANO, J. E. KRZANOWSKI, and G. M CRAWFORD *In* AGARD Aircraft and Bearing Tribological Systems 15 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail NTIS HC A11/MF A01

High performance gears in the modern helicopter must operate at ever increasing torque and RPM. A major consequence of this increased torque and RPM is a significant increase in the surface temperature and increased scuffing of the gears. In response to this problem, Boeing-Vertol introduced a new class of steel (hot work tool steel) as a high performance aircraft gear steel and started a trend which all subsequent work has confirmed to be a correct decision. The three most prominent candidate critical high temperature aircraft gear steels including Vasco X-2M, CARTECH X-53 (PYROWEAR 53), and CBS600 are discussed. The heat treatment responses of these alloys will be compared. Three additional alloys (M50NiL, CBS1000M, and AMAX B) are discussed in less detail. Author

N87-24553# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AGARD CORROSION HANDBOOK, VOLUME 2: AIRCRAFT CORROSION CONTROL DOCUMENTS: A DESCRIPTIVE CATALOGUE
J. J. DELUCCIA, R. D. GERGAR, and E. J. JANKOWSKY (Jaylords, Inc., Philadelphia, Pa.) Mar. 1987 48 p
(AGARD-AG-278-VOL-2; AGARDOGRAPH-278;
ISBN-92-835-1545-5; AD-A181680) Avail: NTIS HC A03/MF A01

This is the second par. of a handbook of Aircraft Corrosion produced by the AGARD Structures and Materials Panel. This volume catalogs sources of information and requirements for corrosion control obtained from documents issued by NATO, France, UK, and US authorities. IATA (International Air Transport

Association) documents are also cited as a commercial reference. Author

N87-29641# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

SUPERPLASTICITY

Aug. 1987 201 p Lecture series held at Wright-Patterson AFB, Ohio, 8-9 Sep. 1987; in Luxembourg, 24-25 Sep. 1987; and in London, England, 28-29 Sep. 1987.

(AGARD-LS-154; ISBN-92-835-1557-9; AD-A191551) Avail: NTIS HC A10/MF A01

Several topics relating to superplasticity in metals are discussed. Superplastic sheet forming, bulk forming of superplastic alloys, cavitation and superplasticity, diffusion bonding of metals, mechanical properties of superplastically formed titanium and aluminum alloys, and designing for superplastic alloys are among the topics covered. For individual titles, see N87-29642 through N87-29649.

N87-29642# Cranfield Inst. of Tech., Bedford (England). School of Industrial Science.

SUPERPLASTICITY: AN OVERVIEW

ROGER PEARCE *In* Advisory Group for Aerospace Research and Superplasticity 24 p (SEE N87-29641 24-26) Aug. 1987

(AGARD-LS-154) Avail: NTIS HC A10/MF A01

An overview is given of superplasticity. Certain alloys, when deformed in tension at particular temperatures and strain rates, show very high elongations. This phenomenon is called superplasticity. Importantly, the flow stresses at which this phenomenon occurs are extremely low. There are two kinds of superplasticity: isothermal superplasticity (ISP) and cycling superplasticity (CSP). Only the former is dealt with here. For ISP, the alloy must possess an ultra-fine grain size which is relatively stable at greater than or equal to 0.5T sub m, where T sub m is the melting point of the lowest melting constituent in the alloy, in absolute units, while for CSP the alloy must be capable of being cycled through a phase change. Stable and unstable tensile flow, the relationship of m to total elongation, production and maintenance of ultrafine grains, dynamic recovery, crystallization, and forming techniques are among the topics discussed in more detail. Author

N87-29643# Washington State Univ., Pullman.

SUPERPLASTIC SHEET FORMING NATO/AGARD LECTURE SERIES ON SUPERPLASTICITY

C. H. HAMILTON *In* Advisory Group for Aerospace Research and Superplasticity 23 p (SEE N87-29641 24-26) Aug. 1987

(AGARD-LS-154) Avail: NTIS HC A10/MF A01

The exceptional ductility of superplastic alloys can be utilized in the shaping and forming of parts, components, and structures which could not be easily or economically produced by materials of more limited ductility. The forming methods which have been demonstrated for superplastic alloys include: blow forming, vacuum forming, thermo-forming, die-less drawing, deep drawing, forging, and superplastic forming with combined diffusion bonding. The technology of superplastic forming (SPF) has been found to benefit from modelling of the process, the results of which can guide the selection of pressurization parameters as well as predict the thinning characteristics and tendency to rupture. These concepts are reviewed. Concepts for minimizing or eliminating cavitation are also discussed. Author

N87-29644# Stanford Univ., CA. Dept. of Materials Science and Engineering.

BULK FORMING OF SUPERPLASTIC ALLOYS

OLEG D. SHERBY and ROBERT D. CALIGIURI *In* Advisory Group for Aerospace Research and Superplasticity 17 p (SEE N87-29641 24-26) Aug. 1987 Prepared in cooperation with SRI International Corp., Menlo Park, Calif. Sponsored in part by Navy and Army

(AGARD-LS-154) Avail: NTIS HC A10/MF A01

The commercial process of gatorizing is a prime example of a successful bulk forming process of a superplastic nickel-based alloy. In this case the one-step production of an integrated unit consisting of turbine blades with disk is achieved. This success is based on the high strain rate sensitivity inherent in superplastic materials. High strain rate sensitivity exponents, m, in crystalline solids can be achieved by one of two methods: the presence of ultra-fine grains or the presence of an internal stress. Ultra-fine grains lead to a high m value (m = 0.5) when the conditions of temperature and strain rate permit grain boundary sliding to be the dominating deformation process. On the other hand, internal stress, which is readily created by thermal cycling conditions in anisotropic expansion materials and in metal-matrix composites, leads to Newtonian viscous behavior (m = 1.0) and is attributed to a slip deformation process. Author

N87-29645# Manchester Univ. (England). Dept. of Metallurgy and Materials Science.

CAVITATION AND SUPERPLASTICITY

NORMAN RIDLEY *In* Advisory Group for Aerospace Research and Superplasticity 14 p (SEE N87-29641 24-26) Aug. 1987

(AGARD-LS-154) Avail: NTIS HC A10/MF A01

Cavitation occurs in many alloy systems during superplastic flow. Cavities either pre-exist or nucleate on grain boundaries and their subsequent growth, coalescence and interlinkage leads to premature failure. The presence of cavities in superplastically formed components to be used for load bearing applications is clearly undesirable. It is apparent that cavity growth is dominated by matrix plastic flow and that coalescence plays an important role in the development of large cavities. If cavitation damage is to be prevented, it is necessary to inhibit the nucleation event and to avoid the presence of pre-existing defects by careful control of the processing required to produce the superplastic microstructure. The influence that microstructural features and deformation conditions have on cavity nucleation is examined for a number of alloy systems. Cavitation can be eliminated by the application of a hydrostatic pressure during forming. This reverses the sense of the driving force for cavity growth. Cavitation damage can be prevented by superimposed pressures of 0.5 and 0.75 of the uniaxial flow stress, although lower levels of pressure can substantially reduce the extent of cavitation. Author

N87-29647# Royal Aircraft Establishment, Farnborough (England).

THE MECHANICAL PROPERTIES OF SUPERPLASTICALLY FORMED TITANIUM AND ALUMINIUM ALLOYS

P. G. PARTRIDGE, D. S. MCDARMAID, I. BOTTOMLEY, and D. COMMON *In* Advisory Group for Aerospace Research and Superplasticity 23 p (SEE N87-29641 24-26) Aug. 1987

(AGARD-LS-154) Avail: NTIS HC A10/MF A01

The behavior of aluminum and titanium alloys under superplastic forming conditions is well documented but there is less published data on the effect of the superplastic forming process on the mechanical properties. These data are essential for the design of structures. The effect of superplastic forming parameters such as temperature, strain rate, strain and post forming heat treatments upon the tensile, fatigue and fatigue crack growth performance of these alloys is reviewed and the mechanical property variations are related to changes in microstructure. During superplastic forming of aluminum alloys, intergranular cavities are formed with increasing strain, which degrades the material and reduces the mechanical properties. Ways to prevent cavitation during and after superplastic forming have been developed and the effect of these treatments on the mechanical properties is discussed. Author

N89-15267# Ecole Nationale Superieure des Mines, Valbonne (France). Centre dEtude de Mise en Forme des Materiaux

A COMPUTER PROGRAM SIMULATING THE HOT FORGING OF METAL POWDER

E. WEY, C. LEVAILLANT, and J. L. CHENOT *In* AGARD, Aerospace Materials Process Modelling 10 p (SEE N89-15262 07-31) Aug. 1988

(AGARD-CP-426) Avail: NTIS HC A12/MF A01

A computer program for the simulation of hot forging of metal powder was developed using a finite element technique. The constitutive equation for powder behavior includes viscoplastic effects and porosity. The relationship between flow stress and equivalent strain rate is given. This model involves also unilateral contact conditions friction with the dies. A remeshing module permits the calculation of very large deformation with complex dies. This simulation program is applied to the forging of an automotive part. The simulation allows one to optimize the die's geometry to achieve complete densification and good strain range everywhere in the worked piece. Author

N89-15268# Middle East Technical Univ., Ankara (Turkey). Dept. of Metallurgical Engineering.
MICROSTRUCTURES, FLOW PROPERTIES AND PROCESSING OF TI6242 ALLOY
ALPAY ANKARA and TAYLAN ALTAN (Ohio State Univ., Columbus.) *In* AGARD, Aerospace Materials Process Modelling 13 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

The physical phenomena that occurs during metal deformation process of Ti 6242 alloy is reviewed. Data on flow properties is obtained by compression tests. Also covered are the flow stress variations with the type of equipment used, deformation heating, effects of temperature, strain, strain rate and microstructural variations. Author

N89-15270# Ecole Nationale Superieure des Mines, Valbonne (France).
SUPERPLASTIC BEHAVIOUR OF SOME TI-6AL-4V ALLOYS INVESTIGATED BY TORSION TESTING
Y. COMBRES, C. LEVAILLANT, and F. MONTHEILLET (Ecole Nationale Superieure des Mines, Sainte-Etienne, France) *In* AGARD, Aerospace Materials Process Modelling 13 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

The work done at CEMEF in the past five years was to compare microstructurally different Ti-6Al-4V alloys and to set down their flow rules for further implementation in computer aided forming process design. Experiments were carried out on a torsion device. Torsion testing is particularly well adapted to the simulation of the forming processes such as rolling or forging. The modeling of isothermal forging and isothermal superplastic bulging are discussed. Author

N89-15271# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Gennevilliers (France).
THE FORGE 2 ISOTHERMAL FORGING MODEL [LE MODELE DE FORGEAGE ISOTHERME FORGE 2]
P. E. MOSSER and Y. GERMAIN *In* AGARD, Aerospace Materials Process Modelling 11 p (SEE N89-15262 07-31) Aug. 1988 In FRENCH, ENGLISH summary
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

A Forge 2 isothermal forging model is described which is based on a fluid-type formulation. The model employs the Tresca (Baque, 1973) friction-law, and is used to determine the friction coefficients. A method of the analysis of the ring test is presented. The isothermal forging variables of the compressor disk are numerically studied for the cases of the forging of actual TA6V specimens and model specimens of a Pb-Sn alloy. Even using simple rheological or tribological laws, the program makes possible the selection of the forging process variables on the basis of criteria such as the texture development and the distribution of deformations. Author

N89-15272# Liege Univ. (Belgium)
COMPUTER PREDICTION OF INTERNAL STRESSES DURING HEAT TREATMENT
D. ASSAKER and M. HOGGE *In* AGARD, Aerospace Materials Process Modelling 15 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

The problem of determining stresses due to thermal and transformation-induced volume changes during the quenching of hot steel bodies is investigated. Since there is no proper experimental way to determine the local stress field during the heat treatment, a finite element model that addresses this problem is developed, which allows for stress history knowledge and prediction of the residual stress field in the finished body. All thermophysical properties are temperature dependent. In case of steel bodies an additional parameter related to the cooling rate enables to localize microstructure state on a Continuous Cooling Transformation diagram. The efficiency of the model is demonstrated through a detailed computation of stresses in a quenched steel cylinder. Author

N89-15281# Cameron Force Co., Houston, TX.
THE APPLICATION OF PROCESS MODELLING TO HEAT TREATMENT OF SUPERALLOYS
R. A. WALLIS, N. M. BHATHENA, P. R. BHOWAL, and E. L. RAYMOND *In* AGARD, Aerospace Materials Process Modelling 15 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

Quenching experiments have been carried out with a flat disk having thermocouples embedded in it. Cooling curves from such tests have provided input data for an inverse heat conduction model which has been used to determine the relationship between the heat transfer coefficient and the part surface temperature for different quenching media. The coefficients obtained have been used in finite element models to predict the temperature and stress distribution within components during heat treatment. The quenching models were validated by trials carried out with instrumented subscale and full size turbine disk forgings. The models have been used to determine the quenching media required to give the cooling rates necessary to meet the property specifications for superalloy components. They have also been used, qualitatively, to reduce the residual stresses developed during quenching with a subsequent reduction in distortion problems during machining. A further application has been the elimination of cracking during the quenching of crack sensitive alloys. Author

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NONMETALLIC MATERIALS

Includes physical, chemical, and mechanical properties of plastics, elastomers, lubricants, polymers, textiles, adhesives, and ceramic materials.

N86-29242# Boeing Vertol Co., Philadelphia, PA.
A STUDY OF THE POTENTIAL BENEFITS ASSOCIATED WITH THE DEVELOPMENT OF A DEDICATED HELICOPTER TRANSMISSION LUBRICANT
R. J. DRAGO, P. J. MANGIONE (Naval Air Propulsion Test Center, Trenton, N.J.), and R. D. WENDRZYCKI *In* AGARD Aircraft and Bearing Tribological Systems 11 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

A common oil is now used in both the engines and transmissions of virtually all U.S military helicopters. While this provides significant logistic advantages, these advantages are attained only by compromising the optimization of the oil for either system. The results of two studies undertaken to determine what benefits would accure through the development of a special oil tailored specifically to meet the unique requirements of high-speed, heavily loaded helicopter transmission systems are summarized. These studies, conducted independently by two major helicopter manufacturers under the direction of the Naval Air Propulsion Center, addressed specific problem areas as related to typical production aircraft in order to reach well-documented conclusions. In addition, the effect of the availability of such a special gearbox lubricant on the development of other advanced-technology components was evaluated and documented. Author

N86-29244# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
REQUIREMENTS ON LUBRICATIN OIL FROM THE VIEW OF A HELICOPTER MANUFACTURER
J. HARTMANN and W. JONDA *In* AGARD Aircraft and Bearing Tribological Systems 6 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail NTIS HC A11/MF A01

Experience with known oil types, used in helicopters for transmissions, engines, hydraulics and brakes has shown that 3 main conditions if available, would improve drastically the performance of the aircraft. These 3 main conditions are: the same type of oil should be usable for all the above mentioned systems; the oils brands, produced according to a common specification, but by different manufacturers, should be mixable without restrictions; and some features of the oil, which are specially important for helicopter operations, should be improved. Author

N86-29249# Air Force Aero Propulsion Lab., Wright-Patterson AFB, OH.
MILITARY AIRCRAFT PROPULSION LUBRICANTS: CURRENT AND FUTURE TRENDS
G. A. BEANE, IV, L. J. GSCHWENDER, C. E. SNYDER, JR., and J. T. SHIMSKI (Naval Air Propulsion Test Center, Trenton, N.J.) *In* AGARD Aircraft and Bearing Tribological Systems 16 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

An assessment of the performance of MIL-L-7808J and MIL-L-23699C Military Specification lubricating oils in turbine engines and helicopter gear boxes is presented along with predicted performance of current and upgraded military specification oils in advanced and growth engine designs. Data is presented on advanced ester base engine lubricants, corrosion inhibited engine oils, and separate helicopter gear box oils evolving from current developmental research efforts. Future high temperature candidate fluids representing the ultimate stability for turbine engine oils are also discussed. Their use, in most cases, entails engine design considerations to accommodate their unique properties. The advantages and disadvantages of the various classes of synthetic lubricants for turbine engine applications are discussed, and deficiencies are identified where additional research programs are needed. Author

N86-29250# Imperial Coll. of Science and Technology, London (England).
FUTURE TRENDS IN HELICOPTER TRANSMISSION LUBRICANTS
H. A. SPIKES *In* AGARD Aircraft and Bearing Tribological Systems 10 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

Some recent fundamental studies relating to the lubrication of helicopter transmissions are presented, as well as implications for future oil development. The resulting enhanced understanding of lubrication mechanisms has shown that real potential exists both for improved performance and for the ability to cater to higher temperatures, by means of the formulation and use of improved transmission oils. If such benefits are recognized and if the new knowledge is correctly applied, there is no reason why helicopter gearbox reliability should not be appreciably improved by the end of the decade. Author

N86-29251# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.)
AIRCRAFT ENGINE OILS AND THEIR BEHAVIOUR AT HIGH TEMPERATURES
K. MAIER *In* AGARD Aircraft and Bearing Tribological Systems 12 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

Characteristics of aero-engine oils are changed considerably under high-temperature conditions (200 to 250 C). Consequences of this are the formation of aging products and deposits, deficiences in the tribological behavior and spontaneous ignition, in extreme cases. The problems arising from these are illustrated using several selected examples, and their effects on engine functioning are described. Author

N86-29252# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
PERFORMANCE MODELLING: A TOOL FOR LUBRICANT DEVELOPMENT
H. E. BANDOW *In* AGARD Aircraft and Bearing Tribological Systems 11 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

A basic requirement for the development of lubricants and aerospace fluids is to understand the physical properties of these fluids required to optimize performance of the lubricated system. Computer models have been used to predict the effects of lubricant properties on rolling element bearing performance. Studies were performed to validate models, to predict performance under various operating conditions, and to predict the effects of proposed design or lubricant changes on system performance. The results of some of these studies are described and compared with experimental measurements. Models which predict traction forces in lubricated contacts from thermal and rheological properties of the lubricant and bearing materials, and the geometry and operating conditions of the contact are compared with experimental results from a two disk traction device with a micro-computer based control/data acquisition system. The capabilities of models with the ability to predict the performance of hydraulic systems, the components making up these systems and lubricated contacts within the components are described and the methodology of studies to determine required fluid properties discussed. Author

N86-29253# Technische Univ., Munich (Germany, F.R.).
SCORING TESTS OF AIRCRAFT TRANSMISSION LUBRICANTS AT HIGH SPEEDS AND HIGH TEMPERATURES
H. WINTER and K. MICHAELIS *In* AGARD Aircraft and Bearing Tribological Systems 9 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

Aircraft engines always contain gears that have to be lubricated under conditions of high speeds and extremely high temperatures. In this field of application scoring damage is likely to occur. In Europe and partly also in the USA the scoring load capacity of gear oils is expressed in terms of FZG Scoring Load Stage. The FZG Gear Test Rig is described. The normal test procedure A/8.3/90 as standardized in DIN 51 354 using A-type gears at a pitch line velocity of v = 8.3 m/s and a starting oil temperature of 90 C is presented. A modified procedure at double speed and increased oil temperature A/16.6/140 is discussed. Because of the high costs and problems with the availability of test gears a modified FZG Ryder Test was developed. The method is presented and comparative results of typical aircraft engine oils in the FZG, the FZG-Ryder and the original Ryder Gear Test are shown. From this experience it becomes obvious that alternative test methods for the evaluation of scoring load capacity of aircraft transmission lubricants can be available in the near future. Author

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PROPELLANTS AND FUELS

Includes rocket propellants, igniters, and oxidizers; their storage and handling procedures; and aircraft fuels.

N86-26468# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
SMOKELESS PROPELLANTS
Jan. 1986 178 p In ENGLISH and FRENCH Conference held in Florence, Italy, 12-13 Sep. 1985
(AGARD-CP-391; ISBN-92-835-0387-2; AD-A166652) Avail: NTIS HC A09/MF A01

Eleven papers are presented from the conference. The specialist meeting was arranged in the following sessions: A review of smokeless propellant technology; Prediction and measurement of signature; Chemistry of smokeless propellants; and Smoke measurements. The purpose of the meeting was to bring together specialized experts in the field of smokeless propellants in order to discuss the definitions of the various degrees of smokelessness, and provide the results of the investigations performed in the last years. The achievements were discussed in the technical evaluation report, which suggests also several subjects for future investigations. For individual titles see N86-26469 through N86-26479.

N86-26469# Royal Ordnance PLC, Waltham Abbey (England). Research and Development Centre.
SMOKELESS PROPELLANTS OF IMPROVED PERFORMANCE
E. A. BAKER *In* AGARD Smokeless Propellants p 6-1 - 6-5 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

For double base propellants the high density of nitramines compared with nitrocellulose/nitroglycerine matrices of equivalent energy levels is particularly attractive where propellant energy levels or charge volumes are restrictive. The inclusion of nitramines generally reduced plateau burning rates and impairs plateau quality, but RDX filled extruded propellants with good plateau ballistics and low temperature dependence, suitable for boost applications were developed. No departure from conventional EDB processing is involved Author

N86-26470# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PROPERGOL COMBUSTION BASED ON OCTOGENESIS [COMBUSTION DES PROPERGOLS A BASE D'OCTOGENE]
G. LENGELLE and J. DUTERQUE *In* AGARD Smokeless Propellants p 8-1 - 8-17 (SEE N86-26468 17-28) Jan. 1986 In FRENCH; ENGLISH summary
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

The investigation of the combustion of solid propellants based on HMX and energetic binder was carried out through the study of HMX and the energetic binder in self-burning, as well as that of their combination in propellants. The condensed phase behavior of the components was looked into by means of thermogravimetric analysis, differential scanning calorimetry, ignition and temperature (microthermocouples) profile measurements, as well as sampling and analysis of the gases produced from the condensed phase. At very low pressure, HMX sustains a staged flame, much like that of homogeneous propellants. The behavior of the binder is close to that of homogeneous propellants. The burning rate of the propellant is a compromise between the rates of the components, without interaction between the HMX flame and that of the binder. Author

N86-26471# Prins Maurits Lab. TNO, Rijswijk (Netherlands).
STABILITY OF NITROCELLULOSE PROPELLANTS ASSESSED VIA THERMAL DECOMPOSITION AND ALTERATION OF THE STABILIZER COMPOSITION
P. VANDEMEY and A. H. HEEMSKERK *In* AGARD Smokeless Propellants p 9-1 - 9-8 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

In the Netherlands the surveillance of propellants is performed by investigating the thermal behavior of the propellant at a temperature of 358 K. This procedure is accepted to represent a degradation equivalent to a storage period of at least ten years at ambient temperatures. To obtain additional information about the degradation of propellants thermal stability tests were performed at various temperatures and under several environmental conditions. Both the thermal behavior of the propellants and the chemical behavior of the stabilizing amine compound were determined during these experiments. The composition of the amine compounds was analyzed using HPLC techniques developed for these experiments. Author

N86-26472# *Consiglio Nazionale delle Ricerche, Milan (Italy).*
BURNING STABILITY OF DOUBLE BASE PROPELLANTS
L. DELUCA, C. ZANOTTI, G. RIVA, R. DONDE, A. VOLPI, C. GRIMALDI, and G. COLOMBO *In* AGARD Smokeless Propellants p 10-1 - 10-17 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

The nonsteady combustion and intrinsic burning stability of double base propellants are studied. Experimental results show that, over a large pressure range, the energetics and the dynamics of double base combustion is controlled by the fizz zone. This permits the classical quasi-steady gas phase assumption to be applied. However, a novel transient flame model is required, since the fizz zone, although thin in time, is thick in space. This novel transient flame model includes several previous models as particular cases; in addition it allows an already existing nonlinear burning stability theory to be immediately applied to double base combustion. In general, double base burning is found to be less stable than composite propellant burning, both statically and dynamically. This is due to the relatively little energy stored in the condensed phase and elongated fizz zone yielding a weak energy coupling at the burning surface. Author

N86-26473# IMI Summerfield, Kidderminster (England).
ELASTOMER MODIFIED CAST DOUBLE BASE PROPELLANTS
G. I. EVANS and L. FACER *In* AGARD Smokeless Propellants p 13-1 - 13-17 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

Cast double base propellants have many attractive features for tactical missile systems, not least where plume signature transparency is at a premium. However, such propellants are limited in mechanical properties, particularly strain capability at low temperatures of -40 C or less. The development of a new class of CDB propellants is described utilizing an elastomer in the binder. The advantages, properties and performance of these EMCDB propellants are given. The field of candidate polymer systems is explored with test results and chemistry of the binder together with the criteria leading to the selection of suitable elastomer binders. Author

N86-26474# IMI Summerfield, Kidderminster (England).
THE REDUCTION OF EXHAUST SIGNATURE IN SOLID PROPELLANT ROCKET MOTORS
G. I. EVANS and P. K. SMITH *In* AGARD Smokeless Propellants p 16-1 - 16-16 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

An important feature of cast double base propellants is that during combustion the propellant itself produces extremely low levels of exhaust smoke. Developments in insulation material and, in particular, charge inhibitors have allowed the low smoke potential of the propellant to be fully realized in rocket motor firings. A further dramatic reduction in exhaust signature was obtained by suppressing secondary combustion in the rocket motor. This was achieved over a wide range of typical propellant charge and motor configurations using propellant additives. Flame suppressed plumes offer the desirable property of low exhaust emissions both in the visible and IR regions of the electromagnetic spectrum. Similarly missile communications both at optical and radio frequency wavelengths are improved by the absence of secondary combustion. The inhibitor and propellant developments concerned are reviewed and the reductions in exhaust signature which are obtained by the optimized use of secondary flame suppression is quantified. Author

N86-26475# *Nobel's Explosives Co. Ltd., Stevenston (England).* Defence and Aerospace Research.
THE CHEMICAL INTERACTION OF BALLISTIC MODIFIERS IN CDB PROPELLANT: ITS EFFECT UPON BALLISTICS AND STABILITY
J. D. M. PEARSON, A. C. J. SHEDDEN, and I. A. DUNCAN *In* AGARD Smokeless Propellants p 17-1 - 17-15 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

During the development of a platonized cast double base propellant it was noted that a spread of burning rates from batch to batch was obtained. Subsequently batches of the propellant preexistantly showed a marked decrease in gas crack lifetime, on accelerated aging, compared with earlier satisfactory results. Extensive work showed the stability problem to be associated with a chemical reaction between the ballistic modifiers. This reaction was reproduced in the laboratory, while at the same time the ballistic variability of the propellant was under investigation. It became apparent that the chemical interaction between the modifiers affected the propellant platonized burning rate and that the by products of this reaction cause the accelerated aging problem. This understanding allowed a new ballistic modifier to be developed which helped solve the stability problem while at the same time gave much more reproducible ballistics. Author

N86-26476# Defence Research Establishment Valcartier (Quebec).
DIRECT EROSIVE BURNING MEASUREMENTS OF A REDUCED-SMOKE SOLID PROPELLANT ROCKET BY FLASH X-RAYS
T. CONSTANTINOU and D. GREATRIX (Toronto Univ., Ontario) *In* AGARD Smokeless Propellants p 18-1 - 18-13 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

Despite the multitude of models available, proper erosive burning modelling continues to be a difficult task in the internal ballistic prediction of solid propellant rockets with high volumetric loading. The majority of models are based on erosive burning measurements using small motors, window motors and with such techniques as imbedded probes or interrupted burning. Such methods, however, are not believed to exhibit the real combustion process. The flash X ray technique using full sized motors gives a more realistic measurement of burning rates. This technique can be used to evaluate the internal ballistic code with different erosive burning models, a pressure-time record can be obtained and compared to experimental data. A comparison and evaluation of the different models, is thus possible. Data based on static firings of reduced smoke motors were analyzed by the above method and the results are presented. Author

N86-26477# Naval Postgraduate School, Monterey, CA.
EXPERIMENTAL TECHNIQUES FOR OBTAINING PARTICLE BEHAVIOR IN SOLID PROPELLANT COMBUSTION
D. W. NETZER and J. P. POWERS *In* AGARD Smokeless Propellants p 19-1 - 19-17 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

A continuing investigation is being conducted to develop techniques to obtain quantitative data that can be used to relate solid rocket propellant composition and operating environment to the behavior of solid particulates within the grain port and exhaust nozzle. The techniques employed are high speed motion pictures of propellant strand burners and slab burners in a cross flow environment, SEM analysis of post fire residue (strand, slab, and motor), determination of D sub 32 across the exhaust nozzle using measurements of scattered laser light, and holograms of burning propellant strands, slabs and motors. In addition, techniques are being studied for automatic retrieval of particle size distributions from holograms taken of the combustion of solid propellants. Actual particle sizes of burning aluminum particles were obtained in high speed motion pictures by using high intensity rear illumination of the burning propellants to eliminate the flame envelopes surrounding the burning particles. Measurements of diffractively scattered light were made for determination of changes in D sub 32 across a solid propellant rocket motor exhaust nozzle. Two dimensional motors were employed to obtain holograms of propellant burned in a cross flow environment. Other efforts were directed at reduction of speckle in the recorded holograms and optimization of techniques for minimizing excessive smoke in the recorded scenes. A computer controlled Quantimet 720 is being used in an effort to obtain particle size distributions from reconstructed holograms. Author

N86-26478# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GAS ANALYSIS FOR THE INVESTIGATION OF THE COMBUSTION OF DOUBLE-BASE PROPELLANTS AND HMX
J. F. TRUBERT *In its* Smokeless Propellants (AGARD-CP-391) p 20-1 - 20-14 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

The linear pyrolysis method under vacuum by conduction and radiation, with analysis by mass spectrometry is used to obtain the composition of the gases produced by solid propellant condensed phase degradation, while minimizing the secondary reactions and under conditions close to actual burning. This method was elaborated with reference to double base propellants, and in the presence of additives. Important quantities of formaldehyde, glyoxal and carbon dioxide are obtained. The presence of low amounts of nitrogen and carbon monoxides, carbon dioxide and water indicates that the gases result mostly from the degradation. The small difference between the quantitative compositions shows that the additive does not act on the condensed phase degradation. This method was applied to HMX. The analysis shows large amounts of several nitrogen oxides (NO2, NO, N2O), formaldehyde, and cyanhydric acid, and small quantities of water, nitrogen and carbon oxides. Author

N86-26479# Brigham Young Univ., Provo, UT. Dept. of Chemical Engineering.
MEASUREMENTS OF DISTRIBUTED COMBUSTION
M. W. BECKSTEAD, P. C. BRAITHWAITE, and D. L. GORDON *In* AGARD Smokeless Propellants p 21-1 - 21-12 (SEE N86-26468 17-28) Jan. 1986
(AGARD-CP-391) Avail: NTIS HC A09/MF A01

Acoustic suppressants are commonly added to low smoke and smokeless propellants to avoid the problem of combustion instability. Although some suppressants are considered to be inert, most actually react with the combustion products. If a particle reacts while traversing a relatively large portion of the system, the interchange of energy between the burning particle and the acoustic environment can result in either a driving or damping contribution to the acoustics of the system, which is referred to as distribution combustion. Instead of using actual solid propellants, and experimental technique was developed to study this mechanism utilizing a gas fired Rijke burner. Advantages of this approach allow testing an additive independent of the propellant burning surface, avoiding the use of solid propellants, and allowing for independent control of frequency, O/F ratio, temperature, and particle addition. Al and ZrC are additives commonly used in solid propellants to suppress combustion instability. Experimental results obtained using Al and ZrC in the Rijke burner indicate that both additives cause an increase in the acoustic growth rate when compared to growth rates obtained without any particles in the system. The increase caused by Al is significantly greater that that caused by ZrC, which is expected because the reaction of Al releases more than twice the energy ZrC does. The increase in the acoustic growth rate due to distributed combustion was found to be directly related to the heat of reaction. Author

N86-29064# Ballistic Research Labs., Aberdeen Proving Ground, MD.
LIQUID PROPELLANT GUN TECHNOLOGY
W. F. MORRISON, J. D. KNAPTON, and P. G. BAER *In* AGARD Interior Ballistics of Guns 16 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

Research and development efforts on liquid propellant guns have increased steadily in the United States over the past five years as a result of progress in both liquid propellant and propulsion technology. The research program is directed toward the use of hydroxyl ammonium nitrate (HAN) based liquid monopropellants in a regenerative liquid propellant gun. The HAN-based liquid monopropellants offer a number of advantages over both solid propellants and other liquid propellant formulations. The regenerative process is based on the injection of propellant into the combustion chamber during the ballistic cycle. The interior ballistic process is summarized to provide a basis for the discussion of experimental gun firing data. A simple inline piston with multiple cylindrical injectors is used as an example. Regenerative investigation in the United States have focused on annular injection configurations, in which the propellant enters the chamber in the form of an annular sheet. A simple version of the configuration was built and tests in 25, 30, and 105 mm. Ballistic data are presented, along with discussions of ballistic repeatability and efficiency. Four computer models of the regenerative interior ballistic process are compared. Author

N86-29065# Royal Armament Research and Development Establishment, Fort Halstead (England).
INGNITION, COMBUSTION, AND PHYSICAL PROPERTIES OF LIQUID PROPELLANTS AT GUN PRESSURES
G. G. COOK and T. O. ANDREWS *In* AGARD Interior Ballistics of Guns 13 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

The internal ballistics of a regenerative injection liquid propellant gun depend on the rate of injection of the liquid propellant rather than on the burning rate, owing to the small size of the droplets produced. The rate of injection is determined by the effect of the compressibility of the liquid on the motion of the piston and by its flow characteristics through the injector. The force constant of the propellant is important as it determines the combustion pressure resulting from any given flow rate. A standard closed vessel was modified and used with a specially developed igniter to investigate the combustion of Otto Fuel II at gun pressure. It was also used to investigate the compressibility of inert liquid at pressures up to 600 MPa. A liquid propellant test vessel was constructed for use in the investigation of the compressibility of live liquids and the flow of liquids at high pressure. Author

N86-29066# Fraunhofer-Inst. fuer Kurzzeitdynamik, Weil am Rhein (Germany, F.R.). Abteilung fuer Ballistik.
MECHANICAL BEHAVIOUR OF PROPELLANT GRAINS UNDER HEAVY DYNAMIC LOAD
G. ZIMMERMAN *In* AGARD Interior Ballistics of Guns 15 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

Special test devices were constructed to simulate the dynamic forces on gun propellant grains during shots at ambient and low temperatures (-40 C). With these devices the dynamic stress at failure, the fragmentation type (pasty, brittle), and other correlated physical characteristics of several propellant types were measured. Conclusions are drawn for the propellant behavior under real gun conditions. Author

N86-29067# Bombrini Parodi-Delfino S.p.A., Rome (Italy).
FIELD ARTILLERY GUN PERFORMANCES RELATED TO TRIPLE-BASE POWDER QUALITY
B. DANDREA, M. PETRUCCI, and M. DILORENZO *In* AGARD Interior Ballistics of Guns 15 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

In order to achieve the best results in the 155-39 mm field field artillary gun, several parameters affecting the triple-base powder quality were investigated. Mainly nitro-cellulose molecular weights (MW) and molecular weight distributions (MWD), determined by means of gel-permeation chromatography (GPC) related to the powder rheological properties are reported. In addition theoretical interior ballistic evaluations, tailored on powders manufactured with different nitrocellulose samples, based on computer program calculation, are compared with the firing test results. Author

N86-29073# Etablissement Technique de Bourges (France).
EXPERIMENTAL STUDY OF THE IGNITION OF EXPLOSIVE CHARGES USING VISUALIZATION OF THE PHENOMENA [ETUDE EXPERIMENTALE DE LALLUMAGE DUNE CHARGE PROPULSIVE PAR VISUALISATION DU PHENOMENE]
C. BERTHOMMIER *In* AGARD Interior Ballistics of Guns 7 p (SEE N86-29063 20-31) Jan. 1986 In FRENCH
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

A three point visualization process was used to study the ignition and combustion phenomena of propulsive charges for large caliber ammunition. The visualization process was made possible by using a translucent sleeve as the barrel. The phenomena studied included the pressure, displacement and the speed of the flame front. The procedure studied made possible an examination of the ignition and combustion processes of various charge configurations. Two examples were studied; the first study pertained to a comparison of two igniter, and the second to a pre-programmed igniter. B.G.

N86-29077# Dynamit Nobel A.G., Fuerth (Germany, F.R.). Dept. of Research and Development-Ammunition.
IGNITION OF HIGH-PERFORMANCE GUN AMMUNITION
H. PENNER *In* AGARD Interior Ballistics of Guns 7 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

Modern high performance cartridges are designed for high loading densities of propelling charges. Sometimes they exceed the normal filling density of the propellant grains. The conditions for fast and complete ignition are discussed and a group of primers for 105 mm-rounds which will ignite the propelling charge in an optimum manner is presented. Author

N87-28595# Bombrini Parodi-Delfino S.p.A., Colleferro (Italy). Defense and Space Div.
PROPELLANT GRAIN DESIGN
S. SCIPPA *In* AGARD, Design Methods in Solid Rocket Motors 20 p (SEE N87-28589 23-20) Mar. 1987
(AGARD-LS-150) Avail: NTIS HC A11/MF A01

A general overview of the current methodologies used at SNIA BPD (Bombrini Parodi-Delfino) in designing solid rocket motor propellant grains is presented. The internal ballistics aspect of grain design is emphasized. The general requirements (thrust versus time curve, volumetric constraints, etc.), the available technologies (propellant types, manufacturing processes, etc.), and the methodology for the selection of the most appropriate technology are described. In particular, propellant characterization, design of internal geometry, and methods for propellant formulation choice are discussed. An analysis of the predictability factors and how they can be taken into account for contingency planning is reported. Finally, the experimental tests commonly used for grain design validation are summarized. Author

N87-28596# Societe Nationale des Poudres et Explosifs, Vert-Le-Petit (France). Technique Autopropulsion.
SIZING SOLID PROPELLANT ENGINE CHARGES *[DIMENSIONNEMENT DES CHARGEMENTS DES MOTEURS A PROPERGOL SOLIDE]*
BERNARD ZELLER *In* AGARD, Design Methods in Solid Rocket Motors 33 p (SEE N87-28589 23-20) Mar. 1987 In FRENCH
(AGARD-LS-150) Avail: NTIS HC A11/MF A01

The goal of solid propellant charge sizing is to design charges which satisfy diverse specifications. Methods utilized to carry out this task are described. The general specifications which must be satisfied for solid rocket engines are discussed with regard to tactical and strategic missiles and space launch vehicles. The various charge types and solid propellant families are reviewed and the specific requirements for propellant charges are addressed. The methods employed to define precisely the propellant, the geometry and the organization of the charge are described. These methods aim at obtaining specific ballistic performances and assuring the overall integrity of the charge when subjected to mechanical stresses. Finally, a reliability estimation technique for propellant charges is briefly described. M.G.

N87-28597# Air Force Rocket Propulsion Lab., Edwards AFB, CA.
STATE OF THE ART OF SOLID PROPELLANT ROCKET MOTOR *GRAIN DESIGN IN THE UNITED STATES*
DURWOOD I. THRASHER *In* AGARD, Design Methods in Solid Rocket Motors 21 p (SEE N87-28589 23-20) Mar. 1987
(AGARD-LS-150) Avail: NTIS HC A11/MF A01

A brief discussion of the basic ground rules and overall considerations in solid rocket motor design is presented. Ballistic design considerations, grain features related to ballistic design and their purposes, primary factors which determine stress and strain levels, and design approaches for avoiding structural weak points are discussed. Emphasis is given to propellant grain structural integrity assurance, including materials characterization, structural analysis, and structural capability verification. Additional topics discussed include: viscoelastic material behavior and the requisite thermomechanical characterization testing and analysis approaches; failure criteria; experimental structural methods including in-situ stress and strain measurement technology; and service life considerations. Unresolved problems are addressed and important ongoing work is summarized. Author

N87-28598# Societe Europeene de Propulsion, Saint-Medard-en-Jalles (France).
DESIGN AND SIZING OF INTERNAL THERMAL INSULATORS FOR SOLID PROPELLANT ROCKET ENGINES [CONCEPTION ET DIMENSIONNEMENT DES PROTECTIONS THERMIQUES INTERNES D'UN PROPULSEUR A POUDRE]
ANDRE TRUCHOT *In* AGARD, Design Methods in Solid Rocket Motors 13 p (SEE N87-28589 23-20) Mar. 1987 In FRENCH
(AGARD-LS-150) Avail: NTIS HC A11/MF A01

The principal objective of internal thermal insulators is to protect the engine structural walls from overheating by combustion gas. They also perform certain secondary functions: adhere the propellant to the structure, accept the relative deformations of the charge and structure and eventually seal the chamber. The general design processes for internal thermal insulators are presented: analysis of the working environment and conditions, materials selection, and thermal and mechanical dimensioning. The calculation methods used for each of these processes are described along with various laboratory and firing tests. Finally, fabrication processes for internal thermal insulation are discussed. M.G.

N87-28599# Societe Europeene de Propulsion, Saint-Medard-en-Jalles (France).
COMPREHENSIVE OPTIMIZATION OF SOLID PROPELLANT ROCKET ENGINES [OPTIMISATION D'ENSEMBLE D'UN PROPULSEUR A POUDRE]
ANDRE TRUCHOT *In* AGARD, Design Methods in Solid Rocket Motors 12 p (SEE N87-28589 23-20) Mar. 1987 In FRENCH
(AGARD-LS-150) Avail: NTIS HC A11/MF A01

The goal of comprehensive optimization of solid propellant engines is to determine the configuration of the highest performance taking into account certain optimization criteria involving the range or payload carrying capability of the vehicle.

An overview of the various specifications (geometric envelope, performance, etc.) and design parameters (operating conditions, geometric parameters, and the technologies of each component) is presented. The development of computer aided design programs is discussed and some example applications are described in order to illustrate the potential uses of the programs for engine pre-design studies. M.G.

N89-16912# Bombrini Parodi-Delfino S.p.A., Colleferro (Italy). Defense and Space Div.

PROPELLANT GRAIN DESIGN

S. SCIPPA *In* AGARD, Design Methods in Solid Rocket Motors 20 p (SEE N89-16906 09-20) Apr. 1988 Previously announced as N87-28595

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

A general overview of the current methodologies used at SNIA BPD in designing solid rocket motor propellant grains is presented. The internal ballistics aspect of grain design is emphasized. The general requirements (thrust vs. time curve, volumetric constraints, etc.), the available technologies (propellant types, manufacturing processes, etc.), and the methodology for the selection of the most appropriate technology are described. In particular, propellant characterization, design of internal geometry, and methods for propellant formulation choice are discussed. An analysis of the predictability factors and how they can be taken into account for contingency planning is reported. Finally, the experimental tests commonly used for grain design validation are summarized. *Author*

N89-16913# Societe Nationale des Poudres et Explosifs, Vert-Le-Petit (France). Direction Technique Autopropulsion.

SOLID PROPELLANT GRAIN DESIGN

BERNARD ZELLER *In* AGARD, Design Methods in Solid Rocket Motors 29 p (SEE N89-16906 09-20) Apr. 1988

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

To design a solid propellant grain is to conceive and to define a grain which satisfies various requirements. The methods and procedures are described which are used today in France to design propellant grains. Described and analyzed are: (1) the various types of grain and the various families of propellant which are available and used today; (2) the detailed requirements that a solid propellant grain must satisfy; (3) the methods which are used to precisely define the propellant, the architecture and the configuration of the grain, and more specifically the methods used in order to ensure required ballistic performance though maintaining structural integrity of the grain; and (4) an overview on a method of solid propellant grain reliability assessment. The improvements needed in the area of grain design analysis and the related technical breakthroughs are briefly presented. Author

N89-16914# Air Force Rocket Propulsion Lab., Edwards AFB, CA.

STATE OF THE ART OF SOLID PROPELLANT ROCKET MOTOR GRAIN DESIGN IN THE UNITED STATES

DURWOOD I. THRASHER *In* AGARD, Design Methods in Solid Rocket Motors 21 p (SEE N89-16906 09-20) Apr. 1988

(AGARD-LS-150-REV) Avail: NTIS HC A11/MF A01

A brief disscussion is presented of the basic ground rules and overall considerations in solid rocket motor design. This discussion includes ballistic design considerations, grain features related to ballistic design and their purposes, primary factors which determines stress and strain with solid rocket motor propellant grain structural integrity assurance, including materials characterization, structural analysis, and structural capability verification. The topics addressed include viscoelastic material behavior and the requisite thermomechanical analysis testing and approaches; failure criteria and the appropriate testing approaches; experimental structural methods, including in situ stress and strain measurement technology; and service life considerations. Author

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ENGINEERING (GENERAL)

Includes vacuum technology; control engineering; display engineering; cryogenics; and fire prevention.

N86-29063# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

INTERIOR BALLISTICS OF GUNS

Jan. 1986 220 p Meeting held in Florence, Italy, 9-11 Sep. 1985; sponsored by the Propulsion and Energetics Panel

(AGARD-CP-392; ISBN-92-835-0388-0; AD-A167107) Avail: NTIS HC A10/MF A01

Topics addressed include: liquid propellant guns; characteristics of solid gun propellants; gun barrel erosion; low vulnerability propellants for guns; experimental and test techniques in interior ballistics; gun ignition systems; new problems in guns; and traveling charge gun theory. For individual titles see N86-29064 through N86-29078.

N86-29069# Royal Military Coll. of Science, Shrivenham (England).

BORE TEMPERATURE AND HEAT FLUX IN A 40 MM GUN BARREL

B. LAWTON *In* AGARD Interior Ballistics of Guns 12 p (SEE N86-29063 20-31) Jan. 1986

(AGARD-CP-392) Avail: NTIS HC A10/MF A01

A method of measuring the bore srface temperature fluctuation in a 40 mm gun is described. Fast response, 1 microsecond, eroding type, surface thermocouples are used and a feature is that they can tolerate up to 3 mm wear and pressures up to 2000 bar. The bore temperature is measured at three positions along the barrel and the pressure is measured at the breech. All three signals are captured using digital oscilloscopes and are transferred to a digital computer. The signals are processed to give instantaneous heat flux, shot velocity, shot travel, and total heat transfer. Gas leakage past the shot is found to be significant. A simple theory is proposed for calculating the maximum bore temperatures and the total heat transfer and this theory is confirmed by measurements on fourteen different rounds made up using three propellants and various charge masses and grain formulations. Author

N86-29070# Prins Maurits Lab. TNO, Rijswijk (Netherlands).

ON THE THERMAL BEHAVIOUR OF THE BARREL DURING THE INTERIOR BALLISTIC CYCLE OF PROPELLANT GUNS

W. J. KOLKERT, M. WAAS, and N. G. THE *In* AGARD Interior Ballistics of Guns 13 p (SEE N86-29063 20-31) Jan. 1986

(AGARD-CP-392) Avail: NTIS HC A10/MF A01

Thermal stress cycling during firing constitutes a major mechanism for erosion, wear, and fatigue in gun barrels and cannon tubes. In order to predict spatial and temporal temperature distributions at the inner envelope of and through the barrel and in the gas dynamic flow accompanying the interior ballistic cycle, a two-dimensional, quasi two-phase flow (turbulent, viscous, and compressible) model, was developed. A one-dimensional model treating radial heat conduction in the barrel was coupled to this flow model. Input parameters for these models were calculated with a one-dimensional, two-phase flow, burning routine, describing propellant deflagration. Besides a description of these models, results of a prediction got heat loss, projectile travel and pressure, temperature and flow velocity distributions in the gas dynamic flow, and temperature-time histories in the barrel wall are given for the interior ballistic cycle of a caliber .50in gun. Although predicted results for heat flow into and through the barrel and predicted temperature-time histories in the barrel cannot be compared with experimental results in a reliable way at this time, predicted results for pressure-time distributions and projectile-travel fit the experimental results in a promising way. Author

N86-29076# Royal Armament Research and Development Establishment, Fort Halstead (England).
NOVEL IGNITION SYSTEMS FOR HEAVY CALIBRE GUNS
C. N. BOWDEN, G. G. COOK, and P. S. HENNING *In* AGARD Interior Ballistics of Guns 11 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

In recent years there was a trend towards steadily rising gun pressures, especially in direct fire weapons and this has caused many functional problems to arise with conventional vent tube ignition systems. To overcome these problems and to allow the process of gun development to continue, the United Kingdom is performing a program of research into a number of ignition systems for heavy caliber guns. These include: spark ignition, laser ignition, and electrical impulse ignition. A number of different spark plug configurations were evaluated. Extensive trials were performed on the ignition characteristics of black powders and black powder substitutes using an experimental 4 J neodymium laser. Work was also performed on the development of high pressure sapphire windows. A study into methods of charge ignition by electrical impulse techniques was also performed. Author

N86-29078# Institut Franco-Allemand de Recherches, Saint-Louis (France).
HIGH-PRESSURE COMBUSTION: COMPARISON OF THEORETICAL AND ACTUAL RESULTS [COMBUSTION SOUS HAUTES PRESSIONS CONFRONTATION THEORIE EXPERIENCE]
D. GRUNE and M. SAMIRANT *In* AGARD Interior Ballistics of Guns 7 p (SEE N86-29063 20-31) Jan. 1986 In FRENCH
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

Following the observation of important variances (30 to 50%) between the theoretical and actual values obtained during a study of the combustion pressure of powders of approximately 1,500 MPa, the differences for several tests were compared. The composition of the combustion gases were analyzed. In addition, the deformation of a manometer explosive device was studied during the ignition stage. Data was obtained concerning the deformation resulting from the high pressure. B.G.

N87-21170# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
ADVANCED INSTRUMENTATION FOR AERO ENGINE COMPONENTS
Nov. 1986 556 p In ENGLISH and FRENCH Symposium held in Philadelphia, Pa., 19-23 May 1986
(AGARD-CP-399; ISBN-92-835-0401-1; AD-A182954) Avail: NTIS HC A24/MF A01

The Symposium was addressed to research scientists and development engineers for aero engines in order to discuss the state-of-the-art and to be informed on new measurement possibilities. The scope included Coherent Anti-Stokes Raman Spectroscopy (CARS), laser anemometry, pyrometry, clearance measurement including X-ray, high speed data acquisition and processing, stress measurement and vibration and thin layer technique, unsteady and transient phenomena, and future prospects. For individual titles see N87-21171 through N87-21205.

N87-21176*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LASER FRINGE ANEMOMETRY FOR AERO ENGINE COMPONENTS
ANTHONY J. STRAZISAR *In* AGARD Advanced Instrumentation for Aero Engine Components 32 p (SEE N87-21170 14-31) Nov. 1986 Sponsored by NASA
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Advances in flow measurement techniques in turbomachinery continue to be paced by the need to obtain detailed data for use in validating numerical predictions of the flowfield and for use in the development of empirical models for those flow features which cannot be readily modelled numerically. The use of laser anemometry in turbomachinery research has grown over the last 14 years in response to these needs. Based on past applications and current developments, the key issues which are involved when considering the application of laser anemometry to the measurement of turbomachinery flowfields are discussed. Aspects of laser fringe anemometer optical design which are applicable to turbomachinery research are briefly reviewed. Application problems which are common to both laser fringe anemometry (LFA) and laser transit anemometry (LTA) such as seed particle injection, optical access to the flowfield, and measurement of rotor rotational position are covered. The efficiency of various data acquisition schemes is analyzed and issues related to data integrity and error estimation are addressed. Real-time data analysis techniques aimed at capturing flow physics in real time are discussed. Finally, data reduction and analysis techniques are discussed and illustrated using examples taken from several LFA turbomachinery applications. Author

N87-21179# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
HOW TO SELECT A LASER VELOCIMETER FOR A GIVEN APPLICATION? [COMMENT CHOISIR UN VELOCIMETER LASER POUR UNE APPLICATION DONNEE]
A. BOUTIER *In* AGARD Advanced Instrumentation for Aero Engine Components 18 p (SEE N87-21170 14-31) Nov. 1986 In FRENCH
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The different types of laser velocimeters are described with reference to their domains of utilization, their qualities, and their limitations. The fringe velocimeters are suited for acquiring local and instantaneous velocity vectors, mean velocity vectors and complete Reynolds Tensors. Their most serious limitation is their inability to measure velocities near the wall which the beams normally strike. This is why two-point velocimeters have been developed for applications with turbomachines where fluid flows are confined to very narrow channels. On the other hand these two-point velocimeters cannot probe flows with a turbulence rate exceeding 10 to 15%. A model of a two-beam velocimeter at ONERA has given very promising results with highly turbulent flows. A conspectus is presented with the objective of providing guidance in the selection of the most appropriate laser velocimeter for a given experimental condition. Author

N87-21183*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMBINED FRINGE AND FABRY-PEROT LASER ANEMOMETER FOR 3 COMPONENT VELOCITY MEASUREMENTS IN TURBINE STATOR CASCADE FACILITY
RICHARD G. SEASHOLTZ and LOUIS J. GOLDMAN *In* AGARD Advanced Instrumentation for Aero Engine Components 15 p (SEE N87-21170 14-31) Nov. 1986 Previously announced as N86-24967 Sponsored by NASA
(AGARD-CP-399) Avail: NTIS HC A24/MF A01 CSCL 14B

A laser anemometer is described that was developed for use in a 508 mm diameter annular turbine stator cascade facility. All three velocity components are measured through a single restricted optical port, both within the stator vane row and downstream of the vanes. The measurements are made through a cylindrical window in the casing that matches the tip radius of the cascade. The stator tested has a contoured hub endwall that results in a large radial flow near the hub. The anemometer uses a standard fringe configuration (LFA) with a fluorescent aerosol seed to measure the axial and circumferential velocity components. The radial component is measured with a confocal Fabry-Perot interferometer. The two configurations are combined in a single optical system and can operate simultaneously. Data are presented to illustrate the capabilities of the system. Author

N87-21203# Oxford Univ. (England). Dept. of Engineering.
A STUDY OF PASSAGE FLOW THROUGH A CASCADE OF TURBINE BLADES USING IMAGE PLANE HOLOGRAPHIC INTERFEROMETRY
M. L. G. OLDFIELD, P. J. BRYANSTON-CROSS (Rolls-Royce Ltd., Derby, England), J. H. NICHOLSON, and C. T. J. SCRIVENER *In* AGARD Advanced Instrumentation for Aero Engine Components 12 p (SEE N87-21170 14-31) Nov. 1986 Previously announced as N87-15970
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Holographic interferograms showing the flow through two passages of a cascade of turbine rotor blades in an isentropic light piston tunnel with full-scale Reynolds numbers, Mach numbers, and gas-to-wall temperature ratios are presented. Double exposure absolute and differential image plane holograms of the complete

flow field under a range of conditions were obtained. The isodensity contours predicted by a time marching throughflow calculation compare well with the positions of the interference fringe on the holograms. The intersections of these fringes with the blade surfaces give blade surface Mach numbers which agree well with those from surface pressure measurements. Wakes, shock waves, and the presence of upstream and side wall turbulence are all evident in the holograms. Author

N87-21204*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
BEAM-MODULATION METHODS IN QUANTITATIVE AND FLOW-VISUALIZATION HOLOGRAPHIC INTERFEROMETRY
ARTHUR J. DECKER *In* AGARD Advanced Instrumentation for Aero Engine Components 16 p (SEE N87-21170 14-31) Nov. 1986 Sponsored by NASA
(AGARD-CP-399) Avail: NTIS HC A24/MF A01 CSCL 20F

Heterodyne holographic interferometry and time-average holography with a frequency shifted reference beam are discussed. Both methods will be used for the measurement and visualization of internal transonic flows where the target facility is a flutter cascade. The background and experimental requirements for both methods are reviewed. Measurements using heterodyne holographic interferometry are presented. The performance of the laser required for time-average holography of time-varying transonic flows is discussed. Author

N87-29484# Norwegian Defence Research Establishment, Kjeller.
AN INTELLIGENT MULTI-TARGET TRACKING SYSTEM
E. HEYERDAHL *In* AGARD, Advances in Guidance and Control Systems and Technology 9 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

An implementation of a general tracking system, integrating the target acquisition and tracking subsystems, was developed. It is based on image analysis and extensive use of models. The system permits improvements compared to in-service trackers in the sense that it enables multi-target tracking, automatic acquisition also during tracking and tracking through obscurations. The system is an implementation of a general tracking system. This system produces alternative estimates of a target and projects the corresponding objects into the image plane. To do this estimates of the projecting function are used. The different projections are synthesized through a thresholding process. The implemented system uses parallel Kalman filters to produce the object estimates and estimates the sensor position through a model of sensor dynamics and measurements of sensor angle velocity. Results, produced by the implemented system from IR imagery of a moving target in field are presented. Author

N87-29648# British Aerospace Public Ltd. Co., Bristol (England). Production Improvements.
DESIGNING FOR SUPERPLASTIC ALLOYS
D. STEPHEN *In* Advisory Group for Aerospace Research and Superplasticity 37 p (SEE N87-29641 24-26) Aug. 1987
(AGARD-LS-154) Avail: NTIS HC A10/MF A01

Substantial evidence exists to support the claim that titanium alloys, when processed by the superplastically formed (SPF) diffusion bonded (DB) route, can compete in weight and more particularly cost, with conventional aluminum fabrication. This is likely to be a major factor in the future exploitation of these processes and clearly requires a revision to the designers traditional views of the areas of application for titanium alloys. However, the development of a combined SPF/DB process for aluminum alloys, with the full range of capabilities provided currently by titanium alloys, remains to be established. Author

N87-29649# Alcan International Ltd., London (England).
THE MANUFACTURE OF SUPERPLASTIC ALLOYS
R. GRIMES *In* Advisory Group for Aerospace Research and Superplasticity 16 p (SEE N87-29641 24-26) Aug. 1987
(AGARD-LS-154) Avail: NTIS HC A10/MF A01

Amongst aluminum alloys, the Al-6 percent Cu-0.4 percent Zr system that typifies the Supral alloys requires a specially developed casting system in order to achieve a very high level of supersaturation with zirconium. Subsequent manufacturing is fairly conventional, the sheet product recrystallizing dynamically during superplastic forming. The higher strength aluminum alloys are conventionally cast but achieve a very fine grain size at sheet stage by careful thermal mechanical treatment during the later stages of semi-fabrication. With titanium, the standard production route for the Ti-6Al-4V alloy results in a product with superplastic capabilities perfectly adequate for most applications. Author

N89-15262# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AEROSPACE MATERIALS PROCESS MODELLING
Aug. 1988 263 p In ENGLISH and FRENCH Meeting held in Cesme, Turkey, 2-4 Oct. 1987
(AGARD-CP-426; ISBN-92-835-0476-3; AD-A202494) Avail: NTIS HC A12/MF A01

The modeling behavior of metallic materials, and in particular the forming of components such as castings and formings, are discussed. For individual titles, see N89-15263 through N89-15281.

N89-15263# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
PROCESSING SCIENCE AND MATERIALS DEVELOPMENT
HAROLD L. GEGEL *In* AGARD, Aerospace Materials Process Modelling 15 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

The development of advanced technologies for the fabrication of close-tolerance parts, in conjunction with the development of advanced materials, plays a key role in the design and manufacturing of affordable aerospace systems. New process and product-design concepts must be evolved in parallel with the development of advanced materials for future systems in order to exploit the achievements being made in materials science and to tailor specific properties while simultaneously producing controlled geometrical shapes. A scientific description of production equipment and, in general, physical objects, media, fields, and interface and material-related phenomena requires theoretical models which are capable of predicting the response of the fabricating system to the initial inputs. The design of a product and the corresponding manufacturing process generally requires both deterministic models and expert systems which utilize designer intuition and logic in finding acceptable solutions. Reviewed here are some of the recent developments in process modeling as related primarily to metalworking systems and how they aid in the understanding of the role of computer and human expertise in modern computer-aided engineering (CAE). Author

N89-15264# Military Academy, Ankara (Turkey).
MODELLING OF DEFORMATION AND MICROSTRUCTURAL CHANGES IN P/M RENE 95 UNDER ISOTHERMAL FORGING CONDITIONS
O. ALNIAK, D. D. MORPHY, T. TERADA, A. K. KOUL, and J-P IMMARIGEON (National Aeronautical Establishment, Ottawa, Ontario) *In* AGARD, Aerospace Materials Process Modelling 18 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

The changes in microstructure induced by forging and their influence on flow strength in hot isostatically pressed P/M Rene 95 as revealed by constant true strain compression tests under simulated isothermal forging conditions are discussed. Results are presented for initially fine (7 micron) and coarse (50 micron) grained compacts tested at temperatures of 1050, 1075 and 1100 C and at strain rates in the range from 10 to the minus 4th powers (-1) to 1 s(-1). Under these tests conditions, both the fine and coarse grained compacts recrystallize and their grain size is refined during flow. This grain refinement gives rise to softening in both materials. Ultimately, their microstructures transform into the same equiaxed fine grained microduplex structure at which point their flow strength becomes identical. Continued deformation at that point produces no further change in grain size or flow strength. Under this steady state regime of deformation, the microduplex grain size and flow strength are independent of the original microstructure but are conditioned by the strain rate at a given temperature. The steady state grain size increases whereas the steady flow strength decreases with a decrease in strain rate and/or an increase in temperature. It is shown how changes in microstructure and flowstrength during isothermal forging can be modelled in P/M Rene 95 compacts by means of established deformation models for predicting peak flow strength, using the steady state deformation

data as a boundary condition for the evolution of microstructure and flow strength and a model for deformation-induced recrystallization during forging that has been recently developed for this class of materials. Author

N89-15265# Marmara Research Inst., Gebze (Turkey). Materials Research Dept.
PREDICTION OF TEMPERATURE DISTRIBUTION IN AXISYMMETRIC EXTRUSION
S. ONURLU *In* AGARD, Aerospace Materials Process Modelling 8 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

In extrusion, the knowledge of temperature distribution is helpful in selecting process variables such as speed, initial temperatures and cooling conditions to optimize the process. This study describes a computer-aided numerical technique for the calculation of temperature distribution in the billet, extruded product and tools. The model is based upon Avitzur's spherical velocity field and extended to include transient heat conduction, heat generations and mass transport effects on the basis of local temperatures and strain rates. The finite difference formulation of the problem considers the heat generation and conduction in each time step of the solution. A computer program is developed to solve the problem. Temperature distributions are calculated as a function of time. Predicted temperatures for the extrusion of aluminum alloys AA 2014 and 2024 are compared with experimental data. Author

N89-15266# University Coll. of Swansea (Wales). Reader in Materials Engineering.
METALLURGICAL MODELLING OF SUPERALLOY DISC ISOTHERMAL FORGINGS
R. W. EVANS *In* AGARD, Aerospace Materials Process Modelling 17 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

The metallurgical structure of superalloy aeroengine disc forgings is a complex function of the forging operation parameters and the post forging heat treatment. It is often desirable to obtain certain specific structures in parts of the disc which are, for instance, resistant to crack propagation and this has traditionally been accomplished by means of a series of production trials. This expensive and time consuming procedure can be considerably shortened if the development of microstructure during the forging can be accurately modelled by a suitable computer code. Described here is such a model and its use in the design of isothermal forged components. The model discribed is a fully thermally coupled visco-plastic finite element algorithm. It treats nodal velocities as the basic unknowns and both the mesh geometry and the various metallurgical structural terms are updated by a single step Euler scheme. Facilities are available for ensuring that surface nodes follow die shapes after impingement, that flow is incompressible and that suitable surface friction forces are applied. Throughout the whole forging process (which may involve the re-meshing of severely distorted elements), the metallurgical history of elements is retained so that the effects of subsequent heat treatments can be assessed. Author

N89-15269# Dayton Univ., OH. Dept. of Mechanical Engineering.
PHYSICAL MODELING AND VISIOPLASTICITY STUDIES OF THE FORGING PROCESS
V. K. JAIN and R. SRINIVASAN (Wright State Univ., Dayton, OH.) *In* AGARD, Aerospace Materials Process Modelling 13 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

An analytical technique, which employs the approach of visioplasticity for evaluating large plastic strains such as those occurring in metalforming, is presented. The distortion of a quadrilateral element of a grid was tracked to compute strains during deformation. Here, two lines of a quadrilateral are used (length before and after deformation and direction cosines before deformation) to determine the true effective strain in the element. Although the method can be applied to any mode of deformation, its application plane-strain deformation is considered. The method has been verified by application to basic cases of deformation such as uniaxial compression, tension, pure shear, and rotation of element. Wedge testing was used for verification of the analytical results of a visco-plastic finite-element program ALPID which was developed to simulate metal flow in deformation processes such as forging and extrusion. Wedge-shaped specimens were machined from plates of 1100-F and 6061-T6 aluminum, and grids were engraved on the meridian plane by means of a CNC engraver. The specimens were annealed and compressed in a channel-shaped segmented die at room temperature. Author

N89-15273# Structural Dynamics Research Corp., Milford, OH.
SIMULATION AND DESIGN OF HIGH PRECISION UNIT PROCESSES VIA NUMERICAL METHODS
ROGER STAFFORD *In* AGARD, Aerospace Materials Process Modelling 21 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

SDRC has developed new computer codes specifically tailored for precise and fist simulations of manufacturing processes. Critical aspects of unit processes involve nonlinear transient heat transfer coupled with slow creeping flow. Finite element methods are chosen. Numerical algorithms are adopted which are specifically suited to the problem. Key elements of these simulations are outlined. SDRC has integrated unit process simulations with CAD/CAM design systems, analysis graphics systems, automated inspection, and data base. An example will illustrate data flow, simulation results, and how engineers are using these tools to design new processes for large complex parts. Author

N89-15274# Technische Hogeschool Twente, Enschede (Netherlands). Dept. of Mechanical Engineering.
A MIXED EULERIAN-LAGRANGIAN FINITE ELEMENT METHOD FOR SIMULATION OF THERMO-MECHANICAL FORMING PROCESSES
J. HUETINK and J. VANDERLUGT *In* AGARD, Aerospace Materials Process Modelling 8 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

A mixed Eulerian-Lagrangian finite element method is developed by which nodal point locations can be adapted independently from the actual material displacements. Numerical difficulties due to large element distortions, as many occur when the updated Lagrange method is applied, can be avoided by this method. Movement of (free) surfaces can be taken into account by adapting nodal surface points in a way that they remain on the surface. Hardening and other deformation path dependent properties are determined by incremental treatment of convective terms. A local and a weighed global smoothing procedure is introduced in order to avoid numerical instabilities. The method has been applied to simulations of an upsetting process, a wire drawing process and a cold rolling process. In the simulation of the rolling process, both workpiece and roll are simultaneously analyzed in order to predict the flattening of the roll. Special contact-slip elements are developed for the tool-workpiece interface. Author

N89-15275# Middle East Technical Univ., Ankara (Turkey). Dept. of Mechanical Engineering.
FINITE-ELEMENT-SIMULATION OF METAL-FORMING PROCESSES
A. E. TEKKAYA *In* AGARD, Aerospace Materials Process Modelling 13 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

For the metal forming industry, numerical simulation procedures, through which the tremendous costs for process development and experimental tools can be reduced, are gaining an increasing significance. Here, a finite element code, based on the well-known elastic-plastic formulation by McMeeking and Rice will be given and some interesting industrial metal forming applications are discussed. The finite element approach is of updated Lagrangian type utilizing a generalized Prandtl-Reuss flow rule together with the v.Mises yield criterion. Nonlinearities resulting from the material response and the complex kinematics of the problem are handled numerically through the self-correcting and the midpoint stiffness methods. Examples of application cover the analysis of residual stresses in extrusion, the simulation of the Sachs boring-out method, as well as the simulation of instabilities and deep-drawing. Author

N89-15276# Argonne National Lab., IL.
GENERIC CASTING MODELING
WILLIAM T. SHA *In* AGARD, Aerospace Materials Process Modelling 16 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

A detailed model is given of fluid flow coupled with heat transfer of a liquid melt for casting processes. The model is an extension of the COMMIX code and is capable of handling castings of any shape, size, and material. While much of the emphasis is placed on fluid flow and heat transfer, a brief mention of R and D needs in modeling of metallurgical aspects, as well as stress/deformation is also outlined. A feature of this model is the ability to track the liquid/gas interface and liquid/solid interface. It can also calculate alloy element distributions providing that constitutive relations such as interfacial drag between alloy elements are available. The flow of liquid melt through the sprues, runners, and gates into the mold cavity is calculated, along with three-dimensional temperature and velocity distributions of the liquid melt throughout the casting process. Author

N89-15277# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Gennevilliers (France).
A NUMERICAL MODEL OF DIRECTIONAL SOLIDIFICATION OF CAST TURBINE BLADES
GHISLAINE LAMANTHE and L. VERMOTDESROCHES *In* AGARD, Aerospace Materials Process Modelling 5 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

A finite element model of the thermokinetics of the directional solidification of cast turbine blades is discussed. The main difficulty to be solved to obtain an appropriate modelling of the phenomenon lies in the high amount of radiative heat transfers, in a case where geometry is complex, thermal gradients high and boundary conditions variable with time. The model treats these transfers by meshing the radiant surfaces and applying shape factors. The other requirements of such an approach are: an appropriate knowledge of the boundary conditions of the furnance, and the thermal properties of materials (ceramic shells, etc.). Experiments have shown a fair consistency between the thermal fields predicted by the model and temperature data recorded during the solidification of a cluster of complex bars representative of turbine blades. Author

N89-15278# General Electric Co., Cincinnati, OH. Aircraft Engines Dept.
USE OF VENDOR CONSORTIUMS FOR IMPLEMENTATION OF PROCESS SIMULATION TECHNOLOGY
SULEKH C. JAIN and KENNETH C. MADDUX (Structural Dynamics Research Corp., Milford, OH.) *In* AGARD, Aerospace Materials Process Modelling 22 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

The aerospace Vendor Supplier Industry in the United States is now moving from the Trial and Error approach to the Plan, Predict and Produce philosophy. This new discipline offers reduced development time, near net shapes, improved part quality, reduced inspection, and hence reduced overall cost. The emphasis now is to make it right the first time in the shortest time and at least cost. During the last decade there has been a tremendous amount of progress in the development of fundamental Computer Aided Engineering (CAE) tools for unit manufacturing process simulation. Much of this effort in the United States has been sponsored and funded by the United States Air Force and other government agencies. The tools have been correlated and validated to actual problems in laboratories and shop floors and a reasonable level of confidence and vendor acceptance has been achieved. These tools include simulation for: forging, extrusion, heat treatment, investment casting, ring rolling, chip removal. The challenge now is to implement these tools at vendor sites and to utilize these technologies on an ongoing basis to assist in preventing real world problems. The success and the status of implementation of this technology with major United States aerospace forging vendors are discussed. Author

N89-15279# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).
INDUSTRIAL INTRODUCTION OF THE MODELING OF AERONAUTICAL FORGING AND FOUNDRY PROCESS SIMULATION [INTRODUCTION INDUSTRIELLE DE LA MODELISATION DE SIMULATION DE PROCEDES EN FORGE ET FONDERIE AERONAUTIQUE]
ERIC BACHELET and YVES HONNORAT *In* AGARD, Aerospace Materials Process Modelling 9 p (SEE N89-15262 07-31) Aug. 1988 In FRENCH
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

Problems encountered in the industrial application of aeronautical forging and foundry process simulation modeling which arise from both the complexity of the processes simulated and the geometries considered are reviewed. It is noted that current three-demensional meshes are useful in modeling complex geometries. Such simulation programs make possible: (1) detailed process analysis; (2) the study of the sensitivity of various fabrication parameters; (3) equipment optimization; and (4) the efficient automation of fabrication. The most advanced modeling integration has been in the industrial production of large axisymmetric forged parts. Author

N89-15280# Inco Engineered Products Ltd., Birmingham (England).
AN APPLICATION OF COMPUTER MODELLING TO ISOTHERMAL FORGING
P. S. BATE *In* AGARD, Aerospace Materials Process Modelling 10 p (SEE N89-15262 07-31) Aug. 1988
(AGARD-CP-426) Avail: NTIS HC A12/MF A01

In isothermal forging the workpiece is maintained at a reasonably constant temperature throughout the deformation. Because the dies must withstand high temperatures and the process times are long, the method is restricted to the production of high values components. This makes the process inherently expensive and so a reliable simulation in useful for process design. Within certain constraints, mainly those concerned with adequate representations of material behavior, finite element methods can provide such a simulation. The method used to model disc and blade-section forging is described. This is a two-dimensional finite element analysis using a finite incremental/iterative technique for elasto-viscoplastic materials. The mesh is defined by material points, and can be readily redefined during the simulation. Graphical display of the material deformation allows likely problems to be identified. Experiments using simple stress state testing have revealed that commonly used relationships are inadequate for predicting the flow stress of important materials. The type used in the modelling described here attempts an inproved relationship, involving a structure related state variable. The evolution of this variable in the model can, together with experimental simulations, give a reasonable indication of the development of microstructure during forging. Author

N89-17685# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
BEHAVIOUR AND ANALYSIS OF MECHANICALLY FASTENED JOINTS IN COMPOSITE STRUCTURES
Mar. 1988 307 p In ENGLISH and FRENCH Meeting held in Madrid, Spain, 27-29 Apr. 1987 Original contains color illustrations
(AGARD-CP-427; ISBN-92-835-0431-3; AD-A199171) Avail. NTIS HC A14/MF A01

The rapidly increasing use of composite structures in NATO aerospace has intensified interest in methods of strength, and life analysis. At the same time the introduction of new tough resins has increased the static strength of composite joints with implications for the corresponding strength in fatigue. A number of NATO nations have built up data bases and developed methods for strength and life analyses; in order to take advantage of these resources the Structures and Materials Panel held a Specialists' Meeting, in conjunction with the 64th Panel Meeting, at Madrid, Spain on 27th-29th April 1987, under the chairmanship of Professor Vittorio Giavotto, to provide a focus for methods of analysis and the identification of research needs. This volume contains the papers presented at this Specialists' Meeting. For individual titles, see N89-17686 through N89-17705.

N89-17706# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
SCATTERING AND PROPAGATION IN RANDOM MEDIA
Mar. 1988 538 p In ENGLISH and FRENCH Meeting held in Rome, Italy, 18-22 May 1987
(AGARD-CP-419; ISBN-92-835-0444-5; AD-A194694) Avail: NTIS HC A23/MF A01

The topic of scattering and progagation in random media has implications for the design, development, and operation of most military systems that radiate energy as a means of accomplishing their functions. Primary emphasis is on scattering and transmission in the atmosphere; however, other related random medium effects are not excluded. Modern methods of characterizing random media, mathematical methods and their applicability, effects on electromagnetic waves and the interpretation of these effects to specific system applications are described. The region of the spectrum considered is essentially unlimited and ranges from very long waves to optics. The performance of existing surveillance communication and navigation systems as well as the design of future systems is influenced by the propagation of energy via random media. An understanding of the nature of the medium and its impact on system design and performance is For individual titles, see N89-17707 through N89-17752.

N89-18441# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Delft (Netherlands). Road-Vehicles Research Inst.
MADYMO CRASH VICTIM SIMULATIONS: A FLIGHT SAFETY APPLICATION
J. WISMANS and J. A. GRIFFIOEN *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 6 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

MADYMO is a computer program for two- or three-dimensional simulation of human body gross motions. The program was designed particularly for crash analyses. In the past years the program was applied and validated extensively for vehicle safety research. An application is described in the field of flight safety: the simulation of a space shuttle crew escape system. Author

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COMMUNICATIONS AND RADAR

Includes radar; land and global communications; communications theory; and optical communications.

N86-27566# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
PROPAGATION IMPACT ON MODERN HF COMMUNICATIONS SYSTEM DESIGN
Mar. 1986 187 p Lecture series held in Brussels, Belgium, 21-22 Apr. 1986; in Issy-les-Moulineaux, France, 24-25 Apr. 1986; and in Copenhagen, Denmark, 28-29 Apr. 1986
(AGARD-LS-145; ISBN-92-835-1521-8; AD-A171300) Avail: NTIS HC A09/MF A01

AGARD Lecture Series 145 is concerned with high frequency communications and is sponsored by the Electromagnetic Wave Propagation Panel of AGARD and implemented by the Consultant and Exchange Program. The aim of these lectures is to survey problems in the field of HF Communications. The lectures cover needs of both the civil and military communities for high frequency communications. They discuss concepts of real time channel evaluation, system design, as well as advances in equipment, in propagation, and in coding and modulation techniques. The lectures are aimed to bring non-specialists in the field up to date so that HF communications can be considered as a viable technique at this time. The problems, difficulties and limitations of HF are also outlined. For individual titles see N86-27567 through N86-27576.

N86-27567# Hull Univ. (England). Dept. of Electronic Engineering.
THE DESIGN OF STATIC AND MOBILE HF COMMUNICATION SYSTEMS
M. DARNELL *In* AGARD Propagation Impact on Modern HF Communications System Design 25 p (SEE N86-27566 18-32) Mar. 1986
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

The lecture deals with more specific aspects of HF communication system design arising from a previous lecture entitled HF system design principles presented as part of AGARD Lecture Series 127 in 1983. The major topics considered are: (1) the design of point-to-point systems; (2) the design of systems involving mobile terminals; (3) system control and frequency management; (4) resistance to interception and disruption. The lecture is intended to provide a technical framework for later lectures covering the more detailed aspects of HF communication system design. Author

N86-27568# Norwegian Defence Research Establishment, Kjeller.
PROPAGATION 1: STATE OF THE ACT OF MODELLING AND PREDICTION IN HF PROPAGATION
E. V. THRANE *In* AGARD Propagation Impact on Modern HF Communications System Design 21 p (SEE N86-27566 18-32) Mar. 1986 Previously announced as N83-30864
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

The lecture reviews the state of the art in HF propagation modelling and describes the principles of radio frequency predictions. As a basis for the discussions, a brief introduction is given to the ionospheric parameters of importance to HF-propagation. Current methods for frequency prediction are semi-empirical, that is they depend upon a large data base of ionospheric physical models of the ionosphere and of radio wave propagation through the medium. In addition models of the noise and interference environment must be included. The lecture discusses the principles on which the methods are based, as well as their limitations. Examples are given of the use of predictions in system planning and communications. The relative importance of skywave and ground wave communications in the HF-band is discussed. Author

N86-27569# Hull Univ. (England). Dept. of Electronic Engineering.
EMBEDDED REAL-TIME CHANNEL EVALUATION TECHNIQUES
M. DARNELL *In* AGARD Propagation Impact on Modern HF Communications System Design 16 p (SEE N86-27566 18-32) Mar. 1986
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

The requirement for real-time channel evaluation (RTCE) in HF systems is identified and discussed in detail. Various scenarios in which RTCE is applicable are examined and classified. Specific RTCE techniques and systems are then described including: Pulse/modulated pulse sounding, chirp sounding, limited channel monitoring, interference characterization, and in-band RTCE The application of RTCE to practical HF systems is discussed and the benefits accruing from its use quantified. Author

N86-27570# Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.
AN INTRODUCTION TO ERROR-CONTROL CODING WITH APPLICATION TO HF COMMUNICATIONS
M. D. GROSSI *In* AGARD Propagation Impact on Modern HF Communications System Design 16 p (SEE N86-27566 18-32) Mar. 1986
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

The increasing demand for reliable, low error-rate, high-speed digital data transmission at HF has created the need for the adopting of coding schemes. As it is well appreciated by the practicing communicator, a problem in high-speed data transmission is the occurrence of errors. Codes provide an effective approach for the reduction of the error rate. Linear block codes (of which cyclic codes are a subclass) and convolutional codes are the main categories of codes of interest to HF communications. They are capable of correcting random errors due to white Gaussian noise, as well as burst errors due to impulse noise. In block codes, a block of information bits is followed immediately by a group of

check bits. The latter verify the presence of errors in the former. In convolutional codes, check bits are continuously interleaved with information bits, and they check the presence of errors not only in the block immediately preceeding them, but in other blocks as well. For the various coding schemes reviewed in the lecture, several numerical examples are given, to help in the quantitative appraisal of the merits of a code, versus required equipment complexity. Author

N86-27571# Signatron, Inc., Lexington, MA.
MODERN HF COMMUNICATIONS, MODULATION AND CODING
P. MONSEN *In* AGARD Propagation Impact on Modern HF Communications System Design 13 p (SEE N86-27566 18-32) Mar. 1986 Previously announced as N83-30867
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

Digital communications over High Frequency radio channels are limited by the effects of time varying multipath signals and an impulsive noise characteristic. Modulation techniques which utilize *adaptive receiver structures in conjunction with advanced error* correction coding concepts can provide quality communication at both low data rates around 10 bps and high data rates around 2400 bps. The multipath channel is examined and two basic constraints are introduced. When the learning constraint is satisfied, it is possible to estimate the channel multipath gain and phase components. The diversity constraint establishes the necessary condition for implicit diversity. For low data rate applications where Intersymbol Interference (ISI) is negligible, adaptive receivers are discussed when both learning and diversity constraints are satisfied. An incoherent adaptive receiver is discussed for applications where the learning constraint is not satisfied. For high data rate applications, both constraints are satisfied in an HF application but ISI effects are severe. Adaptive techniques including equalizers and maximum likelihood sequence estimators are discussed. Experimental results from HF channel simulator tests are presented in a comparison of nonadaptive and adaptive high speed modems. We discuss the use of error correction coding to protect against impulsive noise and show that multipath fading reduces the *theoretical performance capability by only 1 to 3 dB when proper* coding and interleaving are employed. Performance of practical coding schemes using channel state information are used to show the potential performance on an HF channel. Author

N86-27572# *Petrie Telecommunications, Nepean (Ontario).*
EQUIPMENT: ANTENNA SYSTEMS
L. E. PETRIE *In* AGARD Propagation Impact on Modern HF Communications System Design 5 p (SEE N86-27566 18-32) Mar. 1986 Previously announced as N83-30868
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

Some antenna fundamentals as well as definitions of the principal terms used in antenna engineering are described. Methods are presented for determining the desired antenna radiation patterns for HF communication circuit or service area. Sources for obtaining or computing radiation pattern information are outlined. Comparisons are presented between the measured and computed radiation patterns. The effect of the properties of the ground on the antenna gain and the pattern are illustrated for several types *of antennas. Numerous examples are given of the radiation patterns* for typical antennas used on short, intermediate and long distance circuits for both mobile and fixed service operations. The application of adaptive antenna arrays and active antennas in modern HF communication systems are briefly reviewed. Author

N86-27573# Mitre Corp., Bedford, MA.
DEVELOPMENTS IN HF EQUIPMENT AND SYSTEMS MOBILE AND PORTABLE TERMINALS
Q. C. WILSON *In* AGARD Propagation Impact on Modern HF Communications System Design 19 p (SEE N86-27566 18-32) Mar. 1986
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

Before the advent of satellite platforms, sophisticated high frequency (HF) propagation and system research promised improved capability during disturbed ionospheric propagation conditions. However, satellite relays captured the imaginations and pocketbooks of the communications community in the mid-1960s. Consequently, extant HF systems aged while satellite systems were implemented. During peacetime, satellite systems transmit quality low data rate communications and navigation aids to mobile *users, but there is now renewed interest in the low cost and* survivability attributes of HF radio. At this time, when old HF prime systems need replacement for logistical reasons, the need for low cost communications that can survive jamming, nuclear effects, and space warfare is not satisfied. The HF renaissance is the response to this challenge. Logistical replacement procurements that provide new capabilities are redressing the attrition of vacuum-tube radio equipment over the last decade. Procuring organizations typically compile specifications comprising state-of-the-art and new capabilities offered by competing vendors. Integrated circuits, which include microprocessors, synthesizer elements, and other evolving components, have led to new circuit architectures. The first of the following three sections describes: Receivers; Transceivers and Antenna Couplers; Antenna Kits; and Audio Channel Peripherals. Author

N86-27574# Norwegian Defence Research Establishment, Kjeller.
PROPAGATION 2: PROBLEMS IN HF PROPAGATION
E. V. THRANE *In* AGARD Propagation Impact on Modern HF Communications System Design 17 p (SEE N86-27566 18-32) Mar. 1986 Previously announced as N83-30870
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

The ionosphere is not a perfect reflector for HF-waves, and *the lecture will review some of the resulting propagation problems.* Some of these are encountered during undisturbed ionospheric conditions, such as multipath reflections, but most problems are associated with geophysical disturbances. Solar flares and associated magnetic storms cause absorption, low MUF (Maximum Useable Frequency), scatter due to irregularities, etc., The ionosphere is particularly variable in high latitudes where auroral phenomena influence the reflecting properties of the ionospheric layers. The lecture discussed the presently available short term forecasting techniques, and it also deals with possible ways of minimizing the effects of ionospheric disturbances, such as path and time diversity, the use of early warnings, and back-up systems. Author

N86-27575# Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.
MEASUREMENTS OF HF PROPAGATION PARAMETERS FOR REAL-TIME CHANNEL EVALUATION (RTCE) SYSTEMS
M. D. GROSSI *In* AGARD Propagation Impact on Modern HF Communications System Design 14 p (SEE N86-27566 18-32) Mar. 1986
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

HF propagation paths are time-spread and frequency-spread channels, and are characterized by severe variability in the time domain of all their properties, inclusive of path losses. In addition, even when path conditions would be affordable,the link may be severely interfered with by other transmitters. Improvements over present-day link's performance in terms of circuit reliability, data rate and error rate can be achieved through the use of adaptive schemes capable of coping with the variability of the channel. Recent advances in microprocessor technology, in frequency-agile HF equipment and in the understanding of the propagation medium, make it feasible and practical to use adaptive schemes at HF. The simplest approach is to make the link adaptive to a selected channel parameter such as the Signal-to-Noise ratio. At the other extreme, the adaptive links can be designed to respond to all relevant channel functions, such as Signal-to-Noise ratio, multipath spread, Doppler spread, etc. In all cases, a necessary prerequisite *for link's adaptivity is Real-Time Channel Evaluation (RTCE).* The RTCE data gathering must match in scope and complexity the adaptivity scheme that is meant to serve. For instance, if the link's data rate is adjusted only to the Signal-to-Noise ratio, the RTCE must be kept very simple and must be reduced to the sole measurement of the signal intensity and to the level of the noise, inclusive of interference. Measurement of pertinent link's parameters by the RTCE must be performed at several spot frequencies in the band of interest, in order to identify automatically the most suitable carriers for the transmission of the information. RTCE is at present in the R&D phase, and the related activities consist almost solely of the measurement of signal amplitude and noise levels, inclusive of interference, at several frequencies in specific HF paths of interest, with only a few instances of inclusion of multipath spread measurements. At the successful completion of the R&D activity, it is expected that in a form or another,

RTCE and the related adaptive schemes will enter the practice of modernized HF communications. Author

N86-27576# Petrie Telecommunications, Nepean (Ontario).
ADAPTIVE SYSTEMS IN OPERATION
L. E. PETRIE *In* AGARD Propagation Impact on Modern HF Communications System Design 10 p (SEE N86-27566 18-32) Mar. 1986
(AGARD-LS-145) Avail: NTIS HC A09/MF A01

The development and evolution of channel evaluation techniques is described. A recently developed fully automatic HF radio telephone system is discussed which automatically selects the suitable channel and also provides a telephone inter-connects. Also described is a HF message terminal which automatically requests, repeats and confirms message status for sender and receiver. Author

N86-30931# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
DETERMINATION OF ANTENNAE PATTERNS AND RADAR REFLECTION CHARACTERISTICS OF AIRCRAFT
H. BOTHE, D. MACDONALD, and A. POOL, ed. May 1986 138 p
(AGARD-AG-300-VOL-4; ISBN92-835-1530-7; AD-A169584)
Avail: NTIS HC A07/MF A01

The different types of aircraft antennas, their radiation characteristics and their preferred siting on the airframe are described. Emphasis is placed on the various methods for determining aircraft antenna radiation patterns (ARP) and advantages, disadvantages and limitations of each method are indicated. Mathematical modelling, model measurements and in-flight measurements in conjunction with the applied flight test techniques are included. Examples of practical results are given. Methods of determining aircraft radar characteristics are also described, indicating advantages, disadvantages and limitations of each method. Relevant fundamentals of radar theory are included only as necessary to appreciation of the real meaning of radar cross section (RCS) and angular glint. The measuring methods included are dynamic full-scale, static full-scale, sub-scale optical, ultrasonic and radio modelling. References are made to RCS measuring facilities in the USA and Europe and the UK Radio Modelling Facility is used extensively to exemplify the sub scale technique. Author

N87-13291# Rome Univ (Italy). Dipt. di Energetica.
BISTABILITY IN NONLINEAR WAVEGIUDES
M. BERTOLOTTI, C. SIBILIA, and I. ANSELMI *In* AGARD Guided Optical Structures in the Military Environment 8 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The propagation of electromagnetic waves in a nonlinear waveguide is studied. For simplicity a three layer structure is considered with the two external media of semi-infinite extent. The mode dispersion equation is derived together with the power carried by the single mode in the structure, showing that bistability can occur in some case. Author

N87-13294# Communications Research Centre, Ottawa (Ontario). Optical Communications Program.
OPTOELECTRONIC BROADBAND SWITCHING FOR COMMUNICATIONS AND SIGNAL PROCESSING
R. I. MACDONALD and D. K. W. LAM *In* AGARD Guided Optical Structures in the Military Environment 10 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

By employing a hybrid technology using electronic and optical integration, optical isolation levels can be attained in a switch matrix without the need to switch light. Bandwidths of several GHz, subnanosecond switching time and crosstalk below 50 dB were demonstated in monolithically integrated optoelectronic switch matrices. These devices show high promise as central switches in star configuration communication systems where very high bandwidth or very large array size is required. Advantages over foreseeable alternative technologies include size and power consumption as well as performance. In addition, optoelectronic switch matrices have unique properties that suggest their application in a number of signal processing situations where precise broadband signal delays are required, such as in the phasing of arrays, or the production of tunable filters. Recent work in these areas are described. Author

N87-18703# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
SPECIAL COURSE ON INTERACTION OF PROPAGATION AND DIGITAL TRANSMISSION TECHNIQUES
Oct. 1986 308 p Special course held in Jevnaker, Norway, 13-14 Oct. 1986, in Copenhagen, Denmark, 16-17 Oct. 1986, and in Lisbon, Portugal, 20-21 Oct. 1986
(AD-A175698; AGARD-R-744; ISBN-92-835-1539-0) Avail: NTIS HC A14/MF A01

This Special Course has three main objectives: (1) To provide an opportunity for engineers and scientists to learn more of propagation mechanisms and communications system design in frequency bands other than those with which they may be closely associated, thus enabling a cross-fertilization of ideas to take place; (2) To attempt to identify, for the various classes of systems, the propagation measurements/data still required to enable digital communication system design to be made more precise and effective; and (3) To identify trends in the requirements and design techniques for future digital communication systems. This Special Course, sponsored by the Electromagnetic Wave Propagation Panel of AGARD, has been implemented by the Consultant and Exchange Program of AGARD, and was presented at Jevnaker, Norway, 13 to 14 October 1986, at Copenhagen, Denmark, 16 to 17 October 1986 and in Lisbon, Portugal, 20 to 21 October 1986. For individual titles see N87-18704 through N87-18711.

N87-18704# Hull Univ. (England). Dept. of Electronic Engineering.
REVIEW OF MODULATION, CODING AND SPEECH DIGITISATION TECHNIQUES
M. DARNELL *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 17 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

As a basis for the more detailed discussion of specific forms of digital communication system in this special course, this lecture introduces the following topics in general terms: (1) modulation; (2) coding for error control; (3) coding for multiple-access; (4) coding for encryption; and (5) speech digitization. Author

N87-18705# Naval Research Lab., Washington, DC. Ionospheric Effects Branch.
ELF/VLF/LF PROPAGATION AND SYSTEM DESIGN
FRANCIS J. KELLY *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 110 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

The effects of propagation conditions in the ELF/VLF/LF frequency band on the design and performance of digital communications systems are described. The communications channel from a ground-based or airborne transmitting antenna throught the Earth-ionosphere waveguide to the receiver is discussed. Questions of coverage, noise, dispersion, time variance and propagation disturbances are summarized. Author

N87-18706# Deutsche Welle, Cologne (Germany, F.R.).
HF GROUNDWAVE AND SKYWAVE PROPAGATION
KLAUS-JUERGEN HORTENBACH *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 25 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

The principles of HF ground- and skywave propagation are reviewed with regard to regular conditions as well as anomalous phenomena which may effect the signal characteristics and thus may have an influence on the performance of digital communication systems. Particular consideration is given to the statistics of signal fading as a basis for system design. Author

N87-18707# Hull Univ. (England). Dept. of Electronic Engineering.
HF SYSTEM DESIGN
M. DARNELL *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 24 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

This lecture is intended to complement the companion lecture dealing with the propagation aspects of HF communications. The major topics covered are as follows: (1) the design of point-to-point systems; (2) the design of systems involving mobile terminals; (3) system control and frequency management; and (4) resistance to interception and disruption. The lecture attempts to show how the propagation effects discussed in the previous lecture on HF groundwave and skywave propagation are taken into account in the design of HF communications systems for various purposes. Author

N87-18708# Danish Research Center for Applied Electronics, Hoersholm.
METEOR BURST PROPAGATION AND SYSTEM DESIGN
JENS OSTERGAARD *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 19 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

The first truly operational meteor scatter communication system (JANET) was operated in Canada in the mid 1950's at approximately 40 MHz. However the system was severely impaired during a Solar Proton Event, and experimental interest in meteor scatter propagation essentially vanished. SHAPE Technical Center developed and tested a new meteor scatter communication system (COMET) in the mid 1960's in Central Europe and Norway which worked well although it had a fairly low capacity (1 to 4 telegraph channels). The system was tested both at 40 MHz and at 100 MHz to explore the frequency dependent properties of meteor scatter propagation. The advent of satellite communication diverted interest away from meteor scatter propagation for obvious reasons of stable propagation and large bandwidth. Interest in meteor scatter communication has been revitalized as a result of rapid advances in microcomputer technology and digital communication techniques. Some suggested uses for modern meteor scatter communication systems include automatic data collection from unmanned sites, thin-line digital radiolinks, where privacy and exclusive ownership of the communication terminals are essential. Meteor scatter could also be a candidate mode for operation of digital HF communication systems with extended frequency range of operation into the VHF band. The aim of this paper is to present an overview of the meteor scatter propagation mechanism, and the ongoing research efforts which are directed towards the exploration of the potential of meteor scatter propagation as a communication channel. Author

N87-18709# North Atlantic Treaty Organization, Brussels (Belgium). Allied Radio Frequency Agency.
VHF/UHF/MICROWAVE LOS TERRESTRIAL PROPAGATION AND SYSTEM DESIGN
T. K. FITZSIMONS *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 11 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

The telecommunication frequency range under discussion is from 30 MHz up to tens of GHz. For military communications this means the use of systems such as Combat Net Radio, Single-Channel Radio Access, Tactical and Fixed Radio Relay, Air-Ground-Air Systems, Common User Information Systems and Tactical Satellite. For civil communications the systems are not dissimilar - mobile radio, fixed radio relay systems, Air Traffic Control, etc. Of course there is a considerable amount of broadcasting and there are military and civil radar systems in these frequency bands. The spectrum range from 30 MHz to about 5 GHz is for the military in particular, prime spectrum; wide bandwidths (hence digital transmission) can be achieved, most propagation mechanisms are relatively stable and most of this part of the spectrum can be used by tactical systems either operating on the move or moving frequently to new sites. In addition to considerations of wanted performance and necessary characteristics such as ECM, the military systems are designed to meet requirements for rapid deployment in an environment which is difficult and unpredictable from the electromagnetic environment, topographic, and meteorological aspects. Author

N87-18710# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
UHF/SHF SATCOM PROPAGATION AND SYSTEM DESIGN
ALLEN L. JOHNSON *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 18 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

One year after the launch of the Russian Sputnik, the Americans orbited the world's first active communications satellite, SCORE. The communications planners hoped that the line-of-sight communications through satellites would overcome the various propagation problems plaguing long-distance High Frequency (HF) communications. The communications satellite did overcome many of the traditional HF problems but due to the law of conservation of difficulty, a new set of propagation problems emerged. This section deals with some of those problems. A satellite orbiting at approximately 19,200 nautical mile altitude rotates at the same rate as the Earth and, if in an equatorial plane, appears to remain fixed over one point on the Earth. The equatorial synchronous satellite is discussed. The Earth-to-satellite link experiences a variety of propagation effects such as free space loss, attenuation, polarization changes, refraction, and delay as a result of the physics of the link and the normal Earth's atmosphere. These are also discussed. Author

N87-18711# North Atlantic Treaty Organization, Brussels (Belgium). Allied Radio Frequency Agency.
PROBLEMS OF SPECTRUM MANAGEMENT AND SYSTEM COMPATIBILITY
T. K. FITZSIMONS *In* AGARD and Special Course on Interaction of Propagation and Digital Transmission Techniques 10 p (SEE N87-18703 11-32) Oct. 1986
(AGARD-R-744) Avail: NTIS HC A14/MF A01

The problems of radio frequency spectrum management stem basically from requirements that are increasing more rapidly than our ability to exploit certain parts of the spectrum. The expanding demand is caused partly by the transition from analog to digital transmission methods but of course also to the increase in communications needs and uses. Much of the increase in demand is for allotments and assignments in frequency bands already heavily exploited. New frequency bands are periodically added to the table of allocations by the ITU (International Telecommunication Union) and the rate at which this has happened in the recent past is itself an indication in the almost explosive growth in the uses of the radio frequency spectrum. Author

N87-18721# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
MULTIFUNCTION RADAR FOR AIRBORNE APPLICATIONS
Jul. 1986 209 p In ENGLISH and FRENCH Symposium held in Toulouse, France, 14-18 Oct. 1985
(AGARD-CP-381; ISBN-92-835-0395-3; AD-A173978) Avail: NTIS HC A10/MF A01

The present state-of-the-art of multifunction radar and new concepts for the design of future radar systems are presented. Specific subject areas addressed include all-weather operation, signal processing, high resolution imaging (synthetic aperture radar), beam steering, range and Doppler estimation, clutter and interference, equipment and component design, target detection and classification, multifunction integration, and radar system integration. For individual titles see N87-18722 through N87-18760.

N87-18722# Thomson-CSF, Paris (France).
ABOUT THE FUTURE OF AIRBORNE RADAR
MICHEL H. CARPENTIER *In* AGARD Multifunction Radar for Airborne Applications 6 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The present state-of-the-art of airborne multifunctional radar is reviewed and possible developments for future systems are discussed. The operational requirements of military aircraft radars are outlined with particular attention given to target acquisition and tracking, radar navigation and terrain following. The electromagnetic environments these systems will operate in are also characterized. The limitations of present radars are defined

and suggestions are made regarding the directions of future research. Four possible areas of development are addressed: (1) improvement of the range resolution and complexity of the transmitted waveforms; (2) better utilization of the received signals; (3) improvement of angular domain; and (4) cooperation with the electromagnetic countermeasure system and other sensors onboard the aircraft. M.G.

N87-18723# Forschungsinstitut fuer Funk und Mathematik, Werthoven (Germany, F.R.).
SOLID STATE MULTIFUNCTION PHASED ARRAY RADAR
W. D. WIRTH *In* AGARD Multifunction Radar for Airborne Applications 8 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

With an experimental phased array radar system ELRA (electronic steerable radar) operational experience has been gathered. This system was planned for solid state operation, therefore it consists of active receiving and transmitting arrays. The provisional tube power amplifiers are replaced by transistor amplifiers. This change had some implications on the multifunction operation, especially on the selection of transmitted waveforms. The necessary considerations are relevant for future solid state phased array radars. The introduction of monolithic microwave antenna modules will improve the chances of active solid state phased arrays. Author

N87-18724# Radar Systems Group, Los Angeles, CA. Advanced Development Dept.
MULTIMISSION AIRBORNE RADAR FOR THE 1990S
THOMAS H. ROBINSON *In* AGARD Multifunction Radar for Airborne Applications 2 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The continuing trend towards the development and production of aircraft capable of multiple missions indicates that future airborne radars must provide a broad spectrum of air-to-air and air-to-ground modes. This paper investigates the modal and functional requirements of a multimode radar projected for the mid-1990s period. The paper is divided into two sections. In the first, the multimission capabilities of current radars are presented to establish trends and capabilities. In the second, the requirements of the next generation system are established. Current multimode radars lay the basis for future systems. The experience gained on the APG-65 and APG-63/70 radars is presented and conclusions are drawn regarding their impact on future system requirements. Not only are modes and performance reviewed for these radars but also their system architecture. The discussion starts with the APG-65 radar which is the first true multimission radar with programmable signal and data processing. Following this, the evolution of the APG-63 radar, culminating with the most recent upgrading resulting in redesignation of APG-70, is presented. The incorporation of air-to-ground capabilities in the APG-70, resulting from the Dual Role Fighter program, is reviewed. Results from the Advanced Fighter Capabilities Demonstration program are presented showing how high resolution SAR was incorporated into a full weapon delivery solution. The specific radar requirements for the next decade radar system are developed. This development is done in two parts. First, mode requirements are synthesized for air superiority, navigation and strike/interdiction operation. This includes low altitude penetration requirements and a review of radar timeline constraints which arise. Second, the fundamental functional requirements needed to implement the mode requirements are explored. Architectural issues and their impact on reliability and sustainability are also considered. Author

N87-18725# Royal Signals and Radar Establishment, Malvern (England).
MULTIFUNCTION MILLIMETRE-WAVE RADAR FOR ALL-WEATHER GROUND ATTACK AIRCRAFT Abstract Only
K. E. POTTER *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Details of the millimeter wave radar performance are presented which show that with potentially available power sources an all weather capability can be realized. Performance is evaluated as a function of frequency and antenna size, and the use of polarimetry with wide bandwidth/coherent processing is shown to offer potential enhancement for target discrimination. The millimeter wave radar is shown to be potentially capable of satisfying the following functions: take off/landing, terrain following, area correlation, tercom, and acquisition of targets. The above roles can be achieved in an all weather environment making the millimeter wave radar a valuable multifunction airborne radar. Author

N87-18726# Rome Air Development Center, Griffiss AFB, NY.
MULTI-MODE MULTISTATICS FOR PASSIVE/ACTIVE AIRBORNE SURVEILLANCE Abstract Only
ROBERT F. OGRODNIK *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The increasing performance demands for air surveillance assets, as well as the necessity for continued surveillance operations in the presence of enemy jamming anti-radiation missile (ARM) attacks, have increased interest in passive surveillance, in particular multi-mode passive/active multistatic sensing. The use of noncooperative radiation as illuminators of opportunity combined with passive surveillance electromagnetic support measurement (ESM) sensors opens new horizons to multistatic surveillance from a passive airborne platform. Research and field tests have been conducted on ESM augmented bistatics as well as noncooperative multistatics which support the development of airborne multi-mode passive surveillance technology. This work has been conducted under such programs as the Bistatic Enhanced Altimeter Detection (BEAD) and the noncooperative multistatic Passive Coherent Location (PCL). Both BEAD and PCL technology directly support the receiver, signal processing and target location/tracking operations necessary for passive surveillance. The demonstrated technologies for EM interference rejection and multistatic multi-target tracking and location under PCL provide a promising performance bench mark for passive surveillance in the presence of a complex electromagnetic environment. Passive receiver intercept performance under BEAD has provided a receiver design baseline for both look-down and look-up surveillance applications. The technologies under development in BEAD and PCL are presented along with the field test results and the sensor concepts. In particular, spin-off data such as bistatic look-down clutter, noise-floor limitation of noncooperative multistatics and sensitivity limitations set by passive surveillance using signal intercept techniques and illuminators of opportunity are provided. Author

N87-18727# Huntec 70 Ltd., Scarborough (Ontario).
MOTION COMPENSATION REQUIREMENTS FOR A HIGH RESOLUTION SPOTLIGHT SAR Abstract Only
J. S. A. HEPBURN, G. E. HASLAM (Defence Research Establishment, Ottawa., Ontario), D. F. LIANG, and W. S. WIDNALL (Massachusetts Inst. of Tech., Cambridge) *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The Canadian Department of National Defence is developing a high resolution airborne spotlight synthetic aperture radar (SAR). To attain the high contrast, high resolution and low geometric distortion objectives of the project, it is essential that very accurate motion compensation be applied to the radar returns to minimize the effects on SAR image quality of spurious antenna phase center motion. The motion compensation system being developed for the project includes a gimballed master inertial navigation system (INS) located near the center of gravity of the host aircraft, a strapdown inertial measurement unit (IMU) comprising gyroscope and accelerometer triads mounted on the radar antenna, as well as Doppler velocity and barometric altitude sensors for damping the inertial systems. The role of the master INS is to enable high accuracy alignment of the strapdown IMU. The raw sensor data are integrated using a U-D factorized Kalman filter to obtain optimal estimates of the motion of the radar antenna phase center while the SAR window is open. The data are used to adjust both the radar pulse repetition frequency and the phase and displacement of the radar returns. An analysis of the motion compensation requirements was carried out, leading to the specification of the motion compensation sensor configuration and accuracy. The performance of the motion compensation system has been evaluated by detailed computer simulation. This evaluation accounted for all major system error sources, including errors associated with sensors, transfer alignment and computation, with the system operating in a moderately turbulent environment. Author

N87-18728# Defence Research Establishment Ottawa, (Ontario).
IMPLEMENTATION OF AN AIRBORNE SAR MOTION COMPENSATION SYSTEM Abstract Only
D. DIFILIPPO, D. F. LIANG, L. POSTEMA (Lear Siegler, Inc., Grand Rapids, Mich.), and B. LEACH (National Aeronautical Establishment, Ottawa, Ontario) *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 (AGARD-CP-381) Avail: NTIS HC A1C/MF A01

The Canadian Department of National Defence has entered into the Phase 2 development of an airborne synthetic aperture radar motion compensation (SARMC) system, following a Phase 1 feasibility study which led to the specification of the SARMC sensor configuration and accuracy. This paper describes the hardware and software configurations of an airborne SARMC system implemented on board a Convair 580 research aircraft. The hardware configuration includes a gimballed LTN-51 inertial navigation system, a Decca Doppler radar, a baroaltimeter and a motion compensation inertial measurement subsystem (MCIMS). The MCIMS is a specially designed strapped-down inertial measurement unit mounted on the ring gear of the APS-506 radar antenna. Since motion compensation depends critically on knowledge of the MCIMS orientation with respect to the radar line-of-sight to the designated target, a laser alignment procedure was developed and performed to calibrate the azimuth encoder of the antenna ring gear. This procedure is discussed along with experimental results. Substantial effort was dedicated to streamlining the Kalman filter algorithms in the SARMC processing package to obtain a high degree of robustness and computational efficiency while optimally integrating the information from the motion compensation sensors. Preliminary flight trial data are presented and compared with simulation results to indicate the level of performance achievable with this optimized system. Author

N87-18729# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. for Radio Frequency Technology.
MM WAVE SAR SENSOR DESIGN: CONCEPT FOR AN AIRBORNE LOW LEVEL RECONNAISSANCE SYSTEM Abstract Only
C. BOESSWETTER *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 (AGARD-CP-381) Avail: NTIS HC A10/MF A01

The basic system design considerations for a high resolution SAR system operating at 35 GHz or 94 GHz are given. First it is shown that only the focussed SAR concept in the side looking configuration matches the requirements and constraints. After definition of illumination geometry and airborne modes the fundamental SAR parameters in range and azimuth direction are derived. A review of the performance parameters of some critical mm wave components (coherent pulsed transmitters, front ends, antennas) establish the basis for further analysis. The power and contrast budget in the processed SAR image shows the feasibility of a 35/94 GHz SAR sensor design. The discussion of the resulting system parameters points out that this unusual system design implies both benefits and new risk areas. One of the benefits besides the compactness of sensor hardware turns out to be the short synthetic aperture length simplifying the design of the digital SAR processor, preferably operating in real time. A possible architecture based on current state-of-the-art correlator hardware is shown. One of the potential risk areas in achieving high resolution SAR imagery in the mm wave frequency band is motion compensation. However, it is shown that the short range and short synthetic aperture lengths ease the problem so that correction of motion induced phase errors and thus focussed synthetic aperture processing should be possible. Author

N87-18730# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. for Radio Frequency Technology.
ECCM EFFECTIVENESS OF A LOW SIDELOBE ANTENNA FOR SAR GROUND MAPPING Abstract Only
C. BOESSWETTER *In* AGARD Multifunction Radio for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 (AGARD-CP-381) Avail: NTIS HC A10/MF A01

Airborne synthetic aperture radar (SAR) reconnaissance systems in the strip mapping mode are susceptible to jamming. The main electronic counter measure (ECM) threat is commonly understood to be the ground based sidelobe jammer which includes a sensitive intercept receiver and a tracking capability to adapt the jamming power in angle, frequency and bandwidth to the SAR system. The most important of several necessary electronic counter-countermeasure (ECCM) techniques is commonly considered to be a low sidelobe SAR antenna which also improves MTI performance. To characterize the ECCM and cost effectiveness of such an expensive antenna some measures are needed. There are two separate phases: intercept and jamming. Accordingly, two gains are defined: intercept gain and jamming gain. Both are based on the evaluation of the signal-to- (jammer plus clutter plus noise) ratio in the processed SAR image for the configuration airborne sensor-ground based jammer. Both gains descibe the benefits of a low side lobe antenna in terms of jam-free flight distance (intercept) and target contrast enhancement (jamming). It is shown that in the most interesting case of heavy jamming both intercept and jamming phases are discribed by the same set of equations if normalized to the pointing direction R sub 0 of the antenna. It follows that the intercept ratio on the ground equals the reciprocal of the target contrast in the processed SAR image. To discuss both the intercept and jamming gain performance of a given SAR antenna 3-dimensional relief plots and 2-dimensional contour plots are used. They allow the definition of both gains directly. For the parameters of a given SAR reconnaissance system the plots are calculated in an area of 120 nmi x 180 nmi (azimuth x range). By replacing the existing antenna with uniform weighting with an antenna with 25 dB lower sidelobe level the ECCM effectiveness in terms of intercept gain and jamming gain is shown. Since the equations are normalized to the pointing direction of the sensor antenna the results are given in relative terms. By including actual jammer parameters the ECCM effectiveness may also be given in absolute terms. Author

N87-18731# Thomson-CSF, Malakoff (France). Div. A.V.S.
SYNTHETIC APERTURE IMAGING AIRBORNE RADAR
MARC LUCAS *In* AGARD Multifunction Radar for Airborne Applications 4 p (SEE N87-18721 11-32) Jul. 1986 Previously announced as A86-32632
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Airborne synthetic aperture radars are systems able to obtain high resolution ground images, by day or night, independent of weather conditions. Their applications are very broad, both military (reconnaissance), and civilian (mapping remote sensing). Following a brief technical account (synthetic aperture, pulse compression), the paper describes the operational features of an airborne radar system providing high resolution images at long range. Then, a technical description is given. This system can provide in real time, to the ground, radar images by using a high rate data link. It consists of two main parts: (1) an airborne part including the antenna, the radar transmitter-receiver, and the data link unit; and (2) a ground station that realizes, in real time, data reception, synthetic aperture processing, and image exploitation IAA

N87-18732# Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (Germany, F.R.).
MILLIMETER WAVE TRANSMISSION THROUGH MAN-MADE OBSCURATIONS IN A BATTLEFIELD ENVIRONMENT Abstract Only
H. ESSEN and E. P. BAARS *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 (AGARD-CP-381) Avail: NTIS HC A10/MF A01

It is quite well established that millimeter waves exhibit superior transmission features for natural obscurations, i.e., mostly adverse weather-effects, if compared to those in the IR-region. Therefore mm-wave systems are competitors for military surveillance and guidance systems. For these applications the knowledge of the amount of degradation of mm-systems due to obscuration in a battlefield environment has to be assessed in comparison to IR-sensors. The data dealt with in this paper have been gathered during various measurement campaigns. They cover smoke and dust trials with mm-wave instrumentation systems at 47 GHz and 94 GHz and experiments on screening smokes. All trials were performed in conjunction with IR-measurements. For the dust and smoke-trials a bistatic configuration was used with transmitters and receivers located at two opposite sites across an artillery impact area. Results are discussed by means of attenuation-curves for different transmit/receive-polarizations. A comparison of the results of the two employed mm-wave frequencies with the

simultaneously measured IR-data is given for selected events and on a statistical basis over the whole measurement period. For the experiments on screening smokes a monostatic configuration was chosen with a pulsed 94 GHz instrumentation radar operating over a folded transmission path against a corner reflector and armoured target vehicles. By recording the echos from a number of consecutive range gates the attenuation caused by the smoke as well as the backscatter of the smoke cloud and the location of scattering centers within the cloud could be evaluated. Author

N87-18733# Adaptive Sensors, Inc., Santa Monica, CA.
A CFAR DESIGN CONCEPT FOR OPERATION IN HETEROGENEOUS CLUTTER
HAROLD M. FINN *In* AGARD Multifunction Radar for Airborne Applications 12 p (SEE N87-18721 11-32) Jul. 1986 Sponsored by the Army
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

When the heterogeneous clutter field spanning the spatial sampling sliding window can be modeled as two contiguous homogeneous clutter fields with the statistical parameters of each field unknown and independent from field to field and with the transition point between fields also not known, then the cell averaging CFAR (constant false alarm rate) performance significantly degrades yielding target masking effects and loss of false alarm regulation. For the same defined and encountered environment spanning the sliding windows, the performance degradation effects are shown to be largely eliminated when a newly developed class of CFAR test is employed designated as heterogeneous clutter estimating CFAR's (HCE-CFAR). The test initially involves the combined use of multiple hypothesis testing and maximum likelihood estimation procedures to estimate the statistical parameters of each of the two fields, and the transition point between them, and then makes use of the relevant estimated clutter field parameters to effect the final decision rule. HCE-CFAR designs are presented for both the cases when the contiguous fields have Rayleigh first order probability distritubions, and log normal probability distribution. However, the focus of the development and the conducted performance evaluation is for the Rayleigh clutter cases. Author

N87-18734# Marconi Co. Ltd., Chelmsford (England).
HIGH-RESOLUTION MTI WITH SAR Abstract Only
A. FREEMAN *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Moving Target Imaging (MTI) using Synthetic Aperture Radar (SAR) offers considerable potential as an all-weather surveillance tool, monitoring the movement of vehicles on the ground. The purpose of the work described in this paper is to investigate techniques of producing high-resolution images of such moving objects using the radar signals received by an existing airborne SAR system. The first step in the MTI method adopted is the production of a rather crude image of such moving targets as exist in the data. This can be achieved by application of a simple prefilter (for clutter-cancellation) prior to the conventional azimuth (Doppler) processing. The image can then be used for initial detection of the targets. In such images, well-behaved moving targets are distorted by their motions in a particular manner and the parameters of the target motions can be estimated from their shape and other properties. These parameters are measured and then used to construct a 2-dimensional filter matched to the response for each target, for use in the azimuth (Doppler) processing. This technique can be shown to produce high-resolution images of the moving targets with resolution being comparable to that of the conventional airborne SAR images of the ground.
Author

N87-18735# Adaptive Sensors, Inc., Santa Monica, CA.
A SEQUENTIAL ADAPTATION TECHNIQUE AND ITS APPLICATION TO THE MARK 12 IFF SYSTEM
JOHN S. BAILEY, JOHN D. MALLETT, DUANE J. SHEPPARD (Army Electronics Research and Development Command, Fort Monmouth, N. J.), F. NEAL WARNER, and ROBERT ADAMS (Technology Service Corp., Santa Monica, Calif.) *In* AGARD Multifunction Radar for Airborne Applications 11 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Sequential adaptation uses only two sets of receivers, correlators, and A/D converters which are time multiplexed to effect spatial adaptation in a system with (N) adaptive degrees of freedom. This technique can substantially reduce the hardware cost over what is realizable in a parallel architecture. A three channel L-band version of the sequential adapter was built and tested for use with the MARK XII IFF (identify friend or foe) system. In this system the sequentially determined adaptive weights were obtained digitally but implemented at RF. As a result, many of the post RF hardware induced sources of error that normally limit cancellation, such as receiver mismatch, are removed by the feedback property. The result is a system that can yield high levels of cancellation and be readily retrofitted to currently fielded equipment. Author

N87-18736# General Electric Co., Utica, NY. Aerospace Electronic Systems Dept.
HIGH RESOLUTION SIGNAL PROCESSOR FOR LIMITED APERTURE MULTIMODE RADAR
ROBERT L. NEVIN and M. R. OSULLIVAN (O'Sullivan Consulting, Inc., Rancho Palos Verdes, Calif.) *In* AGARD Multifunction Radar for Airborne Applications 10 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The maximum attainable point target detection capability of a search radar in a receiver noise limited situation is fundamentally limited by the radar's power-aperture product. However, the degree to which practical systems approach this maximum performance may be limited by processor power (i.e., processor throughput, resolution, etc.). Furthermore, in clutter limited situations, such as air-to-air look-down search modes, greater processor resolution, in both range and Doppler, can reduce the effective size of the clutter cell competing with the target, and thereby improve subclutter visibility. Recent and ongoing developments have contributed to the application of high-resolution, high-throughput signal processing to multimode, multifunction airborne radars. Both air-to-air and air-to-ground modes benefit in performance from increased processing power and flexibility. The solution to the high resolution processor is based on the experimental Modular Survivable Radar developed by General Electric in the late 1970s, and extended to airborne multimode radar projects. This modular, reconfigurable pipeline consists of high-efficiency stages, each with a narrow range of assigned functions, cascaded to form the full signal processor. Experience in system integration and testing has proven the adaptability of this architecture, which can be particularly useful to achieve the detection range requirements in a small fighter aircraft where physical space and cooling capability limit the power and aperture available to the radar. The architecture of a Programmable Signal Processor (PSP) currently in development for future application is described. This architecture allows Processing Elements (PE's) and memory elements to be configured into parallel pipelines. The PE's are designed to perform linear and nonlinear operations at the same high throughput rate. These features make it highly suitable for integration into the radar signal processor. With respect to this integration, the degree of flexibility required at different points in the pipeline is considered. Author

N87-18737# Forschungsinstitut fuer Funk und Mathematik, Werthoven (Germany, F.R.).
ANGULAR SUPER-RESOLUTION WITH ARRAY ANTENNAS: APPLICATION TO SEEKER-HEADS Abstract Only
U. NICKEL *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Monopulse seeker-heads can give large errors due to closely spaced targets or even completely wrong directions in the case of cross-eye deception. The effective countermeasure against these errors is resolution enhancement. Super-resolution methods offer

the possibility to resolve targets closer than the antenna beamwidth. Such methods are favorable for seeker-head applications, because the target separation as well as the signal-to-noise ratio increases as the missile approaches the target. All effective super-resolution methods require an antenna array with access to the single element outputs. Thus mechanical scanning is replaced by electronic scanning. Depending on the type of missile, sometimes antenna pattern restrictions have to be tolerated. Among all super-resolution methods the parametric target model fitting (PTMF) method seems to be most appropriate for this application. This method tries to fit a completely parameterized target model directly to the measured data. It can be rather easily computed, and it is the only method which can resolve completely correlated targets, which arise in the case of multipath and cross-eye deception. For seeker-heads with few antenna elements an implementation with digital signal processor chips is most suited. Computer simulations and experiments with measured data using the DESAS test equipment show that two targets separated at 0.3 beamwidth can be resolved in azimuth and elevation and that the switch from conventional monopulse to two-target estimation (super-resolution), which is crucial for the approaching missile, can be done by a reliable automatic test procedure. Author

N87-18738# Thomson-CSF, Montrouge (France). Division Equipements Avioniques.

DYNAMICS AND SIGNAL PROCESSING ALGORITHMS FOR HIGH FREQUENCY OF RECURRENCE RADAR MODES [DYNAMIQUES ET ALGORTHMES DE TRAITEMENT DU SIGNAL DANS LES MODES RADAR A HAUTE FREQUENCE DE RECURRENCE]

PHILIPPE LACOMME *In* AGARD Multifunction Radar for Airborne Applications 6 p (SEE N87-18721 11-32) Jul. 1986 In FRENCH

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The dynamics problem in the processing of signals is particularly difficult in the case of high frequency of recurrence (HFR) radar modes. Reception dynamics and necessary signal processing are defined and a typical case is evaluated. The effects of quantification are then analyzed at the various stages of signal processing (coding, rejection filtering, Fourier transformation). It is shown that the quantification noise depends, to a large extent, on the processing algorithms utilized. The presence of a ground echo rejection filter can directly increase the truncation problems owing to the elements situated after the filter. Likewise, the various algorithms used to compute the Fourier transform (fast Fourier transform or Winograd Fourier transform) function very differently vis-a-vis the truncations carried out with the operators. Therefore, in the selection of processing algorithms, it is necessary to consider, not only their performances with regard to the number of elementary operations, but also their sensitivity to quantification noise. M.G.

N87-18739# Rome Air Development Center, Griffiss AFB, NY.

DIGITAL AND OPTICAL SYSTOLIC ARCHITECTURES FOR AIRBORNE ADAPTIVE RADARS

STANLEY LIS, VINCENT C. VANNICOLA, JOHN A. GRANIERO, BARRY P. MEDOFF (Electromagnetic Systems Labs., Inc., Sunnyvale, Calif.), and WILLIAM A. PENN (General Electric Co., Syracuse, N.Y.) *In* AGARD Multifunction Radar for Airborne Applications 13 p (SEE N87-18721 11-32) Jul. 1986

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Systolic architectures for digital and analog, electronic and optical signal processing are presented along with specific applications to adaptive nulling. It is shown how the various architectures provide for the implementation of adaptive algorithms and how technologies affect performance. Their effects on adaptive degrees of freedom, convergence time, null depth, signal to noise ratio are presented along with size, weight, and required power. Adaptive algorithms covered are of two basic types: feedback/iterative and direct methods. Examples of each include the least mean square (LMS) for the iterative type and the QU factorization based on the Givens method for the direct method. Simulation results have verified the performance of the least squares and the systolic array for QU factorization by Givens method. Improved performance was obtained using the modified minimum variance distortionless response algorithm based on the maximum likelihood criteria. An optical implementation of the least squares algorithm over a continuously adaptive multi-path was experimentally evaluated. Thus far, 24 dB of cancellation was achieved over a 7 micro-second multi-path window for 10 mega-Hertz instantaneous bandwidth. Adaptivity in the spatial, temporal and Doppler domains are illustrated and their embodiment into the various architectures are presented. For example, an analog optical processor which generates weights in the spatial and temporal (multi-path) domains for broadband systems is shown. Also shown is a digital systolic architecture which is applied to a direct decomposition method for generation of adaptive weights in the spatial and Doppler domains. A description of brassboard models representing both architectures is included. Author

N87-18740# Marconi Avionics Ltd., Basildon (England). Signal Processing Design Dept.

THE APPLICATION OF MULTI-DIMENSIONAL ACCESS MEMORIES TO RADAR SIGNAL PROCESSING SYSTEMS Abstract Only

DAVID HAYES and BILL STRAWHORNE *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

A multi-dimensional access memory (MDAM) allows a word to be accessed from store either in the manner it was entered or as part of a bit slice of equally spaced or contiguous words. Conceptually, data may be regarded as being stored in an n dimensional hypercube of side length equal to the word length that usefully maps onto a wide range of signal processing operations, (e.g., FFTs, matrix inversion, multiple moments, distance metrics, sorts, searches and correlation decodes), when associated processing units that can carry out both bit parallel and bit serial arithmetic are used. The mapping of the natural multi-dimensionality of a signal processing task onto the MDAM structure is shown to be particularly useful when bit serial, word parallel processors are employed. In these circumstances the facilities of the MDAM make possible a range of useful operations that could only be implemented with great inefficiency using conventional memories. Furthermore, the MDAM considerably simplifies address generation for the I/O of real and complex words (e.g., the corner turn of incoming samples) while allowing useful permutations, such as barrel shifts, to be applied on each memory access for a insignificant cost in extra circuitry. Highly efficient and deeply pipelined, implementations of MDAM/processor structures are discussed that are particulary well suited to VLSI methodologies, in that very wide bandwidth interconnection networks of high complexity can be achieved at relatively low gate and pin counts. Thus, it is possible to form highly parallel multi-MDAM/processor structures that support very high levels of concurrency, identified as necessary for future radar signal processing systems. Moreover these structures translate over classes of operations that are not normally associated with each other. Consequently, these forms can be made extremely general and modular to produce powerful and compact processing kernels for programmable systems that embody high level signal processing constructs in their VLSI fabric and lead to high performance at the minimum silicon cost.

Author

N87-18741# Forschungsinstitut fuer Hochfrequenzphysik, Werthhoven (Germany, F.R.).

ON A SINGLE STEP TECHNIQUE FOR ADAPTIVE ARRAY PROCESSING

JOSEF WORMS *In* AGARD Multifunction Radar for Airborne Applications 6 p (SEE N87-18721 11-32) Jul. 1986

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

An improved adaptation algorithm designed for real time signal processing in antenna arrays is presented. The method is used for determining the filter weights in a sidelobe cancellation system. The Wiener filter equation is solved by using the well known Gauss-Seidel method and a sample matrix estimate. This algorithm (SSM - Single Step Method) combines rapid convergence and numerical stability. Compared with the direct SMI-technique and the Widrow LMS-algorithm, the properties of the proposed algorithm lead us to the conclusion that it is especially well suited for airborne antenna array applications. Author

N87-18742# Thomson-CSF, Montrouge (France). Division Equipements Avioniques.
FORM FACTOR OPTIMIZATION FOR HFR EMISSION [OPTRIMISATION DUE FACTEUR DE FORME EN EMISSION HFR]
PH. LEBIENVENU *In* AGARD Multifunction Radar for Airborne Applications 9 p (SEE N87-18721 11-32) Jul. 1986 In FRENCH
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

In high frequency of recurrence (HFR) emission having a weak form factor, eclispes and sampling result in some significant losses of the signal. The object of this paper is to present evaluation methods for these losses, starting with detection probability curves as a function of distance, and to utilize these methods to determine, under certain constraints of emitted power and computation loads, optimum form factors. M.G.

N87-18743# Alabama Univ., Huntsville. Dept. of Electrical and Computer Engineering.
A GENERAL SOLUTION FOR THE SYNTHESIS OF BINARY SEQUENCES WITH DESIRED CORRELATION SEQUENCE
ROBERT J. POLGE *In* AGARD Multifunction Radar for Airborne Applications 9 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Binary sequences are of considerable interest in many applications. In particular, the performance of a radar depends on the ambiguity function. For the case of binary phase modulation, the zero-Doppler performance of a pulse radar is a function of the discrete autocorrelation of the corresponding binary sequence. Alternately, a binary sequence can be expressed as a sequence of runs where the length of a run is equal to the number of contiguous bits of same sign. Given a run pattern the discrete autocorrelation can be computed easily and more rapidly than with the standard technique. The inverse problem, which is the synthesis of a run pattern given the desired discrete autocorrelation sequence, is much more difficult. This paper develops a set of sequential relations which relate the desired autocorrelation sequence to properties of the run pattern. For example, the autocorrelation at lag 1 defines the number of runs for a sequence of specified length. The autocorrelation at lag 2 now determines the number of runs of length 1. More generally the autocorrelation at lag $(k+1)$ establishes a relation between consecutive runs with *sum* exactly equal to k. Judicious use of these relations greatly facilitates the computer synthesis of binary sequences. While the method is quite general, emphasis is on tracking applications where it is desired to minimize the sidelobes as far as possible. Author

N87-18744# Illinois Univ., Chicago. Communication Lab.
BASIC MONOSTATIC POLARIMETRIC BROADBAND TARGET SCATTERING ANALYSIS REQUIRED FOR HIGH RESOLUTION POLARIMETRIC RADAR TARGET DOWNRANGE/CROSSRANGE IMAGING OF AIRBORNE SCATTERERS
RING-YUEN FOO, SUJEET K. CHAUDHURI (Waterloo Univ., Ontario), and WOLFGANG-M. BOERNER *In* AGARD Multifunction Radar for Airborne Applications 10 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

It has been well known that high frequency radar interrogation may disclose fine geometrical as well as indepth material decomposition of radar targets, whereas low frequency interception may only recover such coarse information as target size and target volume. At low frequencies, a target behaves as if it were a point source; within the resonance frequency regime it may disclose its natural frequency structure; and at high frequencies (PO/GO) its geometrical fine structures. Any target descriptor which is intended to describe the geometry becomes somewhat loose in its validity at low and resonant frequencies. For a target descriptor to describe fine geometrical structure, it has to be defined on a high frequency basis. In the phenomenological wideband polarimetric approach of the polarimetric radar target description first introduced by Kennaugh and further extended by Huynen, the proper specification of frequency range of validity has not been pointed out. In both treatments little care was given to this fact, which resulted in a haphazard early rejection of these important high resolution polarimetric radar target imaging theories because the resulting algorithms were incorrectly applied to the total spectral region. In view of these unsubstantiated claims of the complete uselessness of high resolution polarimetric radar imagery, the main objective is to show, based on rigorous electromagnetic vector scattering theory, that the Kennaugh, and particularly the Huynen polarimetric target descriptors, at high frequencies, can be closely related to specular geometry (in particular, specular curvature). For the purpose of verifying our approach the perfectly conducting ellipsoid is considered versus similar spherical target shapes. Numerical verification with measured scattering data for these shapes is shown, and application of the Kennaugh and Huynen target characteristic descriptors in downrange target discrimination, imaging and identification is suggested or demonstrated. Author

N87-18745# Waterloo Univ. (Ontario). Dept. of Electrical Engineering.
MULTI-(BI)-STATIC HIGH FREQUENCY (PO/GO) RADAR TARGET IMAGING OF AIRBORNE SCATTERERS
SUJEET K. CHAUDHURI and WOLFGANG-M. BOERNER (Illinois Univ., Chicago) *In* AGARD Multifunction Radar for Airborne Applications 12 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Electromagnetic scattering at distances remote from a complex-shaped object, at high frequencies (Physical Optics/ Geometric Optics), is dominated by certain specular components which are highly bistatic aspect and multifrequency dependent. The locations of these specular points on the complex object are known as the scattering centers. Generation of these scattering centers is dependent on the local geometry and local material in-depth decomposition of the object with respect to the aspect directions of the transmitter and receiver locations (monostatic as well as bistatic cases). The knowledge of the locations and the local geometries plus underlying material decomposition of these scattering centers can be useful in developing air-target discrimination/identification algorithms. Based upon this existing available basic multistatic scattering formulation, which is highly polarization-dependent, a basic vector inverse scattering model can be developed to recover these scattering centers from poly-(bi)-static polarimetric (bistatic scattering matrix) signatures which then may be used to formulate target classification, imaging and identification algorithms. The approach adopted in this investigation is based on the solution to the general poly-(bi)-static high frequency *isolated scattering center recovery* problem. Once this direct model solution is established and verified with the analytically model-generated and measured model test data, it is used as a building block toward more complicated inverse problems for the following realistic situations: (1) scattering center recovery with aspect/frequency restricted measurements for more economic/realistic implementation (limited bi/mono-static aspect angles, narrow bandwidth, CW multi-(bi)-static angle data, etc.) for the development of classification/imaging/identification algorithms; and (2) shape/surface material decomposition pattern recognition algorithms based on the knowledge of the recovered distribution of 3-dimensional distributed scattering centers on a complex shape target. Author

N87-18746# Thomson-CSF, Malakoff (France).
TARGET ANALYSIS THROUGH FINE DISTANCE DISCRIMINATION Abstract Only [DISPOSITIF DANALYSE DE CIBLES PAR DISCRIMINATION FINE EN DISTANCE]
R. AMBOS *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 In FRENCH
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Fine target analysis as a function of distance requires an emission with an instantaneous wide band spectra, i.e., for a resolution of 50 cm, 300 MHz are necessary. To develop an analysis technique based on pulse compression with linear frequency modulation, it is necessary to develop very strong BT (bandwidth-time) dispersive lines, to encode and process the compressed pulses very quickly. The principle proposed handles these difficulties in the following manner: to develop the strong BT necessary for the emission by utilizing existing dispersive lines resulting from specific analog processing. M.G.

N87-18748# Siemens A.G., Munich (Germany, F.R.).
THE MIXTURE OF DIFFERENT SEMICONDUCTOR TECHNOLOGIES IN RADAR MODULES AND ITS IMPACT ON COOLING PROBLEMS AND RELIABILITY
ERIK LANGER *In AGARD Multifunction Radar for Airborne* Applications 8 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The T/R-modules of active phased array radars (PAR) contain electronic circuits made from very different materials and technologies. The power dissipation of the dense packed modules produces much heat in the array which has only moderate cooling conditions. Therefore, the electronic devices must operate at ambient temperatures up to 90 C. Despite careful optimization of the heat paths, junction temperatures can rise up to 160 C. Hence failure mechanisms with high activation energies (e.g., 1.85 eV) are relevant, even through they can normally be neglected for reliability estimations. By optimizing the individual devices one can expect that with soft degradation the mean repair interval (MRI) of the array will be about 1 to 3 years accumulated service times. The degradation of electrical performance at high temperatures limits only the transmission power and the receiver noise figure. By application of an Arrhenius graph and modification of the bath tube curve, one can derive reliability figures from stress tests with small numbers of samples in an early state of development. The reliability and packaging problems can be solved, so that T/R-modules can meet the requirements of active PAR. Author

N87-18749# Rome Air Development Center, Griffiss AFB, NY.
MMIC T/R MODULES FOR THE NEXT GENERATION AIRBORNE SURVEILLANCE PLATFORMS
EDWARD J. JONES, MICHAEL O. LITTLE, THOMAS A. MCEWEN, R. HUNTER CHILTON, and JOSEPH P. POLNIASZEK *In* AGARD Multifunction Radar for Airborne Applications 6 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Technology for a lightweight low cost transmit/receive (T/R) module for the next generation airborne surveillance phased array radar is described. The T/R module in an active phased array radar is a primary system cost driver; therefore, a low cost, module had to be developed in order to make future phased arrays affordable. Monolithic microwave integrated circuit (MMIC) technology is the technology being developed to fill the above requirement. MMIC technology is an approach wherein all the active and passive elements of the circuit and their required interconnections are formed on a single semiconductor material, e.g., gallium arsenide. MMIC technology appears to be ideal because of the inherent low cost involved with production of integrated circuits. The low production cost is due to the lack of manual handling and assembly, improved reliability, improved reproducibility, small size and weight, circuit design flexibility, and broadband performance. Author

N87-18750# Rome Air Development Center, Hanscom AFB, MA. Electromagnetic Sciences Div.
LOW-COST, MONOLITHIC BEAMFORMING COMPONENTS FOR RADAR Abstract Only
PAUL H. CARR, SCOTT W. MITCHELL, and RICHARD T. WEBSTER *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Planar, monolithic technology offers the possibility of lowering the cost of beamforming components, which contribute significantly to the high price of phased array radars. The most immediate opportunity for planar technology could be to replace the costly ferrite phase shifters in current use. PIN diode phase shifters have the advantage of faster switching times (sub-microsecond) than ferrites and the disadvantage of slightly higher insertion loss, which is due to the fact that microstrip is inherently more lossy than waveguide. Low cost PIN phasers can be fabricated by monolithic technology or automated, robotic hybrid thick-film techniques. Monolithic phase shifters on GaAs have typical losses of 6 dB and power handling capabilities under a watt. This eliminates them from consideration as replacement for ferrite phasers in the corporate fed arrays considered above. New research results on reducing this insertion loss are presented. The insertion loss is not critical if the phase shifter is followed by an efficient power amplifier. The French have reported on MISFET amplifiers on InP with 33% power added efficiency and a power output at 9 GHz of 4W/mm gate width, which is more than twice that of the best GaAs MESFET. Monolithic technology is especially attractive at mm-wave frequencies, due to the smaller component size and the minimization of parasitics. Results on 44 GHz phase shifters are presented. Electronically variable time delay rather than phase shift is required for low-sidelobe phased arrays having wide instantaneous bandwidth. Monolithic SAW tapped delay lines on GaAs are described for use at center frequencies under 1 GHz. Above 1 GHz, magnetostatic wave devices are capable of continuous variable time delay over a 40 nsec range. Author

N87-18751# Societe d'Etude du Radant, Les Ulis (France).
ELECTRONIC SCANNING ANTENNA FOR MILITARY AIRCRAFT OF THE 1990S Abstract Only [ANTENNE A BALAYAGE ELECTRONIQUE AEROPORTEE POUR AVION DARME DES ANNEES 90]
C. CHEKROUN *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 In FRENCH
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

A 7-bit electronic scanning antenna has been developed. The possibilities of the wide angular coverage (70 deg cone), the radioelectric performance (transmission less than 15 dBi), and the frequency band of this antenna makes it an ideal candidate for the air-to-air multifunction radar of the 90's. A prototype antenna is described and some X band results are given. M.G.

N87-18752# AEG-Telefunken, Ulm (Germany, F.R.). Radio and Radar Systems Group.
EHF MULTIFUNCTION PHASED ARRAY ANTENNA Abstract Only
KLAUS SOLBACH *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The design of a low cost demonstration EHF multifunction-phased array antenna is described. Both, the radiating elements and the phase-shifter circuits are realized on microstrip substrate material in order to allow photolithographic batch fabrication. Self-encapsulated beam-lead PIN-diodes are employed as the electronic switch elements to avoid expensive hermetic encapsulation of the semiconductors or complete circuits. A space-feed using a horn-radiator to illuminate the array from the front-side is found to be the simplest and most inexpensive feed. The phased array antenna thus operates as a reflect-array, the antenna elements employed in a dual role for the collection of energy from the feed-horn and for the re-radiation of the phase-shifted waves (in transmit-mode). The antenna is divided into modules containing the radiator/phase-shifter plate plus drive- and BITE-circuitry at the back. Both drive- and BITE-components use gate-array integrated circuits especially designed for the purpose. Several bus-systems are used to supply bias and logical data flows to the modules. The beam-steering unit utilizes several signal processors and high-speed discrete adder circuits to combine the pointing, frequency and beam-shape information from the radar system computer with the stored phase-shift codes for the array elements. Since space, weight and power consumption are prime considerations only the most advanced technology is used in the design of both the microwave and the digital/drive circuitry.
Author

N87-18753# Technische Hogeschool, Delft (Netherlands). Dept. of Electrical Engineering.
BASIC CHARACTERISTICS OF FM-CW RADAR SYSTEMS
L. P. LIGTHART, L. R. NIEUWKERK, and J. S. VANSINTTRUYEN *In* AGARD Multifunction Radar for Airborne Applications 11 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Due to rapid technological progress in real-time signal processing, FM-CW radar systems are expected to become a more serious competitor to pulse radar systems. This paper deals with basic radar principles such as modulating waveforms and ambiguity functions characteristics. Advantages and disadvantages of FM-CW radar systems are compared to pulse radar systems. The inherent signal processing used in FM-CW radar systems allows a flexible choice of system parameters. In this context aspects like sensitivity, range and velocity resolution are discussed. It is elucidated that the use of digital processors for signal processing (frequency determination, filtering, etc.) offers the possibility to exchange

dedicated hardware solutions with software implementations. Attention is paid to equipment like the antennas, diplexer, transmitter and receiver, and to isolation problems between transmitter and receiver. Results of an experimental FM-CW research radar are shown. In addition, the future prospects of FM-CW radar, with the aerial and solid-state R.F. head-end integrated, are indicated. M.G.

N87-18754# Thomson-CSF, Malakoff (France). Division A. V. S.

RADAR DISPLAY. CONVERSION OF SCANNING: ERRORS AND CORRECTION TECHNIQUES [VISUALISATION RADAR. CONVERSION DE BALAYAGE: DEFAUTS ET TECHNIQUES DAMELIORATION]

JEAN-CLAUDE BARON *In* AGARD Multifunction Radar for Airborne Applications 10 p (SEE N87-18721 11-32) Jul. 1986 In FRENCH

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Video radar information resulting from processing circuits is in polar coordinates. The presentation of this information on a screen requires a preliminary storage in a memory referred to as a radar map memory or image memory. In numerous cases, the organization of image memory in cartesian coordinates is interesting because it allows: (1) certain radar processing to be easily carried out; (2) carrier movement compensation; and (3) direct access for the presentation of the image in the television mode. The conversion of scanning, which allows the recording of video radar (presented in polar coordinates) in the memory in cartesian coordinates, can generate errors, the most prominent of which are the loss of radar information for near distances and images with black zones for very great distances. The techniques which permit the removal or correction of these errors are based on: a harmonization between radar parameters and those of the image memory; processing techniques at the level of memory points or at the level of image pixels; and techniques of filling-in through interpolation. M.G.

N87-18755# Thomson-CSF, Malakoff (France). Division A. V. S.

POSTINTEGRATION OF RADAR IMAGES Abstract Only [POSTINTEGRATION DIMAGES RADAR]

DANIEL GARNIER *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 In FRENCH

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The integration of radar maps, obtained with airborne synthetic antenna radar, enhances the quality of the maps by augmenting the contrast of actual echoes with respect to background noise. The enhancement works especially well on the noise called granulation or speckle, which is characteristic of coherent radar. The integration of radar maps representing a single scene obtained in the course of successive scans, therefore at different angles and distances, requires precise compensation for vehicle movement. This compensation is analyzed for the case of echo storage in an XY memory architecture and a rho-theta architecture. Two types of filters are examined: (1) the RC type; and (2) the sliding average filter. The experimental results are presented and the pros and cons for each procedure are discussed. M.G.

N87-18756# AEG-Telefunken, Ulm (Germany, F.R.).

DUAL FREQUENCY MM-WAVE RADAR FOR ANTITANK HELICOPTER Abstract Only

F. X. JEHLE and H. MEINEL *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Helicopters are gaining increasing significance for air close support, airborne landing, tank unit interdiction and both helicopter and tank engagement missions. To support these mission phases, sensors are required for obstacle warning, navigation, and moving and fixed target indication for weapon designation. The majority of the present systems use optical and infrared sensors; some of them apply laser systems. These sensor systems are subject to considerable limitations with respect to their capability of penetrating bad weather zones, fog, and battlefield environment (dust, smoke, man-made fog etc.). The design concept of a dual-frequency radar operating in millimeter wave range which avoids these drawbacks and complements existing sensors is presented. It consists of a 60 GHz radar subsystem for obstacle warning including the detection of wires up to a range of approximately 500 m; due to the selection of a frequency in the absorption line of oxygen resulting in a high atmospheric attenuation (16 dB/km), the susceptibility to interception and thus also to interference electronic countermeasures can be maintained at a very low level. A 50 GHz radar subsystem (attenuation as low as 0.3 dB/km) with its range of approximately 5 km against targets of interest is used for navigation, fixed and moving target indication as well as weapon designation. Due to the combination of the two subsystems (50/60 GHz), high-value components (antenna, scanner, receiver assemblies, control and indicator units) can be used jointly for both subsystems, so that the special features of each subsystem become available at reasonable expenses.

Author

N87-18757# Alabama Univ., Huntsville. Dept. of Electrical and Computer Engineering.

SIMULATION OF MULTISTATIC AND BACKSCATTERING CROSS SECTIONS FOR AIRBORNE RADAR

ALBERT W. BIGGS *In* AGARD Multifunction Radar for Airborne Applications 11 p (SEE N87-18721 11-32) Jul. 1986

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

In order to determine susceptibilities of airborne radar to electronic countermeasures and electronic counter-countermeasures simulations of multistatic and backscattering cross sections were developed as digital modules in the form of algorithms. Cross section algorithms are described for prolate (cigar shape) and oblate (disk shape) spheroids. Backscattering cross section algorithms are also described for different categories of terrain. Backscattering cross section computer programs were written for terrain categorized as vegetation, sea ice, glacial ice, geological (rocks, sand, hills, etc.), oceans, man-made structures, and water bodies. PROGRAM SIGTERRA is a file for backscattering cross section modules of terrain (TERRA) such as vegetation (AGCROP), oceans (OCEAN), Arctic sea ice (SEAICE), glacial snow (GLASNO), geological structures (GEOL), man-made structures (MAMMAD), or water bodies (WATER). AGCROP describes agricultural crops, trees or forests, prairies or grassland, and shrubs or bush cover. OCEAN has the SLAR or SAR looking downwind, upwind, and crosswind at the ocean surface. SEAICE looks at winter ice and old or polar ice. GLASNO is divided into a glacial ice and snow or snowfields. MANMAD includes buildings, houses, roads, railroad tracks, airfields and hangars, telephone and power lines, barges, trucks, trains, and automobiles. WATER has lakes, rivers, canals, and swamps. PROGRAM SIGAIR is a similar file for airborne targets such as prolate and oblate spheroids. Author

N87-18758# Department of Communications, Ottawa (Ontario).

THE USE OF SIMULATED SYNTHETIC-APERTURE RADAR: SIGNALS OF SHIPS IN THE DEVELOPMENT OF AN AUTOMATIC SHIP CLASSIFICATION SYSTEM Abstract Only

MALCOLM R. VANE and J. K. E. TUNSLEY (London Research and Development, Ontario) *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986

(AGARD-CP-381) Avail: NTIS HC A10/MF A01

One of the major problems encountered in developing and testing any target classification scheme is the collection of an adequate data base for training and testing the classifier. This is particularly a problem if one must obtain radar information from a large number of viewing angles and over a large number of targets, some of which may be unfriendly. A method for obtaining this information by simulation is described. Synthetic aperture radar signals such as would be obtained from either a moving or a stationary ship, are simulated and it is shown how such a facility can be used in the development of an automatic ship classification system. The images of stationary ships are used to train and test the classification system and the images of moving vessels are used to show how the classifier performance degrades if the motion is left uncorrected. A readily available data base such as Jane's Book of Ships is used to compile 3-D outlines of the vessels of interest. These outlines, accurate down to the 1-m level, are used to decompose the ship's superstructure into a set of radar scatterers. The returns from the scatterers are then summed, taking into account the viewing angle of the radar. Using this technique, the radar scattering models for a complete library of ships can be formed, and the library used to develop and test various automatic classification schemes. Examples of simulated SAR images of ships

are given and the real image of a particular ship is compared to its simulated one. The limitations of the technique are discussed, and the use of the data in testing an actual classification scheme is briefly outlined. Author

N87-18759# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
REQUIREMENTS AND APPLICATIONS FOR RADAR SIMULATIONS: A STANDPOINT OF AN AIRFRAME COMPANY
WERNER KOHL and WOLFGANG HETZNER *In* AGARD Multifunction Radar for Airborne Applications 13 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

An overview of requirements and applications for radar simulations performed by an airframe company is presented. The discussion covers offline computer models either as stand alone or implemented within air or sea combat simulations. The use for online models reach from interface simulations to rather complex models for manned aircraft simulations. The paper presents realized examples of radar models for air or sea combat simulations, an experimental engineering tool which simulates a core avionic system, a 1 versus 1 advanced flight simulation with a pilot in the loop and a radar signal simulation implemented in a terrain-following closed loop simulation at an avionic rig. Author

N87-18760# *Thomson-CSF, Montrouge (France).*
CRITERIA FOR THE EVALUATION OF RANGE PERFORMANCES IN AIR/AIR INTERCEPTION Abstract Only [CRITERES POUR LEVALUATION DES PERFORMANCES DE PORTEE EN INTERCEPTION AIR/AIR]
P. RAMSTEIN *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986 In FRENCH
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

Radar range performances are given either as a scanning detection probability of 50%, or a cumulative detection probability of from 85 to 90%, depending on the approach speed of the target and the duration of the scan cycle. These values offer only incomplete data for the evaluation of intercept performance. More complete data can be obtained by considering, for a given target, the acquisition probability, or better, probability of definite acquisition, that is, not following losses at great or moderate distance. A method of fast computation for these probabilities is described which avoids the use of statistical simulation. This method, based on the use of Markov chains, takes into account the logistics of acquisition and target loss, as well as the probability of detection in one pass. Examples are given which show how to optimize the scanning speed and permit a comparison of modes with and without transmission frequency agility. Finally, a discussion addressing the selection of evaluation criteria best adapted to a given operational situation is presented. M.G.

N87-21200# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
COMPRESSOR BLADE CLEARANCE MEASUREMENT USING CAPACITANCE AND PHASE LOCK TECHNIQUES
ROSARIO N. DEMERS *In* AGARD Advanced Instrumentation for Aero Engine Components 10 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The clearance measurement system has several unique features which mimimize problems plaguing earlier systems. These include tuning stability and sensitivity drift. Both these problems are intensified by the environmental factors present in compressors i.e., wide temperature fluctuations, vibrations, and conductive contamination of probe tips. The circuitry in this new system provides phase lock feedback to control tuning and shut calibration to measure sensitivity. The use of high frequency excitation lowers the probe tip impedance, thus mimimizing the effects of contamination. A prototype has been built and tested. The ability to calibrate has been demonstrated. An eight channel system is now being constructed for use in the Compressor Research Facility at Wright-Patterson AFB. The efficiency of a turbine engine is to a large extent dependent upon the mechanical tolerances maintained between its moving parts. On critical tolerance is the blade span. Although this tolerance may not appear severe, the impact on compressor efficiency is dramatic. The penalty in percent efficiency has been shown to be three times the percent clearance to blade span ratio. In addition, each percent loss in compressor efficiency represents one half percent loss in specific fuel consumption. Factors which affect blade tip clearance are identified. Author

N87-21888# Rome Univ. (Italy). Dept. of Electrical Engineering.
SPACE-BASED MULTIFUNCTION RADAR SYSTEMS: FUTURE TOOL FOR CIVILIAN AND MILITARY SURVEILLANCE
G. GALATI and G. LOSQUADRO (Selenia S.p.A., Rome, Italy) *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 9 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

Space-based surveillance systems, including primary radar (SBR) and secondary surveillance radar (SBSR) are of interest for both air traffic control and the air defence. The relevant state of the art, surveillance system architectures with special reference to the European scenario and future work are discussed. Multifunction space-based surveillance for European applications, synthetic aperture radar for remote sensing and system options and tradeoffs are discussed. Author

N87-21889# Thomson-CSF, Meudon-la-Foret (France). SDC Div.
MONOPULSE SECONDARY RADAR: PRACTICAL REALIZATION AND ACHIEVEMENT. MODE S: THE RADAR OF TOMORROW
FRANCOIS DELILLE *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 15 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

There can be no doubt that Mode S will be part of tomorrow's Air Traffic Control (ATC) radar. Its assets in terms of air traffic surveillance and data link are noted. Fundamental characteristics are its compatibility with existing secondary surveillance radar's (SSR), selective interrogation and monopulse reception. The monopulse SSR is a landmark in the transition towards Mode S; it contributes several major improvements, without requiring onboard transponders to be changed. Choices made in the implementation of the system are discussed, in particular as regards the antenna, transmitter, reception and processing techniques. Through these options, full Mode S compatibility is maintained. Practical results have turned out to be conclusive, and so the system was taken into production and already many stations are operational round the world. The Mode S extension which has to be added to the monopulse radar is also described, and it is being operated at Orly as part of an experimental development program. Author

N87-21890# Thomson-CSF, Meudon-la-Foret (France). SDC Div.
***A PRACTICAL EXAMPLE OF MOVING TARGET DETECTION* (MTD) PROCESSING FOR AN AIR TRAFFIC CONTROL RADAR WITH WEATHER CHANNEL**
CHRISTINE BRUNO *In* AGARD Efficient Conduct of Individual Flights and Air Traffic or Optimum Utilization of Modern Technology for the Overall Benefit of Civil and Military Airspace Users 9 p (SEE N87-21881 15-04) Dec. 1986
(AGARD-CP-410) Avail: NTIS HC A15/MF A01

Air Traffic Control (ATC) radar processing of the Moving Target Detector (MTD) type is described. It comprises an independent processing channel called weather channel, which supplies meteorological data. The MTD processing technique is aimed at improving the detection of useful targets in the midst of clutter. The algorithms employed are detailed, as well as the performance to be expected, in particular the improvement in the radar picture presented to the operator. The processing system is made up of programmable processors, of which the architecture and other main features are described, as is the radar station remote monitoring and maintenance system. Finally, results obtained in experiments are given. Author

N87-23859# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
MICROWAVE ANTENNAS FOR AVIONICS
Apr. 1987 161 p Lectures held in Rome, Italy, 7-8 May 1987; in Guenzburg, West Germany, 11-12 May 1987; and in Ankara, Turkey, 14-15 May 1987
(AGARD-LS-151; ISBN-92-835-1547-1; AD-A185152) Avail: NTIS HC A08/MF A01

Even though considerable advances have been made in digital technology and signal processing, antennas continue to play a key role and their performance is often a dominating factor in defining the overall effectiveness of a system. New system requirements, and the need to provide electronic scanning capabilities have presented major challenges to the technology that require substantial improvements over what is currently available. Over the last decade there have been notable advances in antenna and radome design, particularly in sidelobe reduction, electronic scanning, conformal arrays, printed circuit arrays, adaptive control and millimeter wave antennas. Many of these issues are addressed. Future trends and new directions for technological innovation are subjects for round table discussions. For individual titles, see N87-23860 through N87-23867.

N87-23860# Rome Air Development Center, Hanscom AFB, MA. Electromagnetics Directorate.
BASIC PARAMETERS OF ANTENNAS FOR AIRCRAFT, SATELLITES AND MISSILES
ROBERT J. MAILLOUX *In* AGARD Microwave Antennas for Avionics 17 p (SEE N87-23859 17-32) Apr. 1987
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

System requirements for airborne, satellite and missile antennas continue to place increasingly severe demands upon antenna technology. In general these requirements push toward the increased capability to control and modify antenna patterns, and away from the use of small antennas with broad radiation patterns. Increased control can imply several levels of added sophistication. At the lowest level it implies mechanical or electronic scanning of an antenna directive pattern, at the next level there are needs to produce precise low sidelobe radiation patterns, and at the highest level of complexity there is the need to actively suppress jammer interference through the use of adaptive control of a full array or an antenna with sidelobe cancellers. In addition to increased control, there is also a trend toward higher frequencies, even to EHF frequencies where arrays of several thousand elements are necessary for some applications. These needs and applications of antenna technology are examined. Author

N87-23861# Westinghouse Electric Corp., Baltimore, MD. Advisory Engineer-Antenna Development.
AIRCRAFT RADAR ANTENNAS
HELMUT E. SCHRANK *In* AGARD Microwave Antennas for Avionics 7 p (SEE N87-23859 17-32) Apr. 1987
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

Many changes have taken place in airborne radar antennas since their beginnings over forty years ago. A brief historical review of the advances in technology is presented, from mechanically scanned reflectors to modern multiple function phased arrays. However, emphasis is not on history but on the state-of-the-art technology and trends for future airborne radar systems. The status of rotating surveillance antennas is illustrated by the AN/APY-1 Airborne Warning and Control System (AWACS) slotted waveguide array, which achieved a significant breakthrough in sidelobe suppression. Gimballed flat plate arrays in nose radomes are typified by the AN/APG-66 (F-16) antenna. Multifunction phased arrays are presented by the Electronically Agile Radar (EAR) antenna, which has achieved significant advances in performance versatility and reliability. Trends toward active aperture, adaptive, and digital beamforming arrays are briefly discussed. Antennas for future aircraft radar systems must provide multiple functions in less aperture space, and must perform more reliably. Author

N87-23862# AEG-Telefunken, Ulm (Germany, F.R.). Radar Subdivision.
AIRCRAFT ANTENNAS/CONFORMAL ANTENNAS MISSILE ANTENNAS
KLAUS SOLBACH *In* AGARD Microwave Antennas for Avionics 16 p (SEE N87-23859 17-32) Apr. 1987
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

Three major areas of airborne microwave antennas are examined. The basic system environment for missile telemetry/telecommand and fuze functions is sketched and the basic antenna design together with practical examples are discussed. The principle requirements of modern nose radar flat plate antennas are shown to result from missile/aircraft system requirements. Basic principles of slotted waveguide antenna arrays are sketched and practical antenna designs are discussed. The present early warning system designs are sketched to point out requirements and performance of practical radar warning and jamming antennas (broadband spiral antennas and horn radiators). With respect to newer developments in the ECM scenario, some demonstrated and proposed antenna systems (lens fed arrays, phased array, active array) are discussed. Author

N87-23863# TICRA A/s, Copenhagen (Denmark).
SPACECRAFT MULTI-BEAM AND CONTOURED-BEAM ANTENNAS
P. BALLING *In* AGARD Microwave Antennas for Avionics 23 p (SEE N87-23859 17-32) Apr. 1987 Sponsored in part by INTELSAT
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

High gain spacecraft antennas with multiple beams and contoured beams are key components in satellite communications and direct broadcast systems. This is reflected on the latest generation of communications satellites, where the antenna subsystem is the largest subsystem with its weight of more than 300 kg. The antennas achieved a large communications capacity through multiple frequency reuses and may be reconfigured to serve different coverage areas. The current multi-beam and contoured-beam antenna technology is reviewed. Different implementation, reflector or lens with feed array or direct radiating array, are considered. The emphasis is placed upon systems with offset paraboloidal reflectors. The limitations of the offset reflector with respect to beam scanning and cross polarization are reviewed. Computer aided design procedures and design examples are presented. Author

N87-23864# Army Communications-Electronics Command, Fort Monmouth, NJ.
MILLIMETER WAVE ANTENNAS FOR AVIONICS
FELIX K. SCHWERING *In* AGARD Microwave Antennas for Avionics 8 p (SEE N87-23859 17-32) Apr. 1987
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

An overview of the area of mm-wave antennas is presented with emphasis on possible avionics applications. For the purpose of the review, mm-wave radiating structures are grouped into two classes: antennas of conventional configuration and antennas based on new design concepts. The first class is composed of well known antennas such as reflector, lens, horn and slotted waveguide antennas. The second class includes radiating structures such as printed circuit mm-wave antennas, antennas derived from open mm-waveguides, and integrated antennas. Some of these antennas have microwave counterparts, others are new with no microwave heritage. Millimeter wave antennas are usually of very reasonable size and weight, and some of these antennas are suitable for rapid mechanical scanning. They should be sufficiently versatile to satisfy most avionics requirements. Atmospheric propagation conditions vary strongly throughout the mm-wave band and have to be taken into account in the design of mm-wave systems and their antennas. A brief summary of these effects is included. Author

N87-23865# Standard Telephones and Cables Ltd., Paignton (England).
ADAPTIVE ANTENNAS
P. BARTON *In* AGARD Microwave Antennas for Avionics 21 p (SEE N87-23859 17-32) Apr. 1987
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

The basic principles of adaptive antennas are outlined in terms of the Wiener-Hopf expression for maximising signal to noise ratio

in an arbitrary noise environment; the analogy with generalized matched filter theory provides a useful aid to understanding. For many applications, there is insufficient information to achieve the above solution and thus non-optimum constrained null steering algorithms are also described, together with a summary of methods for preventing wanted signals being nulled by the adaptive system. The three generic approaches to adaptive weight control are discussed: correlation steepest descent, weight perturbation and direct solutions based on sample matrix conversion. The tradeoffs between hardware complexity and performance in terms of null depth and convergence rate are outlined. The sidelobe cancellor technique is described. Performance variation with jammer power and angular distribution is summarized and the key performance limitations identified. The configuration and performance characteristics of both multiple beam and phase scan array antennas are covered, with a brief discussion of performance factors. Author

N87-23866# Communications Research Centre, Ottawa (Ontario).
MIC TECHNOLOGY FOR PHASED ARRAYS
R. DOUVILLE *In* AGARD Microwave Antennas for Avionics 19 p (SEE N87-23859 17-32) Apr. 1987
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

The technology and performance of typical transmit receive (T/R) modules which include the basic elements of a phase shifter, a low noise amplifier, and a high power amplifier is emphasized. An overview is given of microwave integrated circuits (MICs) technology with respect to its use in phased array systems for military applications. Historically, the term MIC has been used to refer to planar microwave circuits using one or more different forms of printed transmission lines, all characterized by their ability to be photoetched on a suitable dielectric substrate. Active and passive discrete components such as transistors, chip capacitors and resistors are then attached. This technology is more precisely referred to as hybrid MIC (HMIC). The field of MIC design is currently undergoing a major revolution due to the rapid emergence of monolithic MIC (MMIC) design. In this latter, all components, including the active devices, are fabricated using deposition and etching processes, thereby eliminating the need for attachment of discrete components. These technologies are discussed with respect to their potential in phased array antennas. E.R.

N87-26955# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Hochfrequenztechnik.
THE CURRENT AND FIELD DISTRIBUTION OF A HIGH POWER SATELLITE ANTENNA AFFECTED BY NONLINEAR PLASMA SHEATH PHENOMENA
K.-H. BETHKE and P. EDENHOFER (Bochum Univ., West Germany) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 10 p (SEE N87-26937 21-18) May 1987 Sponsored in part by Bundesministerium fuer Forschung und Technologie, West Germany
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

For electromagnetic and acoustic radiation from antennas in a plasma environment, the fundamental electro- and hydrodynamic equations are presented involving nonlinear source terms up to the third order. A perturbation procedure is applied to derive a numerical solution from a set of coupled integral equations for the linearized (first order) magnetic field and electron density describing the dipole radiation into a homogeneous compressible plasma. The solution is given in terms of an equivalent surface current density based on a Green's function representation. An inhomogeneous plasma sheath is shown to build up around the dipole, where the antenna-to-plasma coupling turns out to be strongest in the near field of a high power transmitting antenna. Author

N87-29518# Hazeltine Corp., Greenlawn, NY. Adaptive Systems Lab.
INCREASING THE USEFULNESS OF AWACS DOWNLINK TRANSMISSIONS BY SEMANTIC COMPRESSION
BONNIE SCHNITTA-ISRAEL and ROY S. FREEDMAN *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 4 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A1[illegible]/MF A01

Preliminary investigation of the data compression by semantic techniques via an automated resource allocation system based on AWACS operator expertise indicates improvement would occur to down link data transmission for C 2 missions. In essence this improvement is obtained by improving the timeliness of information transmission through knowledge directed allocation. In order to specify a complete system, a list of tasks which should be considered are listed. Author

N87-29522# National Aeronautical Establishment, Ottawa (Ontario).
SPEECH IS MORE THAN JUST AN AUDIBLE VERSION OF TEXT
MELVYN J. HUNT *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 12 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Man machine communication by text using keyboards and screens is much more firmly established than voice I/O. Partly because of this, voice tends to be regarded as an audible version of text. This view is misleading: it leads to an underestimation of both the difficulties and the potential of voice I/O. Speech encodes information on factors such as speaker identity and attitude and sentence structure in ways that have no counterpart in text. The style of language appropriate for speech is quite different from that appropriate for text. Speech output and input systems tend to ignore those aspects of the speech signal that are not directly represented in text, and they frequently use a style and syntax suited to text rather than speech. In the case of speech output, the technology needed to exploit the additional aspects of the speech signal is already appearing, and recordings illustrating the possibilities are available. In the case of speech output, the technology is not yet developed, but the ability to manipulate features such as voice quality in speech output systems may be a powerful tool in learning how to exploit such features in speech input systems. Author

N87-29523# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).
VOICE COMMAND AND THE CHANGE OF MENTAL REPRESENTATION DURING TASK PERFORMANCE [COMMANDE VOCALE ET CHANGEMENT DE REPRESENTATION MENTALE DANS LA TACHE]
R. AMALBERTI, D. BATEJAT, and J.-P. MENU *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 10 p (SEE N87-29503 24-06) Feb. 1987 In FRENCH
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

A two task experiment was performed to assess the distribution of mental resources and the competition between mental and speaking resources during task performance. The experiment was designed so that a primary surveillance/detection task was performed along with a secondary task involving the input of flight related information by either keyboard or voice command. Detection time was measured for the primary task and accuracy was determined for both the primary and secondary tasks. Quantitative results show that the use of voice command favors the performance of the primary surveillance task, but, for the secondary task, the voice input was less accurate than the manual keyboard input. Qualitative results with regard to pilot visual comportment and vocal errors are also discussed. M.G.

N87-29524# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
LAYERED PROTOCOLS IN VOICE INTERACTION WITH COMPUTERS
M. M. TAYLOR *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 12 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

The Layered Protocol model for human computer interfaces is described, with special reference to the problems of voice input and output. In a layered protocol, each level passes virtual messages back and forth between human and computer. These virtual messages are realized in the form of interchanges at the level below. The protocol at a level is analogous to the syntax of a sentence, in that it is the method by which the content of a message can be given an agreed interpretation. Each protocol can be designed or evaluated independently of all the others in an interface. The stability of a protocol is determined by its response delays and by the channel capacity of the lower level protocols that support its messages. Sometimes an unstable protocol can be stabilized and speeded by reducing the message rate of the supporting protocols. Users have been observed to do this intuitively. Voice input provides special problems because of the relatively high error probability inherent in the recognizer: errors in other modalities are likely to be due to operator fault. This tends to lead to unwarranted distrust of voice input, and to demands for types of feedback that are probably inappropriate to the level of protocol to which the recognizer is suited. Voice output can be used by the computer to initiate protocols, or to provide a response channel for protocols under conditions where the user's eyes are otherwise occupied. Consideration of protocol demands helps to clarify the requirements for precision in recognition, and for the characteristics of computer responses to voice input; it helps also in judging appropriate conditions for the use of voice output.
Author

N87-29525# University of Southern California, Los Angeles. Dept. of Safety and Systems Management.
THE ROLE OF ASYMMETRIC TRANSFER IN THE EVALUATION OF VOICE GENERATION AND RECOGNITION SYSTEMS
D. L. DAMOS *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 8 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

The results of five experiments examining the effect of voice generation and recognition systems on dual task performance are presented. The extent to which asymmetric transfer biased the data in three of these experiments is determined by using statistical techniques and by comparing the data to the results of between subjects experiments. Generally, subjects performed task combinations better when stimuli for one of the tasks was presented auditorily using a voice generation system rather than visually on a display screen. In contrast, the use of a voice recognition system did not result in better dual task performance than the use of more conventional input devices.
Author

N87-29528# Institute for Perception RVO-TNO, Soesterberg (Netherlands).
VOICE INTERACTIVE SYSTEMS IN SEVERE NOISE CONDITIONS
J. H. M. STEENEKEN and G. LANGHOUT *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 6 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

In a comparison of word recognition performance between human listeners and automatic speech recognition systems (ASR), the human listeners performs much better, especially in severe noise conditions. An application engineer can try to optimize the performance of an ASR system by selecting the optimal noise cancelling microphone and vocabulary for voice input. Some results from a study on the effect of signal handling and vocabulary configuration on the performance of voice input and voice output systems are discussed.
Author

N87-29529# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
EFFECT OF AUDIO BANDWIDTH AND BIT ERROR RATE ON PCM, ADPCM AND LPC SPEECH CODING ALGORITHM INTELLIGIBILITY
RICHARD L. MCKINLEY and THOMAS J. MOORE *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 7 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

The effects of audio bandwidth and bit error rate on speech intelligibility of voice coders in noise are described and quantified. Three different speech coding techniques were investigated, pulse code modulation (PCM), adaptive differential pulse code modulation (ADPCM), and linear predictive coding (LPC). Speech intelligibility was measured in realistic acoustic noise environs by a panel of 10 subjects performing the Modified Rhyme Test. Summary data is presented along with planned future research in optimization of audio bandwidth vs bit error rate tradeoff for best speech intelligibility.
Author

N88-11909# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
THEORETICAL ASPECTS OF TARGET CLASSIFICATION
Jun. 1987 221 p Lecture series held in Rome, Italy, 29-30 Jun., in Neubiberg, Fed. Republic of Germany, 2-3 Jul., and in Noresund, Norway, 6-7 Jul. 1987
(AGARD-LS-152; ISBN-92-835-1553-6; AD-A185125) Avail: NTIS HC A10/MF A01

Various analytical methods and, their numerical implementation, for generating and classifying target signatures under transient and steady state illumination, with emphasis on classification schemes that facilitate extraction of unknown target features in the inverse problem of identification are discussed. Included also are numerical modeling, experimental results obtained under controlled and realistic conditions, and descriptions of range facilities. For individual titles, see N88-11910 through N88-11921.

N88-11910# Polytechnic Inst. of New York, Farmingdale. Dept. of Electrical Engineering and Computer Science.
TARGET STRENGTH: AN OVERVIEW OF SOME RECENT THEORETICAL DEVELOPMENTS
LEOPOLD B. FELSEN *In* AGARD Theoretical Aspects of Target Classification 15 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

A brief review is given of some recent developments and trends in the theory of target scattering and classification. Emphases is on phenomena at high and moderate frequencies. It is in these parametric regions where wave transport phenomena play an essential role.
Author

N88-11911# Ohio State Univ., Columbus. ElectroScience Lab.
UNIFORM GEOMETRICAL THEORY OF DIFFRACTION
P. H. PATHAK *In* AGARD Theoretical Aspects of Target Classification 20 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

Keller's geometrical theory of diffraction (GTD) represents a major breakthrough in solving a wide variety of electromagnetic (EM) radiation and scattering problems at high frequencies. In particular, the GTD is an extension of geometrical optics to include a class of diffracted rays via a generalization of Fermat's principle. These diffracted rays are initiated, for example, from geometrical and electrical discontinuities in a scatter, or from points of grazing *incidence on smooth convex parts of the scattering surface.* However, being a pure ray optical theory, the original GTD falls within the transition regions adjacent to geometric optical shadow boundaries where the diffracted field generally assumes its largest value. This limitation of the GTD is overcome via the uniform version of the GTD which requires the diffracted field to make the total high frequency field continuous across the optical shadow boundaries. The UTD solutions for the diffraction by edges and smooth convex surfaces are reviewed in detail after introducing the basic concepts of GTD.
Author

N88-11912# Naval Postgraduate School, Monterey, CA.
SINGULARITY EXPANSION METHOD: TARGET RESONANCES
MICHAEL A. MORGAN *In* AGARD Theoretical Aspects of Target Classification 5 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

A unified treatment for the natural mode representations for induced currents and scattered fields is described using elementary concepts of causality and superposition. The transient back-scattered field is shown to have the form of a constant coefficient exponential series only in the late-time, after the last directly driven response is received from the scatterer. Prior to this, the early-time response is found to be due to both the direct physical optics fields as well as to a sum of modulated natural modes. Practical implications of this result, regarding aspect-invariant target classification using natural resonances, are discussed. Author

N88-11913# Tel-Aviv Univ. (Israel). Dept. of Electrical Engineering.
THE HYBRID WAVEFRONT RESONANCE METHOD
EHUD HEYMAN *In* AGARD Theoretical Aspects of Target Classification 24 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

When observed over long periods, scattered returns from targets illuminated by broad band signals reveal distinctive features in the early and late time regimes. The features can be explained in terms of the different wave phenomena, progressive and oscillatory, that are dominant during these respective intervals. A recently developed hybrid theory has formulated the connection between them and has provided new interpretations that did not emerge in earlier treatments. These interpretations can clarify issues which have arisen within the singularity expansion method (SEM), in particular, the adequacy of the expansion at early times. Here, the hybrid wavefront resonance theory is reviewed, first within the vigorous context of scattering by a circular cylinder, and then via a ray analysis of scattering by a general (composite) object. Author

N88-11914# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Hochfrequenztechnik.
PHYSICAL OPTICS METHOD: PREDICTION OF RADAR SIGNATURES
V. STEIN *In* AGARD Theoretical Aspects of Target Classification 17 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

There has been increasing interest in the use of the physical optics method in the computation of radar signatures of complicated objects which are large compared to the wavelength. A series of ideal conducting structures for which the physical optics method has been successfully applied to compute the back-scattered field is presented. The basic idea of physical optics following the Huygens-Helmholtz principle is evaluated. The surface integrals for the electromagnetic scattered field are presented and discussed. Some details of the physical optics method, when applied to complicated structures, are considered in the form of a short survey. This includes the hidden surface problem, the ability to predict depolarization effects for certain situations, the evaluation of the phase integral, the extension of physical optics to treat double reflections, the accuracy of the geometrical model and an estimation of the computer time. In the conclusion, some steps for the further extension and improvement of the physical optics method are summarized. Author

N88-11915# Kassel Univ. (Germany, F.R.). Dept. of Electrical Engineering.
THEORETICAL ASPECTS OF TARGET CLASSIFICATION: PHYSICAL OPTICS AND RADON TRANSFORM METHODS
K. J. LANGENBERG *In* AGARD Theoretical Aspects of Target Classification 15 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

Target classification is set up as a multidimensional inverse scattering problem for electromagnetic waves. The target is considered to be of compact support residing in a media with constant wave speed. The scattered field produced by a prescribed incident field is represented by its equivalent sources in terms of Huygens' principle: for the sake of simplicity, the inversion of this representation of the physical optics or weak scatterer approximation linearizes the inverse problem resulting immediately in an inversion formula for the characteristic or singular function of the scatterer if the scattered field is measured as a function of frequency - or as broadband transients - on a closed surface sufficiently remote from the target in an either bistatic or monostatic experimental arrangement. Author

N88-11916# Arizona Univ., Tucson. Electromagnetics Lab.
PARAMETRIZATION IN SCATTERING MODELS
D. G. DUDLEY *In* AGARD Theoretical Aspects of Target Classification 17 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

Parametric modeling in transient wave scattering is discussed. Global modeling based on the body resonances of the scattering object are discussed along with two examples. The nature of the incompleteness of global models is discussed. The concept of the local model, based on ray optic methods, is introduced. Included is an example of local modeling. It is shown that the local model is an order of magnitude more parsimonious and more robust in the presence of noise, compared to the global model. It is concluded that the local model has a better probability of success in practical target classification because of its performance in a noisy environment. Author

N88-11917# Naval Postgraduate School, Monterey, CA.
INPUT SIGNAL SHAPING: K-PULSE
MICHAEL A. MORGAN *In* AGARD Theoretical Aspects of Target Classification 16 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

Classification of electromagnetic scatterers by selective mode annihilation is discussed. After providing a brief description of historical background, the conceptual basis of this methodology is developed, followed by a theoretical explaination of the techniques that are employed. Some particular resonance annihilation schemes that have been implemented and tested are illustrated. Results from the tests using synthetic signals, integral equation computations and experimental transient scattering measurements are featured. Author

N88-11918# Naval Postgraduate School, Monterey, CA.
NUMERICAL MODELING: FINITE METHODS
MICHAEL A. MORGAN *In* AGARD Theoretical Aspects of Target Classification 17 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

Recent developments in computational methods for unbounded electromagnetic problems involving antennas and scattering are considered. Emphasis is given to the numerical implementation of differential equation based formulations using either finite differences or finite elements. Elementary examples are used as conceptual vehicles for introducing finite element and unimoment techniques. The finite element boundary integral method and the field feedback formulation are discussed. Current capabilities are demonstrated by considering some of the important research results utilizing the finite methods. Author

N88-11919# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Hochfrequenztechnik.
NUMERICAL MODELING: INTEGRAL EQUATION METHOD
V. STEIN *In* AGARD Theoretical Aspects of Target Classification 20 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

A review is given of the different expressions for the representation of the electromagnetic fields by integrals over the surface current. The integral equations, which mostly are used for the solution of practical problems, are discussed and the method of moments is outlined, where the use of pulses as basis functions is emphasized. Estimations of the core storage and the computer time are given. Two geometrical models for the scattering structure are discussed in more detail: the service patch model and the wire-grid model. A list of application examples of the integral equation method with references is given. Two further examples are outlined in detail: computation of the radiation pattern of an antenna mounted on a helicopter and determination of the extreme near field of a cube. Author

N88-11920# Naval Postgraduate School, Monterey, CA.
EXPERIMENTS: TEST RANGE FACILITIES, PART 1
MICHAEL A. MORGAN *In* AGARD Theoretical Aspects of Target Classification 16 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

A brief review is given of some of the transient electromagnetic scattering ranges at U.S. universities and research facilities. The Transient Electromagnetic Scattering Laboratory located at the Naval Postgraduate School is discussed. Particular attention is given to the role of this facility in studies of natural resonance target classification studies. Detailed consideration is given to measurement concepts of transient scattering, with examples given to illustrate the procedures and requisite signal processing that is involved. Author

N88-11921# Arizona Univ., Tucson. Electromagnetics Lab.
EXPERIMENTS: TEST RANGE FACILITIES, PART 2
D. G. DUDLEY *In* AGARD Theoretical Aspects of Target Classification 10 p (SEE N88-11909 03-32) Jun. 1987
(AGARD-LS-152) Avail: NTIS HC A10/MF A01

A description is given of the electromagnetic transient range facility at the Lawrence Livermore Laboratory. The range design and the instrumentation for both time domain and broadband frequency domain measurements are discussed. Two examples of experiments are given: scattering from a conducting plate and transmission through an aperture in a screen. Author

N88-19653# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
TERRESTRIAL PROPAGATION CHARACTERISTICS IN MODERN SYSTEMS OF COMMUNICATIONS, SURVEILLANCE, GUIDANCE AND CONTROL
H. J. ALBRECHT, ed. Nov. 1987 269 p In ENGLISH and FRENCH Meeting held in Ottawa, Ontario, 20-24 Oct. 1986
(AGARD-CP-407; ISBN-92-835-0434-8; AD-A194686) Avail: NTIS HC A12/MF A01

New research results in surface propagation characteristics for modern systems applications in relevant frequency ranges are discussed. Ground characteristics and their effects, diffraction and shadowing effects, refraction and reflection at medium boundaries, general system applications, special system applications, and special experimental results are discussed. For individual titles, see N88-19654 through N88-19675.

N88-19654# Norwegian Telecommunications Administration Research Establishment, Kjeller. Research Dept.
AN INVESTIGATION OF TERRAIN RELATED VARIABLES FOR PREDICTING THE MULTIPATH FADE DEPTH DISTRIBUTION ON TERRESTRIAL MICROWAVE LINES
TERJE TJELTA, RODERIC L. OLSEN, and LOUIS MARTIN (Centre National d'Etudes des Telecommunications, Lannion, France) *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 9 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Terrain related variables are shown to be important in an asymptotic prediction equation for the worst month multipath fade depth distribution. From a fading data base for 47 links in northwestern Europe, equations are developed employing up to six variables and an additional variable geoclimatic factor. The best standard error of prediction is 2.8 dB, considerably better than that available from other prediction methods for the same region. A large number of variables are investigated, most of them closely related to the terrain. The results suggest that terrain reflections play an important role in multipath propagation. Author

N88-19655# Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
A REVIEW OF THE ROLE OF SURFACE REFLECTION IN MULTIPATH PROPAGATION OVER TERRESTRIAL MICROWAVE LINKS
RODERIC L. OLSEN, LOUIS MARTIN, and TERJE TJELTA (Norwegian Telecommunications Administration Research Establishment, Kjeller.) *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 23 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

It has long been recognized that surface reflection on overwater microwave radio relay paths plays an important role in causing frequency selective multipath fading. There is mounting experimental and theoretical evidence that ground reflection and scattering has an important role in producing much of the selective multipath propagation effects on overland links. Here, both old and new evidence is reviewed that provides some new insights into the complex mixture of mechanisms involved. Some resulting implications for the design of digital radio links are also discussed. Author

N88-19656# Institut fuer Rundfunktechnik, Munich (Germany, F.R.).
DEVELOPMENT OF A GROUND-CONDUCTIVITY MAP FOR THE AREA OF THE FEDERAL REPUBLIC OF GERMANY FROM MEASURED FIELD-STRENGTH CONTOURS
BERND RAUFMANN *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 5 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

A comparison of ground conductivity values found for 14 transmitter sites with two frequencies showed a linear relation between the effective ground conductivity and the frequency. On this basis all conductivity values were normalized to a frequency of 1 MHz. The average ground conductivity values for each transmitter were associated with four different geographical zones. As there were only slight differences among the average values in three neighboring zones, the conductivity data of this area were unified as a whole. So the final result of the evaluations was a ground conductivity map with only two areas of different ground conductivity. Detailed explanations of the methods applied in the developing process of the conductivity map are presented, and the limits of these methods as well as the statistical distribution of the results obtained are discussed. Author

N88-19657# Nebraska Univ., Lincoln. Dept. of Electrical Engineering.
SCATTERING AND DEPOLARIZATION BY RANDOM ROUGH TERRAIN AND VEGETATION COVERED TERRAIN-UNIFIED FULL WAVE APPROACH
EZEKIEL BAHAR *In* AGARD Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 15 p (SEE N88-19653 12-32) Nov. 1987
(Contract DAAG29-82-K-0123)
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

The principal elements of the full wave approach to problems of scattering and depolarization by rough terrain and vegetation covered terrain are presented. Scattering by random rough surfaces is considered in detail and the full wave solutions are compared with earlier solutions based on geometric optics, physical optics and perturbation theories. It is shown that since the full wave approach accounts for both specular point scattering as well as Bragg scattering in a self-consistent manner, it resolves the discrepancies between the physical optics and the perturbation solutions, and bridges the wide gap between them. Thus, on applying the full wave approach to scattering by composite random rough surfaces, it is not necessary to adapt a two-scale model of the rough surface. The analytical procedures that account for the effects of vegetation on radio wave propagation over a terrestrial path are also presented. They are based on the full wave solutions to scattering by finitely conducting irregularly shaped objects with rough surfaces. Author

N88-19658# Polytechnic Inst. of Brooklyn, Farmingdale, NY. Dept. of Electrical Engineering and Computer Science.
PROPAGATION IN LONGITUDINALLY VARYING DUCTS, WITH EMPHASIS ON GUIDING TO ANTIGUIDING TRANSITIONS
LEOPOLD B. FELSEN *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 7 p (SEE N88-19653 12-32) Nov. 1987
(Contract DAAG29-85-K-0180; F49620-85-C-0078)
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Recent developments in the theory of propagation in longitudinally varying ducts are reviewed, with emphasis on gradual guiding to anti-guiding transitions that convert an initially well-trapped mode field smoothly (adiabatically) into a leaky mode. The connection between the trapped and leaky mode regimes is provided by a parabolic equation or, in certain cases, by an intrinsic mode spectral integral. Numerical implementation for different examples confirms the phenomenology predicted by the analysis and reveals the beaming of initially trapped modal energy into the exterior after the duct disappears. Some consideration is also given to incorporating these concepts into a synthesis of the field excited by a radiating source inside the duct. Author

N88-19659# Communications Research Centre, Ottawa (Ontario). Dept. of Communications.
VHF/UHF PROPAGATION BY DIFFRACTION: CALCULATION BY NUMERICAL INTEGRATION
J. H. WHITTEKER *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 7 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

The method proposed here applies approximate diffraction theory to a terrain model that retains most of the complexity of the real terrain, and finds a solution to the diffraction problem for each particular transmission path profile. The method is to find the radio wave field as a function of height above each terrain point by integrating over the field above the preceding terrain point, using Huygen's principle. The integration is done not only for direct waves, but also for earth-reflected waves. Author

N88-19660# Forschungsinstitut fuer Hochfrequenzphysik, *Werthhoven (Germany, F.R.).*
MONO- AND BISTATIC RADAR COVERAGE DIAGRAMS INCLUDING DIFFRACTIVE WAVE PROPAGATION
HEINER KUSCHEL *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 10 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Here, a digital terrain database, the Digital Landmass System (DLS), having high horizontal and vertical resolution, is used to obtain optical coverage patterns, as well as physical coverage plots. Physical coverage calculations are based on the consideration of wave propagation phenomena such as diffraction and refraction, using a multiple knife edge propagation model in combination with the above mentioned terrain database. Both the terrain model and the terrain database were verified by measurements. Author

N88-19661# Polytechnic Inst. of New York, Brooklyn. Center for Advanced Technology in Telecommunications.
A DIFFRACTION BASED THEORETICAL MODEL FOR PREDICTION OF UHF PATH LOSS IN CITIES
HENRY L. BERTONI and JORAM WALFISCH *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 10 p (SEE N88-19653 12-32) Nov. 1987 Sponsored in part by GTE Labs., Inc. and the New York State Science and Technology Foundation
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

A theory for predicting ultrahigh frequency path loss for cellular mobile radio systems in urban areas outside of the high-rise urban core is presented. In such areas the buildings are of nearly uniform height and form nearly parallel rows. Each row has the appearance of a cylinder lying on the ground, so that propagation is a process of diffraction past many cylinders. Using this approach, researchers developed a model for predicting average path loss that is in good agreement with measurements. Author

N88-19662# Centre d'Electronique de l'Armement, Bruz (France). ITES Div.
A PROGRAM FOR THE CALCULATION OF RADIO-WAVE TRANSMISSION LOSS OVER THE SPHERICAL EARTH AND OVER OBSTACLES
MICHEL RANGER, JEAN-LOUIS REGNIER, MARC ANDREU, and YVES LEPAPE *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 12 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

A new computer program was created to evaluate the radioelectric wave propagation loss around the earth in the frequency range of 30 to 40 MHz up to 10 to 12 GHz. The name of the program is CARDIF. Details of the program are given. Author

N88-19663# New Jersey Inst. of Tech., Newark. Dept. of Electrical Engineering.
CORRECTING RAY FIELD FAILURES CAUSED BY FOCUSING IN AN INHOMOGENEOUS DUCT: A CRITICAL LOOK AT THE GAUSSIAN BEAM METHOD
E. NIVER, M. S. VOGAS, C. J. RUIZ, and L. B. FELSEN (Polytechnic Inst. of Brooklyn, Farmingdale, N. Y.) *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 11 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

The Gaussian beam method (GBM) was investigated for multiple reflected ray fields in a model surface duct (or equivalently, a symmetrically excited full duct with a V-type refractive index profile). The purpose was to ascertain whether a beam stack that adequately represents the field at observation points along a particular ray segment corresponding to a certain number of reflections continues to be adequate along ray segments with a different number of reflections. Optimization was achieved by numerical experiment. *The optimized parameters give good* agreement, but should not be regarded as absolute. Author

N88-19664# Naval Ocean Systems Center, San Diego, CA. Ocean and Atmospheric Sciences Div.
REVIEW OF RECENT DEVELOPMENTS IN EVAPORATION DUCTING ASSESSMENT
JUERGEN H. RICHTER *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 9 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Evaporation ducting is an important propagation enhancement mechanism over the oceans. Recent efforts have shown that the models presently used appear adequate for statistical assessments. An important correction algorithm was developed to remove erroneously high duct heights. A new air-sea temperature probe is under development which is expected to improve in situ evaporation ducting assessment. Author

N88-19665# Portsmouth Polytechnic (England). Dept. of Electrical and Electronic Engineering.
IDENTIFICATION OF MICROWAVE LINE-OF-SIGHT MULTIPATH COMPONENTS
A. HEWITT, L. MARTIN, W. H. LAU, J. AUSTIN, K. H. CRAIG (Science Research Council, Chilton, England), and E. VILAR *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 13 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Fading due to multipath propagation is frequency selective. Given a wideband measurement of the channel transfer function, *it is of interest to estimate the delays and amplitudes of the* multipath rays. Fourier techniques suffer from limited resolution and sidelobes. Alternative parametric methods are available and one, the Prony algorithm, was used in this research. The algorithm was tested against a database of laboratory generated fades involving known delays and amplitudes. The capabilities and limitations of the method are outlined. Results obtained using real in the field measurements are illustrated and discussed, as are the areas to which this approach is applicable. Author

N88-19666# Centre National d'Etudes des Telecommunications, Lannion (France).
REFRACTIVE INDEX, METEOROLOGY AND FADING IN LINE-OF-SIGHT TRANSMISSION PATHS [COINDICE DE REFRACTION, METEOROLOGIE ET AFFAIBLISSEMENTS SUR LES TRAJETS EN VISIBILITE]
LOUIS MARTIN, RODERIC L. OLSEN, and TERJE TJELTA (Norwegian Telecommunications Administration Research Establishment, Kjeller.) *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 12 p (SEE N88-19653 12-32) Nov. 1987 In FRENCH
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

In the development of reliable prediction methods for fixed frequency fading that would be applicable throughout a radio transmission network, it became necessary to account for the radiometric conditions characteristic of each region within a given radio network. A purely meteorological method for the calculation of the geoclimatic factor is proposed and utilized in a prediction formula for fixed frequency fading applicable to a very unfavorable month. The method is based on a simultaneous study of the climate and propagation conditions of two link pairs situated in two different climate regions. Author

N88-19667# Air Force Geophysics Lab., Hanscom AFB, MA.
RADIO AND RADAR HOLES AND MULTIPATH ZONES: THE GLOBAL AND LOCAL INFLUENCES ON ATMOSPHERIC REFRACTIVE STRUCTURE AND RESULTING ADVERSE RADIO AND RADAR PERFORMANCE Abstract Only
OWEN R. COTE, JAMES F. MORRISSEY, and YUTAKA IZUMI *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 1 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Results from recent USAF field testing of digital radio line-of-sight (LOS) and troposcatter (TROPO) radio path performance, in which concurrent fine vertical resolution refractivity profiles were also made, show that multipath effects on LOS and TROPO complement each other both performancewise and weatherwise. Maximum multipath delay is a clear propagation path related event in LOS and a heavy rain/thunderstorm related event in TROPO. Because radio holes and multipath zones occur concurrently, being produced by the same refractive ducting layer, LOS paths can be designed to minimize the occurrence of frequency selective fading at the possible expense of some increase in non-frequency selective fading under strong ducting conditions. Path length is less important in affecting path performance than are duct layer strength and geometry. The rule that maximum multipath delay goes as the third power of path length is not confirmed by these measurements. Measured maximum multipath delay on an LOS is better represented by a half-power dependence on path length. Author

N88-19668# McMaster Univ., Hamilton (Ontario). Communications Research Lab.
THE CORRELATION BETWEEN METHODOLOGICAL AND LOW-LEVEL ANGLE-OF-ARRIVAL MEASUREMENTS
J. LITVA, P. BAUMAN, and N. R. FINES (Communications Research Centre, Ottawa, Ontario.) *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 16 p (SEE N88-19653 12-32) Nov. 1987 Sponsored by Department of National Defence, Ottawa
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Anomalous propagation can cause serious low-angle tracking errors. Here, an investigation into the correlation between data from collocated radio and meteorological experiments is described. The data was recorded on the Ottawa River and consist of both radio and meteorological measurements. The measurements were carried out using a low level beacon and a large synthetic aperature antenna called a vertical profiler. The primary radio parameters consist of the angles-of-arrival of the direct and multipath signals from the beacon. The primary meteorological parameters are relative humidity, temperature, and barometric pressure. Author

N88-19669# Standard Elektrik Lorenz A.G., Pforzheim (Germany, F.R.).
MM-WAVE PROPAGATION AND APPLICATION IN MILITARY COMMUNICATION SYSTEMS
D. ROTHER and E. MUELLER *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 21 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Millimeter (mm) wave characteristics and propagation effects such as atmospheric attenuation, shadowing, reflection, and the influence of fading on radio links are studied. System concepts for short range communications such as internal command post communication are presented and discussed. Author

N88-19670# Forschungsinstitut der Deutschen Bundespost, Darmstadt (Germany, F.R.).
SPACE-DIVERSITY EFFECTS ON LINE-OF-SIGHT PROPAGATION PATHS
H.-G. GILOI, K. METZGER, and R. VALENTIN *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 8 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

The effects of space-diversity reception on the performance of analog and digital radio-relay systems is discussed. The existing results valid for analog systems are reviewed. Some single-frequency measurements of the dependence of the improvement factor in the vertical antenna separation are discussed. It was found that the prediction formula proposed by Hosoya gives a good approximation to the measured dependence. The effect of frequency selectivity of the fading was taken into account for a performance estimation of digital radio links. Author

N88-19671# Department of Trade and Industry, London (England). Radio Regulatory Div.
SOME MEASUREMENTS OF HEIGHT GAIN AT V.H.F.
JOHN FAIRBROTHER, KEVIN A. HUGHES, and DOUGLAS M. HOLDEN (GEC-Marconi Electronics Ltd., Chelmsford, England.) *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 16 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

Some of the published work on antenna height gain is reviewed and limitations of the currently available information are highlighted. Comparison is then made with the results of height gain experiments undertaken in southeastern England at frequencies of approximately 95 MHz and 200 MHz. The variation of height gain is investigated, as is a relationship between height gain and the location variability of received field strength within a given environmental area. It was suggested that within the range investigated (experiments done at 95 MHz used vertical polarization and path lengths varying from about 25 km to 105 km) height gain may be represented as n dB for each doubling of antenna height. The value of n varies with the local environment at the receiving site. Author

N88-19672# Plessey Electronic Systems Research Ltd., Romsey (England).
ENVELOPE AND PHASE STATISTICS FOR NON-GAUSSIAN NOISE AND RESULTING ERROR PROBABILITIES FOR DIGITAL COMMUNICATIONS SYSTEMS
J. H. ROBERTS *In* AGARD. Terrestrial Porpagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 15 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

It is becoming increasingly clear that the electromagnetic environment should be given serious attention from the point of view of its statistical characteristics when systems of communication, command, or control are planned. Here, statistical properties of the envelope and phase are derived in a general manner. A new formula, for example, is given for the probability that a noise envelope sample exceeds a sample of an envelope of signal plus noise. This is the basic statistic needed for assessing incoherently detected situations such as On-Off or FSK. In order to apply the results to specific noise types, three types of non-Gaussian noise are studied: Cauchy noise, quartic noise and

a mixture of Gaussian plus impulsive noise. It is very clear that a non-Gaussian noise with a distribution having a long tail can be very damaging to digital data. Author

N88-19673# British Telecom Research Labs., Ipswich (England). Technology Applications Dept.
THE 6 GHZ PROPAGATION MEASUREMENTS OVER A 51 KM PATH IN THE UK
J. E. DOBLE *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 8 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

For several years British Telecom has operated an experimental 6 GHz digital link over a 51 km path in the worst multipath environment in the UK. Results from this link are discussed with particular emphasis being given to a previously unreported form of cross-polar-isolation (XPI) behavior in which the XPI degrades with both frequency selective and flat components of fading. Such events occur only once or twice a year in the location of the experiment but emphasize the need for the development of interface cancellers if co-frequency cross-polar frequency plans are to become viable. Author

N88-19674# Commerce Dept., Boulder, CO.
AN EHF TELECOMMUNICATION SYSTEM ENGINEERING MODEL
KENNETH C. ALLEN *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 15 p (SEE N88-19653 12-32) Nov. 1987
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

An extremely high frequency telecommunication system engineering model (ETSEM) was developed as an aid in the design of line-of-sight (LOS) communication systems from 10 to 100 GHz. ETSEM provides tabulation of path geometry parameters and analyzes ray path and Fresnel zone clearances to help the engineer design the path. ETSEM also predicts the performance (availability) of both digital and analog systems based on state-of-the-art EHF propagation models and equipment specifications. Attenuation by rain, clear air absorption and multipath are modeled. These are expected essentially to determine the statistics of link availability as limited by propagation impairments. Performance may be predicted by any interval of months of the year. A climatological data base for North America and Europe provides parameters for the propagation models. ETSEM has been implemented on a desk top computer. Weaknesses and limitations of the model are discussed Author

N88-19675# Rennes Univ. (France). Dept. Antennes.
A PROPAGATION CAMPAIGN IN A MARINE ENVIRONMENT UTILIZING A DIGITAL SYSTEM AT 36 GHZ [UNE CAMPAGNE DE PROPAGATION EN MILIEU MARITIME, UTILISANT UN SYSTEME NUMERIQUE A 36 GHZ]
YVONICK HURTAUD and ALAIN JUNCHAT (Centre d'Electronique de l'Armement, Bruz, France) *In* AGARD. Terrestrial Propagation Characteristics in Modern Systems of Communications, Surveillance, Guidance and Control 14 p (SEE N88-19653 12-32) Nov. 1987 In FRENCH
(AGARD-CP-407) Avail: NTIS HC A12/MF A01

A propagation study in a maritime environment that took place at the end of 1984 on the French Atlantic coast is discussed. An 8.448 Mbit/s system working at 36 GHz was used. This experiment studied the attenuation at 36 GHz caused by rain behavior as well as the behavior of the digital link. In order to know the sea state, a buoy with a swell sensor was anchored close to the line-of-sight (LOS). It provided the height of waves. The distribution of the rain drop size measured by the spectropluviometer showed good agreement with the distributions of Marshall Palmer and Joss, et al. Specific attenuation was calculated using these distributions and Mie theory. For selected periods, the whole attenuation of the link is forecast and compared to the experimental values. The digital transmission analysis reveals that the link quality strongly depends on the sea state. When the sea is quiet, the reflection of a part of the incident energy on the water disturbs the link with the tide. Author

N88-27406# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AIR-TO-AIR RADAR FLIGHT TESTING
RANDALL E. SCOTT (Test Group, 6520th, Edwards AFB, Calif.) Jun. 1988 117 p
(AGARD-AG-300-VOL-7; ISBN-92-835-0460-7; AD-A197412)
Avail: NTIS HC A06/MF A01

This volume in the AGARD Flight Test Techniques Series describes flight test techniques, flight test instrumentation, ground simulation, data reduction and analysis methods used to determine the performance characteristics of a modern air-to-air (a/a) radar system. Following a general coverage of specification requirements, test plans, support requirements, development and operational testing, and management information systems, the report goes into more detailed flight test techniques covering a/a radar capabilities of: detection, manual acquisition, automatic acquisition, tracking a single target, and detection and tracking of multiple targets. There follows a section on additional flight test considerations such as electromagnetic compatibility, electronic countermeasures, displays and controls, degraded and backup modes, radome effects, environmental considerations, and use of testbeds. Other sections cover ground simulation, flight test instrumentation, and data reduction and analysis. The final sections deal with reporting and a discussion of considerations for the future and how they may affect radar flight testing. Author

N89-11931# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
MEDIA EFFECTS ON ELECTRONIC SYSTEMS IN THE HIGH LATITUDE REGION
Sep. 1988 225 p Lecture series held in Ottawa, Ontario, 29-30 Sep. 1988, in Geilo, Norway, 24-25 Oct. 1988, and in London, United Kingdom, 27-28 Oct. 1988
(AGARD-LS-162; ISBN-92-835-0478-X; AD-A202423) Avail: NTIS HC A10/MF A01

The lecture series directs its attention to propagation problems and solutions for many systems. The topics include satellite communications over polar and auroral latitudes, over-the-horizon radar, low frequency propagation under high latitude conditions, remote sensing of targets and high latitude regions by active and passive EM systems and HF communications at auroral and polar latitudes. Unique lower atmospheric effects and multipath problems of importance at high altitudes are discussed. For individual titles, see N89-11932 through N89-11941.

N89-11932# Army Communications-Electronics Command, Fort Monmouth, NJ. Center for C3 Systems.
MEDIA EFFECTS ON ELECTRONIC SYSTEMS IN THE HIGH LATITUDE REGION
HAIM SOICHER *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 3 p (SEE N89-11931 03-32) Sep. 1988
(AGARD-LS-162) Avail: NTIS HC A10/MF A01

Modern technology and state-of-the-art research will permit communications, navigation, and surveillance systems to adapt to the complex and rapidly changing medium. However, such adaptability depends to a large extent on: improvement of prediction of auroral, ionospheric and magnetic disturbances; understanding of the mechanisms responsible for the formation of ionospheric inhomogeneties and the propagation related effects; obtaining the long-term data base; and maintaining real time information flow on the natural electromagnetic and particle radiation background. Author

N89-11934# Northwest Research Associates, Inc., Bellevue, WA.
TRANSIONOSPHERIC PROBING AND PROPAGATION
E. J. FREMOUW *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 23 p (SEE N89-11931 03-32) Sep. 1988
(AGARD-LS-162) Avail: NTIS HC A10/MF A01

The propagation of radio waves through the ionosphere is necessary for the operation of many C(3)I systems. The aspects of magnetoionic theory that relate to transionospheric probing are discussed, dispensing rather quickly with the bulk-ionosphere effects and concentrating on the effects of spatially irregular total electron content and scintillation. Regarding the latter, the signal

statistics of scintillation and the channel parameters that describe those statistics are discussed. The geophysical parameters needed to characterize the plasma-density irregularities that produce scintillation are considered. The focus in this regard is the application to user-oriented computer models. In addition to the foregoing, the experimental techniques used to employ scintillation as a diagnostic tool and the radio sources available for transionospheric probing are discussed. Author

N89-11935# Hamburg Univ. (Germany, F.R.). Meteorological Inst.

GROUND/LOWER ATMOSPHERIC CONSIDERATION

H. JESKE *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 22 p (SEE N89-11931 03-32) Sep. 1988

(AGARD-LS-162) Avail: NTIS HC A10/MF A01

The ground-wave propagation of electromagnetic waves in the frequency range below 30 MHz is especially influenced by the ground characteristics (electrical constants, roughness, obstacles) along the path. For frequencies above 30 MHz the main propagation mechanisms are determined by the vertical stratification of the refractive index in the lowest part of the non-ionized atmosphere. The effects are hardly frequency-dependent. The characteristics of the involved media (ground atmosphere) and their influences on electromagnetic wave propagation are discussed with special emphasis to anomalies due to the complex environment of polar regions. Author

N89-11936# Communications Research Centre, Ottawa (Ontario). Radio Propagation Lab.

HF COMMUNICATIONS AND REMOTE SENSING IN THE HIGH LATITUDE REGION

JOHN S. BELROSE *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 42 p (SEE N89-11931 03-32) Sep. 1988

(AGARD-LS-162) Avail: NTIS HC A10/MF A01

Media effects on high frequency communications are discussed. High latitude disturbance zones and magnetic coordinates; the propagation media in the high latitude region; ground effects; radio noise and interference; results of high frequency communications, direction finding, surveillance and remote sensing at high latitudes; *transionospheric high frequency propagation; and over-the-horizon* radar are discussed. Author

N89-11937# Centre National de la Recherche Scientifique, Vernieres-Le Buisson (France).

H. F. RADAR PROBING (INCLUDING MODIFICATION)

P. BAUER *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 15 p (SEE N89-11931 03-32) Sep. 1988

(AGARD-LS-162) Avail: NTIS HC A10/MF A01

At high magnetic latitudes (auroral and polar regions), the ionospheric plasma is governed by the geometry of the magnetic field, the experience of particle precipitations (from 100 MeV solar protons to keV electrons), large and small scale convection electric fields, and strong atmosphere/ionosphere coupling processes. As a result, the various forms of free energy sources feed the growth of plasma instabilities which through nonlinear mechanisms lead to a turbulent cascade of ionospheric inhomogeneities from the regional scale of the ion larmor radii. The scales of the irregularities encompass the wavelength ranges of HF systems, thus providing natural targets for HF radars. While highly horizontally stratified in the D and E layers, the targets are essentially aligned along the magnetic field in the F region. HF radar techniques making use of these properties include: partial reflection systems (D and lower E region), E region auroral radars, F region auroral and polar radars. These techniques characterize: the irregularities and the underlying instabilities, the high latitude plasma convection, and the middle atmosphere motions (gravity waves and tides). A better understanding of the basic plasma processes is also provided by HF ionosphere modification experiments performed from the D up to the F region through the excitation of resonant frequencies and through the local change macroscopic properties such as the electron temperature or the electron density. Author

N89-11939# Northwest Research Associates, Inc., Bellevue, WA.

SATELLITE IN-SITU PROBING

E. J. FREMOUW *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 10 p (SEE N89-11931 03-32) Sep. 1988

(AGARD-LS-162) Avail: NTIS HC A10/MF A01

Of those various media that affect radio propagation, the one that can be probed in situ by means of satellites is the ionosphere. The portion of the ionosphere that can be so probed repeatedly over long periods of time is the F layer. Phenomena that affect and/or can be sensed in the F layer are discussed. Specifically, techniques for, and some recent results on, the two major phenomena identified as affecting the high-latitude ionosphere, particle precipitation and its resulting ionization and ExB drift and the plasma-density irregularities that result therefrom, especially those that produce radiowave scintillation are reviewed. Regarding particle precipitation, attention is confined to electrons in the range of a few tens of eV to a few tens of keV, excluding other species and energies that produce ionization lower that the E layer. Upwelling electrons and the question of balance between currents flowing into and out of the ionosphere, insofar as they can be sensed on board a satellite in the F layer are considered. Thus, we shall consider measurement of the magnetic field, especially the local perturbation field. We'll also indicate the utility of optical remote sensing, in the form of imaging from a platform in the F layer, for providing a plan view related to point measurements on the platform. Primarily we'll consider in-situ measurements of the F-layer thermal plasma, mainly its electron and total ion density, temperature, and drift, giving little attention to the identification of ion species. Accordingly, we'll briefly review the measurement principles of the Langmuir probe, the retarding-potential analyzer, and the ion drift meter. Our consideration of the in-situ electric field will be limited primarily to the d.c. convection field, but it will include structure therein. By way of example, we'll describe in some detail the complement of instruments on board the DNA HiLat and Polar BEAR satellites and results therefrom. Author

N89-11940# Centre National de la Recherche Scientifique, Vernieres-Le Buisson (France).

INCOHERENT/COHERENT SCATTER

P. BAUER *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 17 p (SEE N89-11931 03-32) Sep. 1988

(AGARD-LS-162) Avail: NTIS HC A10/MF A01

Coherent and Incoherent VHF and UHF radars provide a means for studying, in three dimensions, some of the basic physical properties of the atmosphere (from the troposphere up to the thermosphere) and of the ionosphere. The term coherent refers here to pulse phase coherent integration of the scattered radar signals. This technique is applicable whenever the scattering process is stationary over the interpulse period. It is the case for the scattering of electromagnetic waves arising from turbulent atmospheric fluctuations and from ionospheric irregularities. On another hand, incoherent integration has to be used when the scattering occurs from plasma thermal fluctuations in the ionosphere. Mesosphere - Stratosphere - Troposphere (MST) coherent radars give access to atmospheric dynamics (wind and turbulence). Aspect sensitive coherent radars allow one to map the ionospheric electric field and to characterize E region plasma instabilities, whenever such instabilities are sufficiently developed. Incoherent scatter radars provide three dimensional measurements of the electron and ion temperatures, of the electron concentration and of the ion drift vector over the whole ionosphere. Author

N89-11941# Royal Norwegian Council for Scientific and Industrial Research, Kjeller. Environmental Surveillance Technology Programme.

PROPAGATION MEDIUM ADAPTIVE TECHNIQUES FOR ADVERSE COMMUNICATIONS AND FOR REMOTE SENSING

DAG T. GJESSING *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 19 p (SEE N89-11931 03-32) Sep. 1988

(AGARD-LS-162) Avail: NTIS HC A10/MF A01

In general terms, an object probed by electromagnetic waves can be characterized by the distribution of scatters along and transverse to the propagation direction, the chemical surface structure of the object, the surface temperature and the motion

pattern. A unified set of first order expressions derived from basic physical principles characterizing the scattering object is presented. From these it is shown how the propagation medium affects the results of the various remote sensing techniques. In exactly the same way the factors which characterize the propagation medium in relation to communications are derived. It is shown that in regard to the influence of the propagation medium, the problems related to communications are very much unified with those of remote sensing. Author

N89-17709# Polytechnic Univ., Farmingdale, NY. Dept. of Electrical Engineering.

GEOMETRICAL THEORY OF DIFFRACTION FOR HIGH-FREQUENCY COHERENCE FUNCTIONS IN WEAKLY RANDOM MEDIUM WITH INHOMOGENEOUS BACKGROUND PROFILE

R. MAZAR and L. B. FELSEN *In* AGARD, Scattering and Propagation in Random Media 16 p (SEE N89-17706 10-31) Mar. 1988

(Contract F49620-85-C-0028)

(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The localization of high-frequency wave propagation around ray trajectories, and the reflection and (or) diffraction of these local plane wave fields by boundaries, inhomogeneities, and (or) scattering centers was combined via the Geometrical Theory of Diffraction (GTD) into one of the most effective means of analyzing high-frequency wave phenomena in complex deterministic environments. These constructs are incorporated into a stochastic propagation and diffraction theory for statistical moments of the high-frequency field in a weakly fluctuating medium with inhomogeneous background profile. Canonical problems with deterministic GTD furnish the propagators and the local reflection, refraction, and diffraction coefficients that relate incoming and outgoing wavefields. The major analytical building blocks include propagators described in local coordinates centered on the GTD ray trajectories in the deterministic inhomogeneous background environment; multiscale expansions in these coordinates, to chart and solve for the propagation properties of statistical measures of the parabolically formulated ray fields; Kirchoff or physical optics (PO) approximations, generated by GTD incident fields, to establish initial conditions for fields reflected from extended smooth surfaces; and point scatterer solutions to establish GTD initial conditions for small scatterers and edges. Author

N89-17710# Colorado School of Mines, Golden. Center for Wave Phenomena.

MULTIPLE SCATTERING FROM ROUGH SURFACES

JOHN A. DESANTO *In* AGARD, Scattering and Propagation in Random Media 10 p (SEE N89-17706 10-31) Mar. 1988

(AGARD-CP-419) Avail: NTIS HC A23/MF A01

A review of multiple scattering theories is presented with specific application to scattering from rough surfaces. This includes the limitations, advantages, and range of validity of both traditional methods such as the Kirchoff and perturbation methods as well as a discussion of modern methods. The latter include the connected diagram method (integral equations), the smoothing method, the stochastic Fourier transform approach, and the spectral method. The former two methods have an analog in the theory of wave propagation in random media. The latter method is analogous to a method developed for scattering from periodic surfaces. The modern mathematical approach to these problems is stressed. In this approach the exact stochastic integral equations are used to develop equations on averages of the field quantities. The two most prominent equations are the Dyson equation on the first moment of the field, and the Bethe-Salpeter equation on the second moment. For homogeneous surface statistics, the former yields the coherent specular scattering, and the latter yields the incoherent scattering. Formally, both can be expressed exactly in the sense that all orders of multiple scattering are included, but, in order to be solved, must be approximated. The Dyson equation was solved in lowest order approximation and illustrates the necessity of using multiple scattering techniques to describe coherent scattering. The situation with the Bethe-Salpeter equation, however, is not nearly so well understood, and the difficulty of finding approximation techniques for this equation are discussed. Author

N89-17712# Royal Signals and Radar Establishment, Malvern (England).

MARKOV RANDOM FIELDS: A STRATEGY FOR CLUTTER MODELLING

STEPHEN P. LUTTRELL *In* AGARD, Scattering and Propagation in Random Media 8 p (SEE N89-17706 10-31) Mar. 1988

(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The need for models of image texture (or clutter) are briefly reviewed. The use of detailed physical models is prohibited by the difficulty of characterizing the scatterer distribution and the scattering process which cause the texture, and so phenomenological modeling is used. It is proposed that certain statistics of the image be measured, and that synthetic images which are consistent with these measurements be generated by a Monte Carlo method - this allows the need for further statistics to be tested. The relationship of this scheme to the well-known maximum entropy method for constructing least commital probability distributions is pointed out. Furthermore it is shown how a Markov random field model is generated by this process. Finally, some methods are suggested for selecting useful statistics, which are demonstrated by analyzing a synthetic aperature radar image of a wood and a sonar image of the sea bed. Author

N89-17713*# Texas Univ., Arlington. Wave Scattering Research Center.

A SCATTERING MODEL FOR FORESTED AREA

M. A. KARAM and A. K. FUNG *In* AGARD, Scattering and Propagation in Random Media 9 p (SEE N89-17706 10-31) Mar. 1988

(Contract NAG9-115)

(AGARD-CP-419) Avail: NTIS HC A23/MF A01 CSCL 13B

A forested area is modeled as a volume of randomly oriented and distributed disc-shaped, or needle-shaped leaves shading a distribution of branches modeled as randomly oriented finite-length, dielectric cylinders above an irregular soil surface. Since the radii of branches have a wide range of sizes, the model only requires the length of a branch to be large compared with its radius which may be any size relative to the incident wavelength. In addition, the model also assumes the thickness of a disc-shaped leaf or the radius of a needle-shaped leaf is much smaller than the electromagnetic wavelength. The scattering phase matrices for disc, needle, and cylinder are developed in terms of the scattering amplitudes of the corresponding fields which are computed by the forward scattering theorem. These quantities along with the Kirchoff scattering model for a randomly rough surface are used in the standard radiative transfer formulation to compute the backscattering coefficient. Numerical illustrations for the backscattering coefficient are given as a function of the shading factor, incidence angle, leaf orientation distribution, branch orientation distribution, and the number density of leaves. Also illustrated are the properties of the extinction coefficient as a function of leaf and branch orientation distributions. Comparisons are made with measured backscattering coefficients from forested areas reported in the literature. Author

N89-17715# Pennsylvania State Univ., University Park. Dept. of Electrical Engineering.

THE ENHANCEMENT EFFECT OF THE BACKSCATTERED INTENSITY IN A RANDOM MEDIUM

C. C. YANG and K. C. YEH (Illinois Univ., Urbana.) *In* AGARD, Scattering and Propagation in Random Media 11 p (SEE N89-17706 10-31) Mar. 1988

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(AGARD-CP-419) Avail: NTIS HC A23/MF A01

A wave gradually loses its coherence while propagating in a random medium. This is because the wave experiences decorrelation along a propagation path that has uncorrelated irregularities. If, however, different parts of the propagation path have correlated irregularities, the decorrelation of the wave will not proceed as rapidly as otherwise. This effect is most prominently manifested in the case of backscattering where the return wave propagates through the same irregularities as the outgoing wave. The average backscattered intensity can be shown to be higher than that expected from a wave propagating over a path equal to the round trip distance but through uncorrelated irregularities. This phenomenon is known as the enhancement effect. This enhancement effect is clearly revealed when the receiver is moved over closer to the transmitter. As the separation between the

receiver and the transmitter is reduced, the average scattered intensity will increase and reaches a peak when the receiver is co-located with the transmitter. If the wave statistics are in the saturation regime, this maximum increase amounts to a doubling of the average intensity. The enhancement effect is examined under various conditions. There can be backscattering from random irregularities themselves or from a deterministic scatter. The difference between weak and strong scattering is distinguished. The effects produced by various power spectral functions from the random medium are also considered. Author

N89-17717# Royal Signals and Radar Establishment, Malvern (England).
HIERARCHICAL SCATTERING MODELS
E. JAKEMAN *In* AGARD, Scattering and Propagation in Random Media 11 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The most familiar descriptor of multi-scale structure in continuous scattering media is the power law spectrum which characterizes hierarchical or fractal behavior. The mathematical and phenomenological implications of adopting such models in scattering calculations will be discussed with particular reference to the statistical properties of amplitude scintillation generated by a phase changing screen or diffuser. A brief summer of results obtained when the phase itself is a Gaussian random fractal will be followed by a more detailed review of the case when the phase gradient is fractal. This last model is not only more realistic for fluid systems subject to diffusive or other smoothing effects, but is also amenable to mathematical and numerical analysis. The geometrical optics contribution to the scattered intensity pattern is particularly easy to calculate and a number of results for the statistics of ray density fluctuations will be presented. Author

N89-17719# Illinois Univ., Urbana-Champaign.
SPACE-TIME STATISTICS OF WAVES PROPAGATING THROUGH A DEEP PHASE SCREEN
S. J. FRANKE and C. H. LIU *In* AGARD, Scattering and Propagation in Random Media 16 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Wave propagation through a deep phase screen is studied in which the properties vary randomly both with time and space. Two approaches will be discussed. One is analytical, the other involves numerical simulation. In the analytical approach, asympotic expressions for the space-time correlation functions of the wave field are derived for the case of Gaussian random irregularities. For the simulation approach, general prescribed space-time random variations of irregularities are generated and used to represent a time varying phase screen. This technique can be used to model a screen with a power law type of irregularity spectrum. Numerical propagation code is then used to compute the wave fields at the reception plane from which statistics will be calculated. The relations between the statistics of the wave fields and the space-time variations of the medium will be discussed. Applications of the results will be discussed. Author

N89-17720# National Oceanic and Atmospheric Administration, Boulder, CO. Wave Propagation Lab.
LINE-OF-SIGHT MILLIMETER WAVE PROPAGATION CHARACTERISTICS
S. F. CLIFFORD, R. J. HILL, R. B. FRITZ, R. A. BOHLANDER, and R. W. MCMILLAN (Georgia Inst. of Tech., Atlanta.) *In* AGARD, Scattering and Propagation in Random Media 7 p (SEE N89-17706 10-31) Mar. 1988
(Contract MIPR-122-85)
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

From 1983 to 1985 a team of scientists from NOAA's Wave Propagation Laboratory and Georgia Institute of Technology conducted an extensive set of millimeter wave propagation measurements. In five, thirty-day sessions, chosen for the widest variety of weather conditions, millimeter wave frequencies from 116 to 230 GHs were propagated over a 1.4 km horizontal path in Flatville, Illinois. Simultaneous, extensive measurements of the meteorology allowed a detailed comparison of the propagation characteristics with the current state of the atmosphere. The observations of millimeter wave propagation characteristics during clear air and sever weather are reported. Amplitude and phase spectra for propagation in clear air are compared with theory derived using the weak refractive turbulence approximation. Excellant agreement is found. Further, probability density functions appear to be; respectively, lognormal (amplitude) and Gaussian (phase difference), as expected from application of the central limit theorem. Interesting meteorological observations and their millimeter wave signatures will also be presented. Author

N89-17723# Forschungsinstitut der Deutschen Bundespost, Darmstadt (Germany, F.R.).
A PRECIPITATION SCATTER EXPERIMENT AT 30 GHZ
HEINZ SCHMIEDEL and ALFRED OCHS *In* AGARD, Scattering and Propagation in Random Media 8 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

An experiment was initiated to study scattering of microwaves at 30 GHz from precipitation, which is of importance in interference analysis and system coordination. The measurements are made in a bistatic configuration with transmit and receive sites separated by some 25 km. The propagation paths are run in a vertical plane containing the two terminal sites. Four transmitters are operated at different fixed elevations, one receiver is connected to a fixed antenna, a second one to a steerable antenna. Thus a total of eight main-beam intersections are formed, from which precipitation scatter can be received under different scatter angles and at different heights up to 10 km. Both, horizontally and vertically polarized signals are measured. In addition, a line-of-sight link and a rain-scatter link are operated at 30 and 11 GHz for the purpose of comparison. To study precipitation scattering in a situation close to those of actual communication links, a further 100 km path is run at 30 GHz. The main objectives of the experiment are: studies of direct relevance to system design and coordination (long term statistics of transmission loss in various interference configurations, significance of backscatter in relation to forward scatter, influence of the melting layer, scattering from ice crystals up to a height of 10 km, and power density spectra and fading rate of the scattered signal); and studies of physical processes relevant to the precipitation scatter. The experimental set-up is described and first results of the measurements will be given. Author

N89-17724# National Telecommunications and Information Administration, Boulder, CO.
OBSERVED PHASE DELAY THROUGH RAIN AT 96 GHZ
KENNETH C. ALLEN *In* AGARD, Scattering and Propagation in Random Media 11 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Observations of phase delay through rain at 96 GHz are presented. The results are pertinent for target identification when relative amplitude and phase information are used from circularly polarized radar returns. At the transmitter site, a 9.6 GHz source was vertically polarized and a 9.1 Ghz source was righthand circularly polarized. A single local oscillator phased locked both sources. At the receiver site, 1050 m away, the local oscillator was phase locked to the received 9.6 GHz signal. Both left- and right-hand circular polarizations at 96.1 were received using separate antennas. The phase of each polarization at 96.1 GHz was measured relative to the 9.6 GHz reference. This allowed the examination of the behavior of the differential phase delay of the circular polarizations. Author

N89-17725# Technische Hogeschool, Delft (Netherlands). Faculty of Electrical Engineering.
FM-CW RADAR REMOTE SENSING OF HYDROMETEORS
L. P. LIGTHART and J. S. VANSINTTRUYEN *In* AGARD, Scattering and Propagation in Random Media 15 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

In order to investigate phenomena influencing co-polar attenuation and cross-polar discrimination along earth-space satellite paths and terrestrial radio links at frequencies above 10 GHz, the number density, geometry, and orientation of hydrometeors (rain, snow, hail, melting particles) along the path have to be characterized. The modeling of the melting process, the dielectric properties of melting particles, and fall velocity behavior of hydrometeors for Doppler velocity computation with vertically pointing radars are described. Attention is paid to backward scattering of ellipsoidal hydrometeors for radar polarimetry computations at arbitrary elevation angles, and to

forward scattering of spherical hydrometeors for attenuation computations at high frequencies. The multi-parameter FM-CW radar system is able to measure the polarization properties and Doppler velocity spectra of hydrometeors with high resolution in range and reflectivity level. Preliminary results obtained with this radar system are shown, indicating the capabilities of combined Doppler- and polarimetry measurements for classification of hydrometeors along a satellite path. Author

N89-17726# Thomson-CSF, Velizy (France). Centre d'Applications Radars.
MODELING OF ELECTROMAGNETIC WAVE AND SEA SURFACE INTERACTION [MODELISATION DE L'INTERACTION ENTRE UNE ONDE ELECTROMAGNETIQUE ET LA SURFACE DE LA MER]
MICHEL FOURNIER *In* AGARD, Scattering and Propagation in Random Media 14 p (SEE N89-17706 10-31) Mar. 1988 In FRENCH
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The EM systems parameters and signal characteristics used in connection with ocean surface effects are reviewed. Hydrodynamic and statistical properties of the sea surface, including various spectral representations are covered. Finally, available models of EM wave and ocean surface interactions are also reviewed. These models consist of perturbation theory for EM waves which are large with respect to ocean waves, physical optics techniques for small EM wavelengths and a combination of both when EM and ocean wavelengths are of the same order. Author

N89-17727# Memorial Univ. of Newfoundland, Saint Johns. Faculty of Engineering and Applied Science.
ROUGH SURFACE PROPAGATION AND SCATTER WITH APPLICATIONS TO GROUND WAVE REMOTE SENSING IN AN OCEAN ENVIRONMENT
JOHN WALSH and SATISH K. SRIVASTAVA *In* AGARD, Scattering and Propagation in Random Media 15 p (SEE N89-17706 10-31) Mar. 1988 Sponsored by Canadian Dept. of National Defence and Natural Sciences and Engineering Research Council of Canada
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Some properties of the vector integral equation representing a general formulation for propagation and scattering from rough surfaces are discussed. It is shown that under certain conditions the equation may be reduced to a Volterra equation of the second kind in the normal component of the surface field for an initially unexcited surface, and hence some confidence may be had in a Neumann series or successive approximation. Using the formulation, the backscattered field solutions at ground wave frequencies and resulting radar cross section solutions derived previously for a model of the ocean surface are presented and discussed. The source assumed is a vertical pulsed dipole. The choice of receiving antenna is left arbitrary. The second-order cross section contains terms in addition to those provided by existing theories. The additional terms may become very significant in certain Doppler frequency regions and hence required for ocean clutter estimation in the detection of certain types of surface targets. Some of the predictions were verified experimentally. Author

N89-17728# Thessaloniki Univ. (Greece). Dept. of Electrical Engineering.
WAVE-TILT SOUNDING OF TROPOSPHERIC DUCTS ABOVE THE SEA
D. P. CHRISSOULIDIS and E. E. KRIEZIS *In* AGARD, Scattering and Propagation in Random Media 12 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The possibility to detect tropospheric ducts above the sea through airborne wave-tilt measurements is investigated. Sea roughness and tropospheric refractivity anomalies associated with the presence of ducts are incorporated in an iterative procedure resulting in wave-tilt versus frequency diagrams at some altitude above sea level. In general, the diagram correponding to ducting conditions appears sifted by delta f with respect to the diagram of the standard troposphere. This frequency shift is rather insensitive to variations of sea state, duct thickness, and optimum coupling height. It is though strongly dependent on duct intensity, delta M. The diagram of delta f vs. delta M is not far from linear in the VHF band and thus offering itself for delta M through delta f measurements. Author

N89-17729# Royal Signals and Radar Establishment, Malvern (England).
I-BAND MULTIPATH PROPAGATION OVER THE SEA SURFACE
C. J. BAKER and K. D. WARD *In* AGARD, Scattering and Propagation in Random Media 5 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

A series of measurements are summarized which were aimed at studying the phenomenon of multipath resulting from line of sight, two way, microwave propagation over the sea surface. It was observed that the expected lobing structure, due to the interference of the direct and reflected signals is destroyed when the sea surface becomes sufficiently rough, suggesting the coherent part of the forward scattered sea reflection to be zero. Further, it was observed that although the pulse by pulse fluctuations show deep fading characteristics they may be modeled by the Rice-squared distribution. However, it was found that care must be taken in choosing the duration of the measurement when evaluating the statistical properties of the data. Author

N89-17730# Rennes Univ. (France). Dept. Antennes.
MEASUREMENT AND MODELING OF 36 GHZ SEA REFLECTION PHENOMENA [ETUDE EXPERIMENTALE ET MODELISATION DU PHENOMENE DE REFLEXION SUR LA MER A 36 GHZ]
YVONICK HURTAUD, CLAUDE TERRET, JEAN-PIERRE DANIEL, and ALAIN JUNCHAT (Centre d'Electronique de l'Armement, Bruz, France) *In* AGARD, Scattering and Propagation in Random Media 14 p (SEE N89-17706 10-31) Mar. 1988 In FRENCH
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

During the 1984 autumn, a measurement campaign of the propagation of electromagnetic waves at 36 GHz was conducted on the French Atlantic coast, near Lorient. The length of the link between the transmitting site, located on the isle of Groix and the receiving site at Gavres, was 9.7 km. Owing to the small height of the antennas, a part of the emitted energy was reflected by the sea surface. At the reception point, the fields coherent interference produced by the direct and reflected radiations, gave a signal varying periodically with the influence of the tides. In order to study the specular reflection phenomena over the sea, specific measurements were made with the help of an elevator. It allowed the height of the receiving antenna to change on a distance of about 5 meters, maintaining that way, at the same time, steady environmental conditions. Thanks to this device, the forward specular reflection coefficient, at a frequency of 36 GHz could then be determined. The measurements which were made, proved the good agreement between then and the theory, especially in the case of strong roughness. Following these results, a model of propagation based on specular reflection was developed to be compared with the measurements. In some particular meteorological situations, a distortion of the interference figures can be observed, due to variations of the atmospheric structure. Author

N89-17731# Naval Research Lab., Washington, DC. Ionospheric Effects Branch.
RANDOM PROPAGATION THROUGH THE LONGWAVE CHANNEL
F. J. KELLY, F. J. RHOADS, and M. D. ANDREWS (Interferometrics, Inc., Vienna, VA.) *In* AGARD, Scattering and Propagation in Random Media 27 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The longwave propagation channel in the earth-ionosphere waveguide has many characteristics of a random medium. The lower surface of the waveguide is sometimes rough or smooth depending on the propagation path considered. The ionospheric boundary is significantly perturbed by sudden events during both daytime and nighttime. The polar-arctic regions of the world evidence these effects in a striking manner and require different statistical treatment. Recent observation of longwave fields in the arctic will be described and their degree of agreement with statistical predictions displayed. Author

N89-17732# National Telecommunications and Information Administration, Boulder, CO. Inst. for Telecommunication Sciences.

MODELING OF WIDEBAND HF CHANNELS

MARTIN NESENBERGS *In* AGARD, Scattering and Propagation in Random Media 16 p (SEE N89-17706 10-31) Mar. 1988 (AGARD-CP-419) Avail: NTIS HC A23/MF A01

Laboratory simulation of wideband high frequency (HF) system performance is currently not possible because such simulators do not exist. Moreover, there are no validated HF channel models for bandwidths of the order of one megahertz, on which to base the simulator design. Additive distortions, namely noise and interference, in the HF band are briefly reviewed. An introduction and an appraisal of past narrowband HF models are presented: their background, validation tests, and the NTIA/ITS development of the Watterson's simulator. That laboratory tool, judged best by many, works in real time and offers accurate representations of HF channel bandwidth up to 10 or 12 kHz. In the present study an extension to wideband models is attempted. Unfortunately, it suffers from an apparently serious shortage of measured data for the time-varying channel transfer function. A possible wideband model is hypothesized, conjectures are made, many questions are raised, but hardly any are answered. One is left faced with a requirement for an experimental program that is to ascertain the wideband characteristics of multipath fading for digital radio transmission in the HF band and over propagation paths of interest. Author

N89-17733# National Telecommunications and Information Administration, Boulder, CO. Inst. for Telecommunication Sciences.

PROPAGATION AND PERFORMANCE MEASUREMENTS OVER A DIGITAL TROPOSCATTER COMMUNICATIONS LINK

JOHN J. LEMMON *In* AGARD, Scattering and Propagation in Random Media 13 p (SEE N89-17706 10-31) Mar. 1988 Sponsored by Department of the Army, Washington, DC (AGARD-CP-419) Avail: NTIS HC A23/MF A01

Propagation and performance measurements that were obtained over a digital troposcatter communications link betwee Bockberg, West Germany, and West Berlin are discussed. The measurements were unusual in that three general types of data were collected simultaneously over the link: propagation data, digital performance data, and meteorological data. The propagation data include received signal level (RSL) and multipath measurements made with a channel probe, the performance data consist of bit-error data obtained from a 1.544 Mbps T1 bank, and the meteorological data (in the form of radiosonde messages) were used to generate profiles of the radio refractive index over the link. The basic principles and instrumentation of the channel probe and the test configurations used to obtain these data are discussed. Then the results of analyses of these data are presented and discussed. These results include the measured impulse response of the channel, delay spread, RSL, bit-error ratios, and refractive index profiles. Potential relationships among these results are investigated in order to assess the impact of various troposcatter channel conditions on digital radio performance. In particular, both the definition and methods of utilizing the all important parameter of delay spread. These considerations range from the simple parameter of 2 sigma values to a more complete evaluation of the dynamic properties of delay-spread derived from the channel probe data. Previous studies have addressed many facets of troposcatter propagation. An attempt was made to bring all of these facets together, to present a more complete description of the troposcatter channel, and to enhance future digital upgrades of existing troposcatter links. Author

N89-17734# National Telecommunications and Information Administration, Boulder, CO. Inst. for Telecommunication Sciences.

MEASUREMENT, MODELING AND SIMULATION OF LOS MICROWAVE CHANNELS

JAMES A. HOFFMEYER and LEWIS E. VOGLER *In* AGARD, Scattering and Propagation in Random Media 16 p (SEE N89-17706 10-31) Mar. 1988 (AGARD-CP-419) Avail: NTIS HC A23/MF A01

A brief summary of prior work in the field of microwave line-of-sight (LOS) channel propagation measurements, channel models, and channel simulators is presented. The objective of these efforts is the reliable prediction of microwave radio performance on any specified link. The ideal channel simulator is one that operates at RF, operates under computer control, is dynamic, stimulates both minimum and nonminimum phase distortions, and has a dual channel capability for the comparative evaluation of space and frequency diversity radios. Significant parameters of this ideal simulator should be based on a model that was validated through propagation measurements on different representative paths. Although much progress was made, a number of issues remain. The work in the area of channel simulation, propagation measurements, and modeling is described. Together with channel measurement programs currently underway, this work should be helpful in the resolution of many of the remaining issues. Author

N89-17735# Emmanuel Coll., Boston, MA.

STRUCTURES OF DENSITY AND VELOCITY FLUCTUATIONS IN THE AURORAL OVAL AND THEIR IMPACT ON COMMUNICATION AND RADAR SYSTEMS

SUNANDA BASU, SANTIMAY BASU, W. R. COLEY, and N. C. MAYNARD (Air Force Geophysics Lab., Hanscom AFB, MA.) *In* AGARD, Scattering and Propagation in Random Media 14 p (SEE N89-17706 10-31) Mar. 1988 (Contract F19628-86-K-0038) (AGARD-CP-419) Avail: NTIS HC A23/MF A01

A class of ionospheric irregularities in the auroral oval associated with large structured plasma flows was recently isolated with radar and satellite in-situ measurements. These density irregularities have large power spectral densities (PSD) at short scale lengths. The density and velocity spectra in such regions are characterized and their impact on scintillation observations and radar performance are discussed. The structures plasma flows may occur in association with large or small field aligned currents. The velocity spectra have fairly shallow power spectral indices in regions of large field aligned currents and are steep in regions of small current flows. The density spectra, on the other hand, can be described by a power law index of approximately -2 in both the large and small field aligned current regions. The temporal structure of scintillations will thus be dictated not only by the scattering strength but also by the large flow velocities encountered in the auroral oval. The density structures with large PSD at short scale lengths are expected to introduce considerable ionospheric clutter in HF radar systems. The effect of E-region conductivity in modifying small-scale F-region structure and its implication for communication and radar systems is discussed. Author

N89-17736# Telettra S.p.A., Chieti (Italy).

IMPULSE RESPONSE MEASUREMENTS AND CHARACTERIZATION OF WIDEBAND VHF RADIO LINES

P. LOMUZIO, G. GUIDOTTI, N. BENVENUTO, and S. PUPOLIN (Padua Univ., Italy) *In* AGARD, Scattering and Propagation in Random Media 14 p (SEE N89-17706 10-31) Mar. 1988 (AGARD-CP-419) Avail: NTIS HC A23/MF A01

Results of an experiment to determine the characteristics of VHF radio links are presented. The experiment was conducted in a plain surrounded by mountainous area with a system that allowed the measurement of the delay spread (difference between the maximum and minimum delay propagation paths) due to multipath propagation. Various sites were explored with measurements being made at different carrier frequencies within the VHF band. In this experiment, an interesting result was that delay spreads increase with the carrier frequency. Author

N89-17738# Cambridge Univ. (England). Ocean Acoustics Group.

CROSS-FREQUENCY CORRELATION OF INTENSITY FLUCTUATIONS IN THE PHASE-CHANGING MEDIA

SARAH J. MILLER *In* AGARD, Scattering and Propagation in Random Media 4 p (SEE N89-17706 10-31) Mar. 1988 (AGARD-CP-419) Avail: NTIS HC A23/MF A01

The cross-correlation of intensity fluctuations at two different wave frequencies is a useful tool in remote sensing of sources and random phase changing media. The cross-spectrum of these fluctuations is investigated here for the model of a deeply modulated phase changing screen. An analytic expression is obtained for this spectrum and the effect of increasing frequency differences is demonstrated. Finally, the statistics of the wave fields in the far field are examined by comparing the second and

fourth moments. It is shown that the relationships of these moments is consistent with the assumption that the statistics of a monochromatic field are normal in the far field, but inconsistent with wave fields of different frequencies having a joint normal distribution there. Author

N89-17739# Laboratoire Central de Telecommunications, Paris (France).
MODELING ELECTROMAGNETIC WAVE PROPAGATION THROUGH A STRONGLY-FLUCTUATING IONIZED MEDIUM BY THE PHASE SCREEN METHOD [MODELE DE PROPAGATION D'UNE ONDE ELECTROMAGNETIQUE DANS UN MILIEU IONISE A FORTES FLUCTUATIONS PAR LA METHODE DES ECRANS DE PHASE]
Y. BENIGUEL and B. GIBERT (Aerospatiale Etablissement des Mureaux, France) *In* AGARD, Scattering and Propagation in Random Media 11 p (SEE N89-17706 10-31) Mar. 1988 In FRENCH
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

An irregular medium, such as the high altitude ionosphere, is defined statistically using the mean value and variance of electron density and the spectral density of propagation index fluctuations. This data permits the characterization of the signal phase as a random variable in the medium propagation. The spatial distribution of the irregularities, connected with the action of the terrestrial magnetic field, produces a very anisotropic medium. The propagation calculation is difficult to carry out if one simply specifies a variation profile of the mean electron density. The method described and used in this paper consists of the discretization of the medium in successive phase screens of low density. The method of resolution is explained. The results presented support signal amplitude, phase and scintillation rate calculations. Author

N89-17743# Messina Univ. (Italy). Istituto di Struttura della Materia.
SELECTIVE EXTINCTION OF A DISPERSION OF SINGLE AND AGGREGATED LAYERED SPHERES
F. BORGHESE, P. DENTI, R. SAIJA, O. I. SINDONI (Chemical Research and Development Center, Aberdeen Proving Ground, MD.), and G. TOSCANO *In* AGARD, Scattering and Propagation in Random Media 4 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The extinction coefficient for a low-density dispersion of small stratified spheres as well as for that of their binary aggregates was calculated. The results are discussed for 50 A spheres with a core of MgO and a coating of Al, a case in which a dramatic shift of the resonance peaks as a function of the thickness of the coating occurs. This suggests that a suitable choice of the thickness could produce selective extinction in a wide range of frequency, although this effect could be strongly weakened if a considerable percentage of spheres aggregate. Author

N89-17744# Societe Mothesim, Le Plessis-Robinson (France).
ELECTROMAGNETIC REFLECTIVITY IN NON-HOMOGENEOUS CONTINUOUS RANDOM MEDIA WITH CYLINDRICAL SYMMETRY [REFLECTIVITE ELECTROMAGNETIQUE D'UN MILIEU ALEATOIRE INHOMOGENE CONTINU A SYMETRIE CYLINDRIQUE]
G. MULLER and F. MOLINET *In* AGARD, Scattering and Propagation in Random Media 12 p (SEE N89-17706 10-31) Mar. 1988 In FRENCH
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

For the calculation of electromagnetic reflectivity in random media, it is common to separate the mean reflectivity of the medium from its fluctuations. However, studies have shown evidence of marked interaction between the two. A calculation scheme is presented which takes into consideration the interaction between the medium mean reflectivity and fluctuations. The medium discussed is an ionized plasma with fluid flow. Cylindrical coordinates are used for field calculations. Results for global and local phenomena and turbulence are discussed. Author

N89-17746# New Mexico State Univ., Las Cruces. Dept. of Physics.
NON-LINEAR EFFECTS ON THE ATMOSPHERIC TRANSMISSION OF HIGH-FLUX ELECTROMAGNETIC BEAMS
R. L. ARMSTRONG *In* AGARD, Scattering and Propagation in Random Media 3 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The propagation of an intense beam of electromagnetic radiation through the atmosphere is accompanied by a host of interactions between the beam and atmospheric constituents present along the propagation path. These interactions may have significant influence on the characteristics of the propagating beam. Aerosol-beam interactions are discussed which, in many cases of practical interest, are the dominant interactions between the atmosphere and the propagating beam. Theoretical experimental insights are reviewed in a survey of this complex problem. Author

N89-17747# Rome Air Development Center, Hanscom AFB, MA. Applied Electromagnetics Div.
A STATISTICAL ANALYSIS OF POLAR METEOR SCATTER PROPAGATION IN THE 45 TO 104 MHZ BAND
M. J. SOWA, J. M. QUINN, J. E. RASMUSSEN, P. A. KOSSEY, and J. C. OSTERGAARD (Danish Research Center for Applied Electronics, Hoersholm.) *In* AGARD, Scattering and Propagation in Random Media 9 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Data being acquired over a 1200 km path in northern Greenland, to characterize the polar meteor scatter channel, are described. The data include both propagation and projected communication statistics. The propagation statistics include arrival rates and duty cycle as a function of frequency and received signal level. The communication statistics include estimates of the performance of a number of candidate systems in terms of throughput and message delivery time, as a function of frequency, time-of-day, season, data rate, and modulation, for a specified bit-error-rate, message length, and packet size. Author

N89-17748# Hamburg Univ. (Germany, F.R.). Meteorologisches Inst.
MONTE CARLO SIMULATION OF MULTIPLE SCATTERING EFFECTS OF MILLIMETER WAVES FROM RAIN FOR A BISTATIC RADAR
P.-H. VOSS and H. JESKE *In* AGARD, Scattering and Propagation in Random Media 9 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Within the scope of rain measurements with a bistatic dual-polarization radar, the influence of multiple scattering effects is discussed. The determination of multiple scattering intensities (up to sixth order) for frequencies of 33 and 9.5 GHz in dependence on rainfall rate, single scattering albedo, volume scattering coefficient, number of ground reflections, antenna beam widths, and dimensions of the rain volume was done by the aid of an efficient Monte Carlo algorithm. The results show that multiple scattering cannot be neglected interpreting the scattered electromagnetic field on the basis of the normal radar equation. The portion to total scattering can become more than 5 percent for shorter microwaves and stronger rain rates (say 50 mm/h). Author

N89-18565# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
EFFECTS OF ELECTROMAGNETIC NOISE AND INTERFERENCE ON PERFORMANCE OF MILITARY RADIO COMMUNICATION SYSTEMS
Dec. 1988 420 p Meeting held in Lisbon, Portugal, 26-30 Oct. 1987
(AGARD-CP-420; ISBN-92-835-0487-9) Avail: NTIS HC A18/MF A01

To achieve reliable communications, a thorough knowledge of the communications channel is required. It is important for system design to characterize the channel, which in general consists of intentionally radiated signals, noise of either natural origin or radiated from man-made sources or composite variations of these signals. The various noise and interference sources existing in the communications channel impose a fundamental limit on achievable radio system performance. Communications equipment

must be designed to cope with the effects of electromagnetic noise and interference. The symposium examined how to determine the effects of these disturbances by measuring, modelling and particularly simulating the characteristics of unwanted signals. Communication system design and performance were also discussed. For individual titles, see N89-18566 through N89-18597.

N89-18566# GTE Government Systems Corp., Westborough, MA. Strategic Systems Div.
RADIO NOISE CHARACTERISTICS AND THEIR SYSTEM PERFORMANCE IMPLICATIONS
JOHN R. HERMAN *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 18 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

This survey reviews the impacts of correlated-pulse impulsive noise on communication coding and system performance. Examples of atmospheric and man-made noise are provided to set the background. The statistical characteristics of radio noise are defined and several noise mitigation techniques are discussed. Author

N89-18567# Rome Air Development Center, Hanscom AFB, MA. Propagation Branch.
BALLOON MEASUREMENT SOFT LOW FREQUENCY TE AND TM ATMOSPHERIC NOISE
JOHN P. TURTLE and PAUL A. KOSSEY (Air Force Geophysics Lab., Hanscom AFB, MA.) *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 11 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Measurements of Transverse Electric (TE) and Transverse Magnetic (TM) atmospheric noise, obtained during a five-hour flight of a free-floating balloon are discussed. The balloon carried three low frequency receivers and three (orthogonal) loop antennas to measure TE and TM atmospheric noise at 42.5 kHz, and the normal (TM) and converted (TE) signals from ground-based transmitters at 37.2 kHz, 48.5 kHz and 60 kHz. A description of the low frequency instrumentation is given, along with discussions of the TE and TM data acquired during the flight, most of which (four hours) occurred at a free-floating altitude of about 21 km. Emphasis is on the TE-to-TM signal and noise ratios observed during the flight. The use of such data to validate TE and TM atmospheric noise prediction codes is also discussed. Author

N89-18568# Pacifica-Sierra Research Corp., Los Angeles, CA.
LIGHTNING GENERATION OF LOW-FREQUENCY TE ATMOSPHERIC NOISE
EDWARD C. FIELD, JR. and CHRIS R. WARBER *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 13 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The role of horizontal lightning strokes in producing transverse-electric low-frequency atmospheric noise is discussed. The fields generated by such strokes are calculated as a function of frequency, stroke altitude, stroke orientation, and the state of the ionosphere. Results show that horizontal strokes are weak TE noise radiators unless their altitude exceeds a few kilometers. Above several kilometers, however, horizontal strokes can radiate Transverse Electric (TE) noise almost as efficiently as vertical strokes radiate transverse-magnetic noise. Because TE noise does not propagate as well as Transverse Magnetic (TM) noise, the TE/TM noise ratio tends to diminish with distance, particularly under disturbed ionospheric conditions. Most horizontal lightning channels do, in fact, occur above 3 km and are more frequent than vertical channels. Moreover, the horizontal structure of lightning is typically 2 or 3 times greater in extent than vertical structure, even for cloud-to-ground strokes. It therefore appears that horizontal lightning is high enough, occurs often enough, and has enough channel length to radiate substantial TE noise. TE atmospheric noise might therefore be stronger than previously believed. Recent balloon-borne measurements on the TE/TM noise ratio seem to confirm that conclusion. Author

N89-18569# Interferometrics, Inc., Vienna, VA.
VLF RADIO NOISE
MICHAEL D. ANDREWS, LORRAINE DEBLASIO, and FRANCIS J. KELLY (Naval Research Lab., Washington, DC.) *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 18 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The Ionospheric Effects Branch of the Space Science Division at the Naval Research Laboratory is engaged in an ongoing program to measure the natural noise environment at VLF. A Navy P-3 aircraft has been used to measure the ambient noise at 35 kHz. There are three orthogonal loop antennas so that both TE and TM components of the noise can be measured. Mean noise levels and values for V sub d will be presented for 1620 observations on seven days in July and August 1986. Examples of the observed APDs are shown. This experiment observed values for V sub d significantly lower than the C.C.I.R. values which probably indicates that these observations were heavily influenced by local noise rather than atmospherics. Author

N89-18570# Stanford Univ., CA. Space, Telecommunications and Radioscience Lab.
A NEW GLOBAL SURVEY OF ELF/VLF RADIO NOISE
A. C. FRASER-SMITH, R. A. HELLIWELL, B. R. FORTNAM, P. R. MCGILL, and C. C. TEAGUE *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 15 p (SEE N89-18565 11-32) Dec. 1988
(Contract N00014-84-G-0202; N00014-81-K-0382; F19628-84-K-0043; NSF DPP-83-16641)
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Stanford University is presently operating a global network of eight computer-controlled receiving systems, or radiometers, for the measurement of electromagnetic noise in the 10 to 32,000 Hz (ELF/VLF) frequency band. Each radiometer consists of two-dual-channel receivers, each with two crossed loop antennas (East-West, North-South). One of these receivers has a response covering the frequency range 10 to 500 Hz and the other covering the range 200 to 32,000 Hz. A bank of narrow-band filters (5 pct) bandwidth is used to monitor the noise present at 16 selected frequencies throughout the overall range of operation. The output of these filters is continuously sampled and statistical averages computed and recorded on magnetic tape, along with samples of the raw data. Broadband samples of the ELF/VLF noise are also taken periodically (typically one minute every hour) to provide a check on system performance and to aid in the interpretation of the statistical data. The digital data are being used primarily for statistical studies of the global distribution of ELF/VLF noise. Plots of minimum, maximum, average, and rms noise amplitudes versus frequency can be comparatively easily prepared for a wide variety of time intervals for each radiometer location. Plots of the noise statistic V sub d amplitude probability distributions are also easily prepared. Author

N89-18571# SRI International Corp., Arlington, VA. Information Sciences and Technology Center.
MAN-MADE RADIO NOISE AND INTERFERENCE
G. H. HAGN *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 15 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Considered here is what the scientific community currently knows and does not know about man-made radio noise. Both empirical and analytical noise are discussed. The measurement of man-made noise also is discussed. The measurement of man-made noise levels (and related statistics) during military exercises is suggested. A man-made radio noise program is described which would help fill the voids in current knowledge. Author

N89-18572# Science Research Council, Chilton (England).
TRANSHORIZON COCHANNEL INTERFERENCE PATH MEASUREMENTS IN EUROPE
MARTIN P. M. HALL *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 10 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Existing methods for predicting co-channel interference levels are very inadequate, and development of these methods has been severely limited by the lack of suitable data. There are particular problems within Europe because there is a wide range of climatic and geographical conditions. COST Project 210 was set up to provide suitable data and prediction methods. The prime objective is to develop and evaluate models to serve as a basis for frequency planning co-ordination procedures and interference calculations, in order to improve the organization of further radio communication systems within Europe. After giving an up-to-date statement on the COST 210 activities set out above, early results obtained from three representative areas of study are given: (1) statistics of high signal level, and case studies, essentially in clear-air conditions, on paths of 150 to 300 km from France to the U.K. (in collaboration with CNET (Paris), CNET (Lannion), Portsmouth Polytechnic, IBA and RSGB); (2) hydrometeor scatter studies using a 10 cm wavelength dual-polarization radar at RAL, where a radar-derived raincell database is being used to simulate interference paths and to examine relative effects of ice and rain, etc; and (3) hydrometeor scatter statistics and case studies on a 131 km overland path (in collaboration with DTI), and a 48 km overland path, both in conjunction with the radar mentioned above, and two oversea paths of 201 and 302 km (in collaboration with CNET). Author

N89-18573# Manchester Univ. (England). Inst. of Science and Technology.
EXPERIMENTAL OBSERVATIONS OF SPECTRAL OCCUPANCY AT HF
GEOFFREY F. GOTT, PATRICK J. LAYCOCK, ARUP R. RAY, and MARK MORRELL *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 8 p (SEE N89-18565 11-32) Dec. 1988 Sponsored by the Science and Engineering Research Council, United Kingdom and the Ministry of Defence, United Kingdom
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

An experiment to measure spectral occupancy at HF has been undertaken since the sunspot maximum of 1982, and examples of the results are presented. Also, a mathematical model is being fitted to the experimental data, and initial results of this aspect of the work are included. Author

N89-18574# Army Information Systems Command, Fort Huachua, AZ. Engineering and Integrations Center.
NOISE MEASUREMENT SYSTEMS/TECHNIQUES
CALVIN B. CHRISTIANSON *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 9 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The evolution of noise management systems, types of and capabilities of systems that have been used in the last decade, and a small portable system that was developed for noise measurements are briefly discussed. The use of this small system for noise measurements in the field and resulting data is presented. Author

N89-18575# Naval Ocean Systems Center, San Diego, CA.
SIGNAL NOISE/INTERFERER COMBINER UNIT PROGRAMMABLE (SINCUP)
EMILIO MARTINEZDEPISON *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 9 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The Signal Noise Interferer Combiner Unit Programmable (SINCUP) has been developed to facilitate laboratory performance testing of Very Low Frequency (VLF/Low Frequency (LF) receivers. To accomplish this, the unit allows the combining in controlled amounts of various real-world environmental and manmade interference with an information carrying signal. The externally modulated signal is combined with internally/externally generated Gaussian noise and/or with an internally/externally generated interferer. In order to test modern digital processing techniques, such as Adaptive Null Steering, Eigenvector Sorting, and Widrow-Hoff adaptive filters, SINCUP is capable of generating and meeting much higher signal-to-noise plus interference ratios than earlier channel simulators. The present software has been written to accommodate a dynamic signal-to-noise ratio (SNR) range from -60 to +60 dB. Higher dynamic range units could be implemented. Author

N89-18576# National Telecommunications and Information Administration, Boulder, CO. Inst. for Telecommunication Sciences.
EFFECTS OF NOISE AND INTERFERENCE ON SYSTEM PERFORMANCE
ARTHUR D. SPAULDING *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 17 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

A summary is given of the two basic types of noise processes that confront us: narrowband processes composed of various collections of narrowband intentionally radiated signals, coherent pulse trains, various kinds of unintentionally radiated manmade noise, etc., all termed Class A; and broadband processes such as atmospheric noise from lightning and various forms of manmade noise such as automotive ignition noise, etc., termed Class B. After a short summary of these noise processes, stating only the models in current use, a review is given of the performance of normal (linear) systems in Class A and Class B noise, not in great detail, but sufficiently to give a good feel for the diverse performance degradations obtained. Examples of both digital and analog systems are used. After reviewing the substantial degradation the real-world interference environment can cause the existing systems, results are given of the performance of systems especially designed to take advantage of the actual interference, showing very substantial performance improvements. Examples of both techniques currently being pursued, parametric and nonparametric, are used. Author

N89-18577# Communications Research Centre, Ottawa (Ontario).
THE DESIGN AND PERFORMANCE OF AN ADAPTIVE PACKET-SWITCHED HF DATA TERMINAL
G. R. NOURRY and A. J. MACKIE (Intellitech Canada Ltd., Ottawa, Ontario) *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 10 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Adaptive techniques form a useful set of tools for combatting the time and space variability of HF channels and the other factors adversely affecting HF communications. These techniques have been implemented together with packet-switching in a vehicle called the HF data terminal. The terminal is characterized by adaptivity at all levels of its design, including a real-time channel evaluation and channel selection mechanism, an adaptive link protocol for channel optimization, and a fully distributed and adaptive routing algorithm for the selection of routes in an HF network. The adaptivity is implemented via a suite of robust, low-overhead, adaptive protocols that work even in low-bandwidth and error-prone environments. With the exception of channel evaluation/selection, all forms of adaptivity are dynamic and not negotiated over HF links. The data terminal has been tested over both short and long HF links. The performance of this system is illustrated with results from these tests. It is shown that, in addition to fully automatic operation, the system provides a significant improvement in HF communications reliability and survivability. Throughput was demonstrated to be an order of magnitude greater in existing HF communications systems. Author

N89-18578# Plessey Research Roke Manor Ltd., Romsey (England).
DESIGN CONSIDERATIONS FOR AN AUTOMATED HF DATA NETWORK WITH ADAPTIVE CHANNEL SELECTION
R. J. GOODWIN and A. P. C. REED *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 11 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

A fully automatic HF data network has been designed which adapts to changing propagation and interference conditions. Frequency management at network level derives real time propagation data which is supplied to all network stations. At link level, propagation prediction, interference assessment and link sounding together provide adaptive channel selection for each call. Efficient and reliable message transmission is achieved using a novel FEC/ARQ protocol which also provides for adaptive changes in data rate or channel reselection during the call. Frequency management and network management functions can be executed by any subset of stations in the network and no special sounding equipment is required. Author

N89-18579# Manchester Univ. (England). Inst. of Science and Technology.
EXPERIMENTAL ROBUST HF MODEMS INCORPORATING ADAPTIVE EXCISION
GEOFFREY F. GOTT, PAUL DOANY, SIU W. WONG, and E. PHILIP DARBYSHIRE *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 10 p (SEE N89-18565 11-32) Dec. 1988 Sponsored by Ministry of Defence, United Kingdom
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Two 75 bits/sec modems which are able to operate in the presence of severe interference from other HF users, frequency selective fading, and noise are described. One modem is a frequency hopper (with a total bandwidth of about 200 kHz) and the other occupies a single voice channel. Author

N89-18580# Hull Univ. (England). Dept. of Electronic Engineering.
ARTIFICIAL INTELLIGENCE IN HF COMMUNICATION SYSTEMS
A. P. JOWETT *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 25 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The current status of HF communications system design is reviewed. Attention is given to the constituent components of HF systems. The need for automatic system control and frequency management is presented. A new method of in-band real-time channel evaluation (RTCE) is described and a proposed co-channel interference model is included. A formalized HF systems design philosophy is presented in order to achieve optimum performance in noise and interference environments, and compatibility with other types of communication systems. Author

N89-18581# Hull Univ. (England). Dept. of Electronic Engineering.
PROCESSING TECHNIQUES FOR RADIO COMMUNICATIONS IN NON-GAUSSIAN NOISE ENVIRONMENTS
M. DARNELL *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 15 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The different forms of background noise/interference environment encountered by various types of radio communication systems are considered. Shortcomings of the analytical models available for these environments are then identified. The fundamental characteristics of radio paths which affect their ability to pass information are then examined, and certain general design principles established. Finally, several procedures and techniques with the potential to enhance radio system performance in non-Gaussian environments are described. Author

N89-18582# York Univ. (England). Dept. of Electronics.
IMPROVED CODING AND CONTROL OF HF SYSTEMS IN A NON-GAUSSIAN NOISE ENVIRONMENT
J. HAGUE *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 17 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

A HF communication system which is capable of adapting various parameters, such as frequency and coding scheme, to provide the user with the most reliable HF path is described. Each transceiver/ATU is of amateur-grade, and is capable of delivering approximately 150 W over the range 2 to 30 MHz. The transceivers are fully computer-controllable, and this enables automatic channel selection to be achieved. When used with 10m whip antennas, a cheap and portable HF system results; however, for some channels, the 10m antenna will not present an ideal match to the system, and thus the automatic tuning facility of the ATU is used to achieve a match, which may take up to 3 seconds. Due to this constraint, broadband antennas for the probing channel become desirable, at the expense of making the system less portable. The coding/control software runs on two 8085 systems. Each 8085 system is equipped of 8 Kbytes of ROM and 8 Kbytes of RAM, and therefore reasonably complex algorithms may be accomodated. Additional memory cards may be added to the system at a later date as required. Presently, Golay (23,12) and other half-rate codes (the Golay (23,12) code is in fact implemented as a (24,12) code for ease of system timing), are supported by the system, but it is intended to utilise other coding schemes, such as the embedded-array code (Darnell, Honary & Zolghadr, 1986) at a later date by modifying the software. Author

N89-18583# Istituto per le Telecomunicazioni e l'Elettronica G. Vallauri, Livorno (Italy).
ELECTROMAGNETIC CODE FOR NAVAL APPLICATIONS
F. CRESCIMBENI, F. BESSI, and S. CHITI (IDS Ingegneria dei Sistemi S.p.A., Pisa, Italy) *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 12 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The use of an increasing number of electronic apparatus became vital to meet the high performance required for military navy applications. Thus the number of antennas to be mounted on shipboard greatly increased. As a consequence of the high antenna density, of the complexity of the shipboard environment and of the powers used for communication and radar systems, the EMC (Electro-Magnetic Compatibility) problem is playing a leading role in the design of the topside of a ship. The Italian Navy has acquired a numerical code for the antenna siting and design. This code, together with experimental data measured at the Italian Navy test range facility, allows for the evaluation of optimal sitings for antenna systems on shipboard, and the prediction of their performances in the actual environment. The structure of this code, named Programma Elettromagnetico per Applicazioni Navali, (Electromagnetic Code for Naval Applications) is discussed, together with its capabilities and applications. Also the results obtained in some examples are presented and compared with the measurements. Author

N89-18584# Naval Ocean Systems Center, San Diego, CA.
NARRATIVE COMPRESSION CODING FOR A CHANNEL WITH ERRORS
JAMES W. BOND *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Sysems 15 p (SEE N89-18565 11-32) Dec. 1988 Previously announced as N88-25673
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Data compression codes offer the possibility of improving the throughput of existing communication systems in the near term. This study was undertaken to determine if data compression codes could be utilized to provide message compression in a channel with up to a .10 bit error rate. The data compression capabilities of codes were investigated by estimating the average number of bits-per-character required to transmit narrative files. The performance of the codes in a channel with errors (a noisy channel) was investigated in terms of the average numbers of characters decoded in error per bit error and of characters printed in error per bit error. Results were obtained by encoding four narrative

files, which were resident on an IBM PC and use a 58 character set. The study focused on Huffman codes and suffix/prefix comma-free codes. Other data compression codes, in particular, block codes and some simple variants of block codes, are briefly discussed to place the study results in context. Comma-free codes were found to have the most promising data compression because error propagation due to bit errors are limited to a few characters for these codes. A technique was found to identify a suffix/prefix comma-free code giving nearly the same data compression as a Huffman code with much less error propagation than the Huffman codes. Author

N89-18585# Forschungsgesellschaft fuer Angewandte Naturwissenschaften, Werthoven (Germany, F.R.).
NEW METHOD FOR SUPPRESSION OF GONIOMETER OF ERRORS BY RADIO NOISE FROM OVERHEAD POWER LINES
J. BENGER, G. DEUBACH, and G. KOSEL *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 9 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Overhead power lines below 70 kV often generate impulsive radio noise by sparking which may heavily interfere on the performance of military VHF communication systems. The first part of this presentation deals with that kind of radio noise, its characteristics and possible sources and shows some measurements. Measurements also show that radio noise from sparking overhead power lines may influence automatic goniometer direction finding: one gets a wrong bearing, that of the noise source. Therefore, a new method for eliminating this noise influence was investigated. It determines the lower envelope of the direction finder (DF) signal and is only applicable in the digital area of signal processing. The method is described and its effectiveness is presented. Author

N89-18586# Victoria Univ. (British Columbia). Dept. of Electrical and Computer Engineering.
JAMMING AND ELECTRONIC COUNTERMEASURES
VIJAY K. BHARGAVA and QIANG WANG *In* AGARD, Effects of Electromagnetic Noise and Interference on *Performance* of Military Radio Communication Systems 11 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

There is no single jamming strategy that is worst for all spread spectrum systems and there is no single spread spectrum system that is best against all jamming waveforms. Examined here are the following potential jammers: (1) broadband and partial-band jammers; (2) continuous wave and multitone jammers; (3) pulse jammers; and (4) repeat-back jammers. In order to operate in the presence of jamming, military communication systems must incorporate one or more of the primary countermeasure techniques in their designs, such as spread spectrum, error control coding, and steerable-null antennas. The basic design approach for such anti-jam communication systems is introduced. Ground rules for system performance are specified by stating assumptions regarding jammers and anti-jam systems along with definitions of the fundamental system parameters. Two useful examples of such systems, namely, coherent direct sequence spread, phase-shift-keying (DS/PSK), and non-coherent frequency-hopped frequency-shifted keying (FH/FSK) systems are presented. Because coding and interleaving are extremely important in anti-jam system design, the impact of these techniques is illustrated with examples. Author

N89-18587# Rhode and Schwartz G.m.b.H., Munich (Germany, F.R.).
ECM RESISTANCE IN THE HF BAND BY USE OF ADAPTIVE REACTION AND FREQUENCY HOPPING
G. GREINER, P. ISELT, and G. MUELLER *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 9 p (SEE N89-18565 11-32) Dec. 1988 Sponsored in part by SHAPE Technical Center
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

In shortwave communications, change of frequency either by adaptive reaction or by frequency hopping as a means of protection against jamming must be adapted to the particular transmission characteristics of shortwaves. Adaptive reaction to a new frequency is a technique used for maximizing the throughput and optimizing reliability, and is an Electronic Counter Counter Measure (ECCM) against conventional jamming systems. As a result of the analysis and reaction times of follower jammers, frequency hoppers with 10 to 20 hops/s can provide adequate protection against electronic counter measures (ECM) also in the 90's. In this case, effective error correction techniques are required because of the high proportion of disturbed hop channels. Hopping systems with hop rates of more than 100 or 1000 hops/s are discussed. An HF communication system with adaptive reaction and freqency hopping of up to 20 hops/s is presented. Results are presented of field trials with adaptive reaction and frequency hopping with a dwell time of 160 ms corresponding to 6 hops/s. A test system with reproducible channel characteristics of the HF channel is described. Author

N89-18588# Communications Research Centre, Ottawa (Ontario).
PREDICTING THE EFFECTS OF NOISE AND INTERFERENCE ON FAST FREQUENCY-HOPPED M-ARY NCFSK SYSTEMS
E. BARRY FELSTEAD, JOHN S. BIRD, and U. ANDREJ TENNE-SENS *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 11 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Calculation of the performance, in terms of received bit error probabilities, of fast frequency-hopped M-ary non-coherent frequency-shift-keyed (NCFSK) systems is discussed. A general method of calculating accurately the performance of such systems for arbitrary M, degraded by system noise and both partial-band-noise and multi-tone jamming is introduced. Some typical results are presented and it is shown for a fixed hop rate how the use of time diversity, through repetition of each symbol on several hops, can dramatically improve performance; M may be simultaneously increased to keep the data rate high. This technique in conjunction with only simple error-correction coding can make the system quite robust. System degradation due to multipath can fortuitously be overcome by the same anti-jam techniques. Author

N89-18589# *Instituto* Superior Tecnico, Lisbon (Portugal).
INHERENT-JITTER EFFECTS IN THE NEW RAPID ACQUISITION METHOD FOR FREQUENCY-HOPPED PUSH-TO-TALK SPREAD SPECTRUM SYSTEMS: A JITTER-FIGHTING SCHEME
JORGE M. N. PEREIRA and AUGUSTO A. ALBUQUERQUE *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 20 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

A critical problem in Push-to-Talk Frequency-Hopped Spread-Spectrum systems is its vulnerability to eavesdropping during the necessary preamble, or to possible reproduction by a would-be interferer. A new acquisition method has been envisioned, and is presented, to reduce this weakness, permitting the receiver to work in lower signal-to-noise ratio and to acquire faster than in any known system. The essence of the new method is the use of sliding-window integration non-coherent detectors and a decision rate much higher than the hopping one, and coincident with the window-relocation rate. The inherent-jitter effects in the new method are described, and results presented for an optimal (omniscient) system, after jitter-bypassing. A jitter-fighting scheme is then proposed and its performance and adequacy analyzed. Author

N89-18590# LuTech, Inc., Dallas, TX.
DEVELOPMENT OF A NEW HIGH ALTITUDE ELECTROMAGNETIC PULSE (HEMP) ENVIRONMENT AND RESULTING OVERHEAD LINE RESPONSES
F. M. TESCHE and P. R. BARNES (Oak Ridge National Lab., TN.) *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 20 p (SEE N89-18565 11-32) Dec. 1988
(Contract DE-AC05-84OR-21400)
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Being able to accurately determine the response of an electrical system which is excited by a high altitude nuclear electromagnetic pulse (EMP) requires a knowledge of the time history of the incident EMP field strength, as well as its angle of incidence and polarization. A commonly used, unclassified, description of this

environment is provided by the Bell Laboratory waveform. Recent studies have shown, however, that this EMP waveform tends to over-estimate the response of an above-ground transmission line by more than an order of magnitude. As a result, other unclassified high altitude EMP environments have been developed. Discussed here is the development of two alternate unclassified EMP environment descriptions: one arising from a simple radiating dipole moment model, and the other resulting from curve-fitting the calculated fields from a computer code named CHAP. For both of these EMP models, the electric field at two earth observation points are compared. These fields are then coupled to an above-ground line and the resulting open-circuit voltage responses are compared. Using the CHAP EMP environment, a limited parametric study of the peak positive and negative open-circuit line voltage is then performed and surface plots of these peak voltages are presented. Author

N89-18591# Federal Armed Forces Defense Science, Munster (Germany, F.R.). Agency for NBC Protection.
EMP-INDUCED TRANSIENTS AND THEIR IMPACT ON SYSTEM PERFORMANCE
RICHARD J. STURM *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 7 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The interaction of electromagnetic waves with complex systems is still a puzzling phenomenon. Presented here is an attempt to show how information about the sequence of interaction steps can be extracted from the whole set of data which are recorded during an electromagnetic pulse (EMP) test of a complex system. The basic idea is to separate the interaction process in two or more steps, the external interaction, coupling through e.g., an aperture, and the internal interaction. The internal interaction results in the all important results in the all important pin currents/voltages which endanger the proper function of the system. In case of EMP the induced currents can reach peak values of more than 100 A even on short cables in compact systems (helicopters, tanks, etc.). The type of upset and damage which have been observed after illumination with EMP-like fields are reported. The basic concept of the determination of the EMP-vulnerability is discussed and explained by examples. Author

N89-18592# BDM Services Co., Albuquerque, NM.
SHIELDS FOR PROTECTING CABLES FROM THE EFFECTS OF ELECTROMAGNETIC NOISE AND INTERFERENCE
L. O. HOEFT, J. S. HOFSTRA, R. J. KARASKIEWICZ, and B. W. TORRES *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 10 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The intrinsic electromagnetic property of a cable or connector shield is its surface transfer impedance. This is the ratio of the longitudinal open circuit voltage measured on one side of the shield (normally the inside) to the axial current on the other side (normally the outside). In cases where a high electric field is present at the surface of the shield, the transfer admittance or charge transfer elastance is also important. Measurements of typical cables, connectors, backshells and cable terminations are presented and explained in terms of simple models. Author

N89-18593# Army Electronics Command, Fort Monmouth, NJ. Center for Command, Control and Communications Systems.
AUTOMATING SPECTRUM MANAGEMENT OF TACTICAL COMMUNICATIONS TO MINIMIZE MUTUAL INTERFERENCE AND MIXIMIZE FREQUENCY REUSE ON THE BATTLEFIELD
SAMUEL M. SEGNER *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 14 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Automating spectrum management of tactical multichannel line of sight (LOS) and tropospheric (TROPO) communications systems began in the early 80's with the establishment of the Automated Battlefield Spectrum Management and Engineering (ABSME) studies and analysis program and its test bed for software evolution, the Army Automated Tactical Frequency Engineering System (ATFES) pilot program in U.S. Army Forces, Europe (USAREUR). The ATFES is a minicomputer based, four echelon pilot system deployed in Europe as a vehicle to research potential battlefield spectrum management capabilities through operational evaluation of software and operating procedures during major USAREUR exercises. The pilot system provides a go to war asset for use until the software is transitioned to the communications system control centers/elements for evolving switched systems; it is mounted in existing tactical demand access and VHF combat net radio (CNR) management is described in this paper. Interoperable distributed data base processing is the key to spectrum management responsive to highly maneuverable forces. Author

N89-18594# Industrie per lo Spazio e le Comunicazioni S.p.A., Rome (Italy).
COSITING OF RADIO TERMINALS
GIUSEPPE CUCINOTTA and RAFFAELE AZZARONE (Marina Militare, Livorno, Italy) *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 11 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The causes of the radiocommunication channel degradation are identified when receivers and transmitters or transceivers are colocated in mobile platforms or in sites where space is at a premium. System and equipment parameters are evaluated to minimize the degradation of the receivers performance in cosited radio installations, together with additional technical and operational resources necessary to support this target. Furthermore the parameters necessary for computer simulations of cositing effects and associated frequency management are identified. Author

N89-18595# City Univ., London (England). Chemical Energy Research Centre.
INTERMODULATION INTERFERENCES IN RADIO SYSTEMS
P. S. W. HO, L. H. BEVAN, A. C. C. TSEUNG, and W. S. WILKINSON *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 8 p (SEE N89-18565 11-32) Dec. 1988 Sponsored in part by the Science and Engineering Research Council, United Kingdom and the Home Office, United Kingdom
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

The phenomenon of intermodulation is introduced first. The origins of intermodulation interference in a radio communication systems are considered. Mechanisms responsible for this interference, for example, ferromagnetic nonlinearity and electron tunnelling are considered, and a model based on a metal-semiconductor rectifying junction is suggested. An experimental setup for measuring intermodulation levels of specially treated test samples and the operating procedures are then described. A general principle to overcome the structural intermodulation problem is outlined. Experimental results for some chemical and metallic coatings, and their merits are presented next. Lastly, the usefulness of monitoring the background intermodulation level of a test site is given. In conclusion, the joint effect is the first order in determining the degree of seriousness of the intermodulation problem and the use of high conductivity coating provides the most feasible solution. Author

N89-18596# Army Electronics Command, Fort Monmouth, NJ. Center for Command, Control and Communications Systems.
AUTOMATING THE DECONFLICTION OF JAMMING AND SPECTRUM MANAGEMENT
SAMUEL M. SEGNER *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 12 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

Powerful airborne and ground based jammers are being fielded by all services and nations as part of their intelligence/electronic warfare (I/EW) combat capability. For their survivability, these I/EW systems operate far from the FLOT; this creates rather large denial areas to friendly forces when they jam. Manual coordination between IE/W managers and spectrum managers is not practical to take on targets of opportunities or track the intended enemy victims when these victims counter by frequency maneuvers. Two possible architectures, one centralized, the other decentralized, are explored as is the applicability of the electromagnetic compatibility (EMC) software developed for the U.S. Army Automatic Tactical Frequency Engineering System (ATFES) pilot

program. The proposed approach is to apply the principles of the Joint Commanders EW Staff (JCEWS). The initial simplified software to demonstrate the computer aided coordination at VHF is explained Author

N89-18597# Royal Aircraft Establishment, Farnborough (England).
DETERMINING THE AZIMUTHAL DISTRIBUTION OF NOISE AND INTERFERENCE ACROSS THE HF SPECTRUM AT THE RAE RECEIVING STATION, COBBETT HILL, SURREY, ENGLAND
H. L. SPONG *In* AGARD, Effects of Electromagnetic Noise and Interference on Performance of Military Radio Communication Systems 14 p (SEE N89-18565 11-32) Dec. 1988
(AGARD-CP-420) Avail: NTIS HC A18/MF A01

An increasing interest in techniques for nulling out unwanted signals and interference in the HF band makes it more important to establish not only the magnitude of the signals but the direction from which they are emanating and whether they are of a spasmodic or continuous nature. The Royal Aircraft Establishment (RAE) has been anxious for some time to build up a data base of such information from which statistical trends may be derived and applied to research into more effective HF communications systems for the Royal Air Force. Given here is a simple outline of a measurement system built around a Multi-Vee antenna, a Rohde and Schwarz ESH3 measurement receiver and a Hewlett Packard HP9836 computer all installed at the RAE Receiving Station, Cobbett Hill. The various formats available on the HP9836 computer for displaying the data, for example, Signal versus Time and Signal versus Direction, etc., are given. Data acquired form this system has so far been based upon two measurement methods. The first takes up to five frequencies of interest across the band and measures these at the same time or times on consecutive days in an effort to determine the constancy or otherwise of the direction and magnitude of the interfering signals. The second approach has been to evaluate the measurement system as a means of gathering data on channel occupancy. Author

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ELECTRONICS AND ELECTRICAL ENGINEERING

Includes test equipment and maintainability; components, e.g., tunnel diodes and transistors; microminiaturization; and integrated circuitry.

N87-22094# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
THE POTENTIAL IMPACT OF DEVELOPMENTS IN ELECTRONIC TECHNOLOGY ON THE FUTURE CONDUCT OF AIR WARFARE, VOLUME 3
Dec. 1986 119 p Proceedings of the AGARD Avionics Panel Workshop, The Hague, Netherlands, 21-25 Oct. 1985
(AGARD-AR-232-VOL-3; ISBN-92-835-1541-2; AD-A178424)
Avail: NTIS HC A06/MF A01

Advances in microelectronics have resulted in circuit densities many orders of magnitude greater than in current usage, making possible higher speed circuitry and greater storage capacity. RF techniques are also leading to monolithic microwave integrated circuits and microstrip antennas with corresponding reductions in size and weight. In addition, rapid advances are taking place in computer architecture and software that will provide improved information processing and control. This, coupled with progress in artificial intelligence and man-machine interface, offers promise of greatly improved battle management in the cockpit. The scale of changes is such that the nature of air warfare should be significantly affected over the next twenty years. This study examined the potential of electronic technology and potential benefits such as improvements in information processing, reduction in size and weight, increased reliability and maintainability; determined the applicability of such improvements to avionics and command and control systems and such functions as navigation and guidance, communications, surveillance, cockpit engineering and electronic warfare, and examined the impact on air warfare in the time period 2000 to 2010 Author

N87-23867# Massachusetts Univ., Amherst. Dept. of Electrical and Computer Engineering.
PRINTED CIRCUIT ANTENNA TECHNOLOGY
DANIEL H. SCHAUBERT *In* AGARD Microwave Antennas for Avionics 15 p (SEE N87-23859 17-32) Apr. 1987
(AGARD-LS-151) Avail: NTIS HC A08/MF A01

Printed circuit antennas are being used on a variety of spacecraft, aircraft, and projectiles where their low profile and conformability minimize interference with the structural and aerodynamic properties of the vehicle. The basic microstrip antenna has been studied extensively, but some important aspects of its performance are not yet characterized by the analyses that are available to the designer. Furthermore, new applications in millimeter wave monolithic phased arrays are forcing the designer to use substrates that are electrically thick and that may have a high permittivity. Several characteristics of microstrip antennas are described and some that are being studied with the aim of improving antenna performance are identified. A brief description of analysis techniques available to the designer and researcher are presented. Finally, several aspects of monolithic and integrated phased arrays are considered. General properties of these arrays are discussed, and then several architectures and their associated printed circuit radiators are presented. Author

N87-26954# ERA Ltd., Leatherhead (England). Applied Physics Dept.
RADIATION CHARGING AND BREAKDOWN OF INSULATORS
D. K. DAVIES *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 7 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

An experimental investigation of the charge produced by photo-emission from insulators in vacuo is described. It is shown that the emission from materials commonly used in spacecraft construction, such as polyimide, as well described by solid state theory, but that externally applied fields modify both the emission dynamics as well as the eventual saturation charge density. The energetics of the electric breakdown of such charged surfaces is analyzed. Author

N87-26959# Atomic Energy Research Establishment, Harwell (England).
SURFACE MODIFICATION TO MINIMISE THE ELECTROSTATIC CHARGING OF KAPTON IN THE SPACE ENVIRONMENT
D. VERDIN and M. J. DUCK *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 12 p (SEE N87-26937 21-18) May 1987 Sponsored in part by the Royal Aircraft Establishment, Farnborough, England
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

The electrostatic charging of Kapton under electron irradiation is reduced by coating it with a dispersion of indium oxide in a soluble polyimide. The proportion of oxide in the coating and its thickness are chosen to give an optimum balance between the surface resistivity and the thermo-optical properties of the film. Author

N88-10809# Electronique Serge Dassault, Saint Cloud (France).
DEDALE: AN EXPERT SYSTEM FOR ANALOG CIRCUIT MAINTENANCE
MICHEL MUENIER and PHILIPPE DEVES *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

DEDALE is an expert system designed to cover the diagnostic phase of an analog circuit. DEDALE allows the fast and intelligent identification of circuit faults. Its ability is not limited to a few circuits; it is able to troubleshot fairly quickly any new circuit with minimum initial knowledge. Author

N88-23792# Naval Weapons Center, China Lake, CA. Microelectronics Branch.
MICROELECTRONICS THE NEXT FIFTEEN YEARS
DEAN WALLACE *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 5 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Some future trends in microelectronics are predicted. The focus is on CMOS integrated circuit technology. CMOS is presently the leading integrated circuit technology, and all trends show that it will continue to dominate the integrated circuit market in the future. Twin tub and silicon on insulator (SOI), identified as the two leading CMOS technologies in the future, are examined. These two technologies have the capability of giving maximum CMOS device performance. With device geometries shrinking, the problems associated with scaling are introduced, and some possible solutions are examined. A brief description is given of some fundamental limits in integrated circuit technology. Author

N89-17695# Aeritalia S.p.A., Turin (Italy). Combat Aircraft Group.
A STUDY TO OPTIMIZE THE CFRP-AL MECHANICAL JOINT IN ORDER TO REDUCE ELECTRICAL RESISTANCE
F. CIPRI and M. PELOSI *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 11 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

The aim is to show what could be the kind of joints that would reduce the electrical resistance when a carbon fiber reinforced structure has to be jointed with an aluminum part. Assembly of specimens has been considered in fixed and removable configurations. The materials used to prepare the specimens to be jointed were carbon fiber reinforced plastic F263-T300 Fabric 3K70PW and Aluminum alloy 2024 - T3. Author

N89-18468# Oce Nederland B.V., Venlo.
BUILT-IN SELF TEST
B. JANSEN and A. J. VANDEGOOR (Technische Hogeschool, Delft, Netherlands.) *In* AGARD, Software Engineering and Its Application to Avionics 16 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Because of the increasing complexity of digital circuits, it is becoming more and more difficult to determine whether a circuit is correct or faulty. Faults in a circuit can hardly be detected just by looking at the outside what the reaction of the circuit is to a certain input sequence. Fault tolerant computing can be a solution. Built-In Self Test (BIST) techniques can also be used to verify whether the circuit is correct, not only during normal operation, but also during the early development periods. The result of using BIST techniques is a considerable reduction of time between design and the final product, and a reduction of maintenance time and cost. BIST is a test method of which the circuit can separate itself from the surrounding logic, and perform a test. After the self test, the circuit reports to the surrounding logic whether it is correct. The advantage of BIST is that it is a universal and systematic test method with a solid mathematical foundation. Based on the stuck-at fault model, it is possible to compute the fault coverage, which is the number of faults detected by the BIST method. The theory of BIST is described. A circuit is divided into combinational and sequential parts, which are tested separately. The sequential parts are tested with a so-called scan-path test. Alternative test methods to test the combinational parts are described. The method to compute the number of patterns needed to detect all faults with a certain probability as function of complexity of the circuit is given. The theory of CRC signature analyzers, and the probability of masking are also described and illustrated with some examples, which can directly be used in practice. Author

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FLUID MECHANICS AND HEAT TRANSFER

Includes boundary layers; hydrodynamics; fluidics; mass transfer; and ablation cooling.

N86-29068# Royal Military Coll. of Science, Shrivenham (England). School of Management and Mathematics.
PRESSURE WAVE: GUN BARREL INTERACTIONS
A. B. CROWLEY and W. P. C. KING *In* AGARD Interior Ballistics of Guns 11 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

The interaction of pressure waves generated during the internal ballistics cycle with the vibrations of a tank barrel, and the possible effects on accuracy, are described. The investigation is based on codes simulating the complete internal ballistics cycle, including the venting of gases after shot exit, and the longitudinal and flexural vibration modes of the barrel, both of which were developed at the Royal Military College of Science. The computative effects of pressure waves on both accuracy and structural integrity are discussed for a number of different charge and barrel configurations. Author

N86-29071# Ecole Royale Militaire, Brussels (Belgium). Dept. of Applied Chemistry.
INTERIOR BALLISTICS OF SMALL ARMS: PARTICULAR PROBLEMS. PART 1: HEAT TRANSFER AND COOK-OFF PHENOMEN IN A SMALL CALIBER WEAPON
R. MEYSMANS *In* AGARD Interior Ballistics of Guns 10 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

The first results obtained since beginning in 1983 are summarized. Induction periods and critical temperature, measured during salvo-firing in a small caliber weapon are compared with the values theoretically predicted by means of a mathematical model, describing as correct as possible what happens in the combustion chamber. The determination of some physico-chemical parameters, to be used in the mathematical model, is discussed. Author

N86-29072# Ecole Royale Militaire, Brussels (Belgium). Dept. of Armament and Ballistics.
INTERNAL BALLISTICS OF SMALL ARMS: PARTICULAR PROBLEMS. PART 2: THERMODYNAMIC MODEL, POWDER PARAMETERS, INITIATION
E. CELENS *In* AGARD Interior Ballistics of Guns 23 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

The applicability of the thermodynamic model was studied in small caliber weapons. The use of appropriate computer algorithms for optimal exploitation of closed vessel trials was examined. To better understand the initiation phase, the working of primary high explosive compounds was studied by visualizing the ignition phenomenon in a transparent chamber. The results obtained in these studies are summarized. B.G.

N86-29074# Fraunhofer-Inst. fuer Kurzzeitdynamik, Weil am Rhein (Germany, F.R.). Abteilung fuer Ballistik.
MEASUREMENT OF IMPORTANT BALLISTIC FLOW PROPERTIES BY SPECTROSCOPIC TECHNIQUES
G. KLINGENBERG *In* AGARD Interior Ballistics of Guns 18 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

Considerable progress was made in recent years in probing the gun interior ballistics cycle and the subsequent muzzle flow dynamics. With the amount of experimental research done, more detailed information was obtained to describe the many complexities of the flow phenomena which are associated with the discharge of a weapon. A survey of some of the experimental research is reviewed, pointing out the capabilities as well as the limitations and constraints encountered in ballistic environments. The experimental diagnostics described includes spectroscopic techniques for measuring the temperature and gas velocity in reacting two-phase flows produced by the combustion of both solid and liquid propellants. These techniques are the emission

and/or absorption methods, reversal and Abel inversion methods, and laser Doppler spectrometry. In particular, an intrusive emission *gauge technique is described which permitted the thermometric* probing of optically thick propellant gases in highly pressurized combustion chambers. Sample results of these measurement will be presented. In addition, efforts directed towards the adequate simulation of reacting ballistic flows by mean of a gas gun simulator are described. Author

N86-29075# Concentration, Heat and Momentum Ltd., London (England).
MODELLING THE BEHAVIOUR OF ADDITIVES IN GUN BARRELS
N. RHODES and J. C. LUDWIG *In* AGARD Interior Ballistics of Guns 11 p (SEE N86-29063 20-31) Jan. 1986
(AGARD-CP-392) Avail: NTIS HC A10/MF A01

A mathematical model which predicts the flow and heat transfer in a gun barrel is described. The model is transient, two-dimensional and equations are solved for velocities and enthalpies of a gas phase, which arises from the combustion of propellant and cartridge case, for particle additives which are released from the case; volume fractions of the gas and particles. Closure of the equations is obtained using a two-equation turbulence model. Preliminary calculations are described in which the proportions of particle additives in the cartridge case was altered. The model gives a good prediction of the ballistic performance and the gas to wall heat transfer. However, the expected magnitude of reduction in heat transfer when particles are present is not predicted. The predictions of gas flow invalidate some of the assumptions made regarding case and propellant behavior during combustion and further work is required to investigate these effects and other possible interactions, both chemical and physical, between gas and particles. Author

N86-29173# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SHOCK-WAVE BOUNDARY LAYER INTERACTIONS
J. DELERY (Office National d'Etudes et de Recherches Aeronautiques, Paris, France), J. G. MARVIN (National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.), and E. RESHOTKO (Case Western Reserve Univ., Cleveland, Ohio) Feb. 1986 223 p
(AGARD-AG-280, ISBN-92-835-1519-6; AD-A171302) Avail: NTIS HC A10/MF A01

Presented is a comprehensive, up to-date review of the shock-wave boundary-layer interaction problem. A detailed physical description of the phenomena for transonic and supersonic speed regimes is given based on experimental observations, correlations, and theoretical concepts. Approaches for solving the problem are then reviewed in depth. Specifically, these include: *global methods* developed to predict sudden changes in boundary-layer properties; integral or finite-difference methods developed to predict the continuous evolution of a boundary-layer encountering a pressure field induced by a shock wave; coupling methods to predict entire flow fields; analytical methods such as multi-deck techniques; and finite-difference methods for solving the time-dependent Reynolds-averaged Navier-Stokes equations used to predict the development of entire flow fields. Examples are presented to illustrate the status of the various methods and some discussion is devoted to delineating their advantages and shortcomings. Reference citations for the wide variety of subject material are provided for readers interested in further study. Author

N87-20212# MATRA Service Aerodynamique, Velizy-Villacoublay (France).
SIMULATION OF A JET DEFLECTION SYSTEM WITH THE AID OF THE EULER EQUATIONS [SIMULATION D'UN SYSTEME DE DEVIATION DE JAT A L'AIDE DES EQUATIONS D'EULER]
M. BREDIF, J. J. CHATTOT, C. KOECK, and P. WERLE *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 11 p (SEE N87-20199 13-02) Nov. 1986 In FRENCH
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

The solution method for the Euler equations is applied to the calculation of nozzle flow in missiles fitted with jet control surfaces. The approach utilized, an explicit finite volume method with convergence acceleration through the multigrid technique, is briefly described. The numerical results obtained are analyzed in detail and the interaction between the control surface and the nozzle wall is examined. Comparisons with experimental results are carried out. It is shown that the numerical simulation of the flow through the nozzle system with the jet control surface permits the accurate prediction of the thrust vector deviation due to control surface deflection, whereas the axial thrust loss is estimated low. Author

N87-20213# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Theoretical Aerodynamic Group.
NUMERICAL SIMULATION OF INTERNAL AND EXTERNAL INVISCID AND VISCOUS 3-D FLOW FIELDS
STEFAN LEICHER *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 27 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A numerical method for solving the 3-D Euler equations in geometrical complex domains was developed. The approach divides the computational space into multiple blocks whose structure follows the natural lines of the conficuration. A systematic, multi-block grid generation scheme is used to produce the grid. The flow solutions are obtained by solving the Euler equations by a finite volume discretization and a Runge-Kutta time stepping scheme. The main advantage of this method is the applicability to complex geometries, for example complete aircraft configurations including wing, fuselage, canard and tail. The coupling with a 3-D boundary layer method allows to account for viscous effects. Another application for the method was the simulation of flows in the presence of a propeller. Author

N87-20222*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, CA.
USING THE BOUNDARY-LAYER EQUATIONS IN THREE-DIMENSIONAL VISCOUS FLOW SIMULATION
WILLIAM R. VANDALSEM and JOSEPH L. STEGER *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 12 p (SEE N87-20199 13-02) Nov. 1986 Previously announced as N86-28061
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A simple and computationally efficient algorithm for solving the unsteady three dimensional boundary layer equations in a time accurate or relaxation mode is presented. The algorithm is used to compute the separated flow over a 6:1 ellipsoid at angle of attack and the transonic flow over a finite wing with shock induced separation. *These results are* compared to available experimental data. A method of using the boundary layer algorithm to accelerate a Navier-Stokes computation is also presented. Example computations indicate that a boundary layer algorithm can be used to improve both the accuracy and efficiency of a Navier-Stokes algorithm. Author

N87-20223# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
COMPUTATION OF THREE-DIMENSIONAL FLOWS BY VISCOUS-INVISCID INTERATION USING THE MZM METHOD
M. LAZAREFF and J. C. LEBALLEUR In AGARD Applications of Computational Fluid Dynamics in Aeronautics 15 p (SEE N87-20199 13-02) Nov. 1986 In FRENCH; ENGLISH summary
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

The MZM numerical method (Multi-Zonal-Marching) previously suggested for solving the hyperbolic set of equations of the viscous layers, and the three dimensional turbulent mean velocity profiles modelling suggested for computing separated flows over infinite swept wings, have lead to the development of a very general three dimensional boundary layer method, fit for use on complex geometries, with any prescribed structured mesh, in view of a viscous-inviscid interaction analysis. The method was used successfully for computing transonic wings without separation, with solution of the coupling and rigorous integration of the boundary layer equations starting from the stagnation point. New results are here presented, without coupling, for configurations of ellipsoids of revolution, or flattened ellipsoids, at 30 deg or 60 deg of incidence, and for a geometry of the slender lifting-body type at 30 deg of incidence and 10 deg of yaw angle, with a quasi-total accessibility of the computation domain. These boundary-layer-alone calculations display a flow structure which exhibits a strong analog with accumulations lines, the numerical solution giving access to both sides of these lines. Author

N87-21182# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
EVALUATION OF L2F-MEASUREMENTS IN UNSTEADY TURBINE FLOW
W. FOERSTER, R. SCHODL, and H. KRUSE *In* AGARD Advanced Instrumentation for Aero Engine Components 12 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The L2F-velocimeter is a suitable device with which to perform experimental studies on instationary effects in turbomachines. The execution and the evaluation of L2F-measurements within and near the rotor blade channel of a single-stage, cold air test turbine are discussed. The measurements provide information on instantaneous distribution of the 2-D flow vector as well as the components of random fluctuating velocity. The turbine rotor flow is periodically unsteady because of the upstream inlet guide vanes. In order to ensure the almost complete reconstruction of all possible rotor-to-stator orientations, the discrete measurements are evaluated by combining a local and chronological interpolation procedure. A discussion of experimental uncertainties in this application of the L2F-technique is included. Author

N87-21185# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
THE FLOW AROUND A SQUARED OBSTACLE
D. F. G. DURAO, M. V. HEITOR, and J. C. F. PEREIRA *In* AGARD Advanced Instrumentation for Aero Engine Components 13 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Laser-Doppler measurements of the velocity distribution around and in the wake of a two-dimensional squared obstacle for Re = 14000 are reported. The results were measured with a counter interfaced with a microprocessor. The counter was built based on a specific design to quantify and diminish errors resulting from bias sources. In addition the periodic character of the flow in the wake was characterized by measurements of turbulence spectra with Fast Fourier Transformation instrumentation. The values of the predominant frequencies were correlated with the flow Reynolds number. Author

N87-21193# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
DIGITAL IMAGE PROCESSING APPLIED TO FLUID DYNAMIC PROBLEMS
J. M. BUCHLIN *In* AGARD Advanced Instrumentation for Aero Engine Components 10 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Applications of visualization techniques associated with Digital Image Processing in fluid dynamics are discussed. Two typical fluid flow problems of interest for propulsion are selected to illustrate the purpose. The mixing properties of the jet are discussed. Laser tomography and light scattering from micro-droplets of oil lead to the quantification of the three dimensional concentration field. The local heat transfer distribution on a heated surface from oblique and co-liner impinging jets is discussed. Thermographic imaging system is used. Digitized infrared pictures are processed to provide local and average values of the heat transfer coefficients. Author

N87-21928# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
FUNDAMENTAL STUDIES ON SHOCK-WAVE/ BOUNDARY-LAYER INTERACTIONS IN A 3-D CHANNEL
R. BENAY, T. POT, and J. DELERY *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 20 p (SEE N87-21927 15-07) Mar. 1987 In FRENCH; ENGLISH summary Original language document was announced in IAA as A87-21068
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

Detailed experimental data on shock-wave/boundary-layer interaction in 3-D flows is still relatively scarce. This fact brought ONERA to undertake experiments in view of producing as complete a literature as possible on a three-dimensional transonic channel flow with shock. The test set-up is a channel with a 100 x 120 mm inlet section. The lower wall of the channel is humped while the other three faces are flat. In operation, a continuous supersonic flow is started and shock recompressions formed on the descending part of the hump. The flow in the interaction region was carefully analyzed by using, in particular, a three-color LDV system. The tests brought out a strongly three-dimensional flow structured very differently from the one observed in 2-D channel flows. It was revealed that in the presence of the strong adverse pressure gradient of the shock, a 3-D boundary layer tends to thicken less than a 2-D boundary layer, since the flow can reorganize in a much more complex fashion in the three directions of space. The precise data obtained were analyzed to arrive at a better understanding of the phenomena from a physical point of view, and also constitute a data base for validating the calculation models being developed. Author

N87-21933# Cambridge Univ. (England). Dept. of Engineering.
EXPERIMENTAL OBSERVATIONS ON AN UNSTEADY, NORMAL SHOCK/BOUNDARY LAYER INTERACTION
In AGARD Transonic and Supersonic Phenomena in Turbomachines 14 p (SEE N87-21927 15-07) Mar. 1987
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

An experiment is described in which a normal shock interacts with the natural turbulent wall boundary layer in a parallel sided duct at Mach 1.3 and 1.5. The shock wave is vibrated in symmetric fashion by a rotating cam mounted in the tunnel diffuser. The design of this experiment, particularly, the efforts to obtain a pure forcing signal, is discussed. Shock motion analysis at reduced frequencies of order 0.2 to 2 and amplitude parameters of 2 to 20 percent (based on equivalent chord) is presented. Unsteady surface pressure measurements under the interaction were made and demonstrate that there is negligible phase change between the shock motion and the surface pressures. It appears reasonable to utilize quasi-steady assumptions in the calculation of the surface pressures at the low frequency conditions tested. Author

N87-21939# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NUMERICAL VISCOUS-INVISCID INTERACTION METHOD FOR INTERNAL SEPARATED FLOWS AND SHOCK WAVE-BOUNDARY LAYER INTERACTION
J. C. LEBALLEUR and D. BLAISE *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 20 p (SEE N87-21927 15-07) Mar. 1987 In FRENCH; ENGLISH summary
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

A calculation method for internal transonic separated flows, and for shock wave-boundary layer interactions, is presented. It is based on developments in indirect numerical solvers with viscous-inviscid splitting, well conditioned at high Reynolds numbers. The viscous flows are calculated with the defect formulation theory, here simplified with thin layers approximations compatible with an integral method. The direct and semi-inverse strong coupling methods, and the direct and inverse defect integral methods with turbulence models involving 0, 1, or 2 integral transport equations, which were previously suggested for airfoils flows, were generalized to internal flows for which the inviscid field requires the use of an Euler solver. Results are obtained for turbulent flows in transonic shocked channels with backpressure, involving multiple shock wave-boundary layer interactions, and incipient or extensive separations. The method is also applied to supersonic shock wave-boundary layer interactions, for compression ramps or shock wave-reflexions. First results obtained for computing viscous flows in cascades are presented. Author

N87-21946# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
MODELING HIGH REYNOLDS NUMBER INTERNAL FLOWS BY NUMERICAL SOLUTION OF THE NAVIER-STOKES EQUATIONS [CALCUL D'ECOULEMENTS INTERNES A GRAND NOMBRE DE REYNOLDS PAR RESOLUTION NUMERIQUE DES EQUATIONS DE NAVIER-STOKES]
L. CAMBIER, B. ESCANDE, and J.-P. VEUILLOT *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 20 p (SEE N87-21927 15-07) Mar. 1987 In FRENCH Original language document was announced in IAA as A87-21030
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

A finite difference approach is taken for solving the time-averaged Navier-Stokes equations for high-Re turbulent flows. Subgrid-scale features are incorporated into the calculations to account for phenomena in viscous thin layers, and a turbulence model which includes two transport equations is defined to describe

turbulence along the mixing length. The spatial discretization is performed using the Green's function integrated along the flow contours. *Results are provided from sample calculations for a Re* = 80,000 flow through a row of compressor blades. Additionally, comparisons are made of different turbulence models for a shock wave-boundary layer interaction. IAA

N87-21948# *Office National d'Etudes et de Recherches* Aerospatiales, Paris (France).
DETERMINATION OF THE SUPERSONIC CASCADE ENTRANCE ZONE [DETERMINATION DE LA REGION DE CAPATION D'UN GRILLE D'AUBES SUPERSONIQUE]
GEORGES MEAUZE *In* AGARD Transonic and Supersonic Phenomena in Turbomachines 12 p (SEE N87-21927 15-07) Mar. 1987 In FRENCH; ENGLISH summary
(AGARD-CP-401) Avail: NTIS HC A16/MF A01

Incidence phenomenon, well known for supersonic straight cascades, is analyzed and extended in the general case of a cascade of a stream-surface with variable radius and thickness. The special configuration of a radial cascade is studied in detail. From this analysis, it is possible to point out some rules for the optimization of the entrance part of supersonic cascades. Author

N87-22137# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
ROUND TABLE DISCUSSION ON MODELLING OF TIME-VARIANT FLOWS USING VORTEX DYNAMICS
Feb. 1987 104 p In ENGLISH and FRENCH Discussion held in Aix-en-Provence, France, 10 Apr. 1986
(AGARD-AR-239; ISBN-92-835-0405-4; AD-A179039) Avail: NTIS HC A06/MF A01

In recent years there has been a marked growth in the applications of vortex dynamics to time-varying flows, usually involving separated regions with vortical structures. The flow models are based on distributions of vortex elements which may vary in complexity. This Report is a compilation of invited papers on the topic presented at the AGARD Fluid Dynamics Panel Round Table *Discussion held in Aix-en-Provence, France, in April 1986. The* papers cover current and projected developments in France, Germany, Greece, Italy, Netherlands, UK and USA. The Report provides a good overall view of the state of the art of the topic, covering both the achievements and the deficiencies requiring *future research.* The outstanding problems center on how the effects of viscosity can be realistically modelled, particularly in three dimensional flow, and what might be done to deal with the effects of compressibility. For individual titles, see N87-22138 through N87-22144.

N87-22138# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
COMPUTATION OF UNSTEADY FLOWS USING THE POINT VORTEX METHOD [CALCUL D'ECOULEMENTS INSTATIONNAIRES PAR LA METHODE DES TOURBILLONS PONCTUELS]
Y. MORCHOISNE *In* AGARD Round Table Discussion on Modelling of Time-Variant Flows Using Vortex Dynamics 15 p (SEE N87-22137 15-34) Feb. 1987 In FRENCH
(AGARD-AR-239) Avail: NTIS HC A06/MF A01

The computation of unsteady flow of an inviscid, incompressible fluid around wing, rotor, or fuselage configurations may be carried out with the various singularity methods. The object of this report is to briefly describe the doublet-point vortex methods and discuss some applications which have been recently investigated including a double delta wing, a rotor in forward flight, a helicopter fuselage, and a helicopter in forward flight. M.G.

N87-22139# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for *Theoretical Fluid Mechanics.*
VORTEX DYNAMICS: A REPORT ON WORK IN GERMANY
H. OERTEL *In* AGARD Round Table Discussion on Modelling of Time-Variant Flows Using Vortex Dynamics 10 p (SEE N87-22137 15-34) Feb. 1987
(AGARD-AR-239) Avail: NTIS HC A06/MF A01

This article reviews the numerical work relevant to the vortex dynamics method carried out in Germany supplemented by results from the Franco-German Research Institute Saint Louis, ISL. The introduction includes the development of two- and three-dimensional simulation methods and is followed by a *discussion of the results in shear layers, trailing far wakes,* aerodynamical profile flow simulation with spoiler and the simulation of three-dimensional structures in wakes. Author

N87-22140# Defense Industries Directorate, Athens (Greece).
SIMULATION OF IMPINGING SHEAR LAYERS USING VORTEX DYNAMICS
ARGYRIS G. PANARAS *In* AGARD Round Table Discussion on Modelling of Time-Variant Flows Using Vortex Dynamics 26 p (SEE N87-22137 15-34) Feb. 1987
(AGARD-AR-239) Avail: NTIS HC A06/MF A01

Organized vortices have been observed within the oscillating shear layers that impinge on a surface. It is believed that the feedback force necessary for the generation of these vortices is produced by their interaction with the reattachment surface. In the present work, models for studying the interaction of lines or of finite-area vortices with edges that simulate cavity-type of flows or edge-tones are examined. According to the analysis, the interaction of vortices with an edge induces periodic pressure fluctuations similar to those measured in oscillating flows. Also, when the geometry of an edge is such that no oscillation has been observed, the amplitude of the induced pressure pulses is insignificant. Thus, the hypothesis about the role of the vortex/edge interaction is supported. Author

N87-22141# Politecnico di Torino (Italy). Dept. of Aerospace *Engineering.*
VORTEX DYNAMICS-SURVEY OF THE ACTIVITY IN ITALY
M. GERMANO *In* AGARD Round Table Discussion on Modelling of Time-Variant Flows Using Vortex Dynamics 6 p (SEE N87-22137 15-34) Feb. 1987
(AGARD-AR-239) Avail: NTIS HC A06/MF A01

The activity in modelling time variant flows using vortex dynamics is at present very limited in Italy. Moreover the contributions are principally in fundamental areas or in areas outside the aeronautical field. Author

N87-22142# National Aerospace Lab., Amsterdam (Netherlands).
MODELLING OF TIME-VARIANT FLOWS USING VORTEX DYNAMICS-ACTIVITIES IN THE NETHERLANDS
H. W. M. HOEIJMAKERS *In* AGARD Round Table Discussion on Modelling of Time-Variant Flows Using Vortex Dynamics 9 p (SEE N87-22137 15-34) Feb. 1987
(AGARD-AR-239) Avail: NTIS HC A06/MF A01

Activities in the Netherlands in the area of simulating low-speed flows using vortex elements are summarized. Aspects of some of the methods developed are highlighted and plans for future work are indicated. Author

N87-22143# Cambridge Univ. (England). Dept. of Engineering.
FLOW MODELS USING VORTEX DYNAMICS: WORK IN THE UNITED KINGDOM
D. J. MAULL *In* AGARD Round Table Discussion on Modelling of Time-Variant Flows Using Vortex Dynamics 18 p (SEE N87-22137 15-34) Feb. 1987
(AGARD-AR-239) Avail: NTIS HC A06/MF A01

A review is given of work in the United Kingdom on vortex dynamics. This method of modelling separated flows is applied to unsteady flow around aerofoils, bluff bodies, boundary layers and pollution studies. Many applications are given and some of the difficulties in using the method described. Author

N87-22144# California Inst. of Tech., Pasadena.
RECENT ACTIVITY IN VORTEX METHODS IN THE UNITED STATES
A. LEONARD *In* AGARD Round Table Discussion on Modelling of Time-Variant Flows Using Vortex Dynamics 10 p (SEE N87-22137 15-34) Feb. 1987
(AGARD-AR-239) Avail: NTIS HC A06/MF A01

Vortex methods for flow simulation continue to have a wide-ranging appeal as a means of developing a better understanding of a complex flow and, in many cases, obtaining useful quantitative data. Part of the appeal is in the relative simplicity of the computer code that is required to do the job and, usually, in the relatively low computational cost. For example, experience

has shown that some fairly complex three-dimensional flows may be simulated with a hundred or so vortex elements (sections of a vortex tube). Another aspect of the appeal is the visualization of the flow in terms of vortex dynamics, an aspect that aids in the physical understanding of the flow. In this paper, recent activity in the United States concerning flow simulation with vortex methods is reviewed. We consider three main areas of effort: separated flows in two-dimensions (Section 2), simulations using the method of contour dynamics (Section 3) and three-dimensional flows (Section 4). Finally, in Section 5, we cite directions for future efforts that look particularly promising. Author

N87-22145# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
COMPUTATION OF THREE-DIMENSIONAL BOUNDARY LAYERS INCLUDING SEPARATION
Feb. 1987 218 p AGARD Special Course held in Rhode-St-Genese, Belgium, 14-18 Apr. 1986; sponsored by the von Karman Inst. and AGARD
(AGARD-R-741; ISBN-92-835-0407-0; AD-A179085) Avail: NTIS HC A10/MF A01

The Special Course on Computation of Three-Dimensional Boundary Layers Including Separation was sponsored by the AGARD Fluid Dynamics Panel and the von Karman Institute and presented at the von Karman Institute, Rhode-Saint-Genese, Belgium, on 14 to 18 April 1986. The Course presented a comprehensive review of experimental aspects of three-dimensional boundary layers with emphasis on the use of fundamental experiments to improve models for turbulence and transition. A review of various calculation methods was given, including the calculation of transition and calculations which aid in aerodynamic design. Numerical differential methods were discussed and viscous-inviscid interactive schemes and procedures were reviewed. Calculations of corner and tip region flows was covered in detail. For individual titles, see N87-22146 through N87-22153.

N87-22146# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Aerothermodynamique
THREE-DIMENSIONAL BOUNDARY LAYERS: INTRODUCTION TO CALCULATION METHODS
JEAN COUSTEIX *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 49 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

This paper gives an outline of problems encountered when faced with the calculation of three-dimensional boundary layers. The various topics which are discussed are: geometry of axis systems, boundary layer equations, global equations, nature of the system of equations, integral methods, singularities in boundary layer calculations, numerical techniques, turbulence modelling. Author

N87-22147# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.
PHYSICS AND MODELLING OF THREE-DIMENSIONAL BOUNDARY LAYERS
P. BRADSHAW *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 19 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

This section of the course is an introduction to the physics of three-dimensional (3D) turbulent flows and a discussion of modelling - the use of experimental data in developing calculation methods. Only conventional Reynolds-averaged calculation methods will be discussed: for simplicity, only differential methods, in which variables are predicted at each point in the boundary layer, will be treated, but similar principles should apply to integral methods. Author

N87-22148# National Aerospace Lab., Amsterdam (Netherlands).
THREE-DIMENSIONAL SHEAR LAYER EXPERIMENTS AND THEIR USE AS TEST CASES FOR CALCULATION METHODS
B. VANDENBERG *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 13 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

Three-dimensional shear layer experiments are discussed with a view to those developing calculation methods. The emphasis is on the selection of useful experiments for comparisons with calculations and the proper way to perform the comparisons. A review of more recent three-dimensional shear layer experiments is included. Author

N87-22149# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
THREE-DIMENSIONAL LAYERS: LAMINAR-TURBULENT TRANSITION
DANIEL ARNAL *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 34 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

The first part of this paper is devoted to a brief survey of transition problems in two-dimensional flows. The main elements of laminar instability theory are presented and used for elaborating some practical transition criteria. In three-dimensional situations, the problem is much more complex, because transition may occur through streamwise instability, cross-flow instability or leading edge contamination. It is assumed that the streamwise instability can be studied by using two-dimensional results. On the contrary, the cross-flow instability and the leading edge contamination constitute typical features of three-dimensional flows, as it is illustrated by experimental results. The extension of linear stability theory to these last problems is discussed, and transition criteria are developed. Moreover an intermittency method allows the transition region to be calculated. These techniques are applied to swept wings and bodies at incidence. Author

N87-22150# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
EVALUATION OF RESULTS OF BOUNDARY-LAYER CALCULATIONS WITH REGARD TO DESIGN AERODYNAMICS
E. H. HIRSCHEL *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 29 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

The tools for the preprocessing of geometrical and inviscid flow data for boundary-layer computations, and for the postprocessing of the computed data are discussed. After a presentation of some important basic properties of three-dimensional boundary layers, the definition of coordinates, the computation of the metric properties, and transformation laws are given. Then the relations for the boundary-layer parameters, which are used in engineering work, like the wall-shear stress, friction forces, skin-friction lines, displacement properties etc., are presented. They are complemented with applications from design aerodynamics. The question what can be seen from boundary-layer results with regard to separation is then addressed. Basic topographical considerations are made, and basic topological rules are demonstrated. Finally practical separation indicators which can be applied to boundary-layer results are listed. Applications from design aerodynamics close the paper. Author

N87-22151# Douglas Aircraft Co., Inc., Long Beach, CA.
AN APPROACH TO PRACTICAL AERODYNAMIC CALCULATIONS
TUNCER CEBECI *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 40 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

The emphasis of these lectures is on the numerical solution of three-dimensional boundary-layer equations using forms of Keller's Box scheme and interaction with solutions of inviscid-flow equations. Calculations are described for the flow over a circular cylinder started impulsively from rest and a prolate spheroid at angle of attack, and were obtained with prescribed free-stream velocity distribution; the results emphasize the need for the

Characteristic Box finite-difference scheme, which automatically satisfies the numerical stability criterion, in regions of flow where the w-velocity component is negative. Corresponding calculations, this time with a novel interactive method, are reported for the flow over the leading edge of a thin ellipse, over an oscillating airfoil and around wings; the results confirm that the interactive procedure provides accurate solutions, without numerical problems, in regions of flow separation. Author

N87-22152# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PROGRESS IN VISCOUS-INVISCID SOLVERS (VIS)
J. C. LEBALLEUR *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 3 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

The aim of these lectures was an introduction to the further extensions of boundary layer theory, which rely on the development of full viscous-inviscid interaction solvers, in three-dimensional flows. At the present time, however, the state of the art still does not accommodate the full 3D-problem. It is more or less restricted, on one hand, to advances in uncoupled 3D-boundary layer problems, direct or inverse, and, on the other hand, to developments in full viscous-inviscid solvers for the 2D or quasi-3D infinite swept wing flows, the latter developments involving the coupling and the calculation of quasi-3D closed separations. The present lectures were mainly devoted to the developments obtained by the author and his colleagues in these two areas. These developments were outlined after describing shortly the different strategies which can be used to split the Navier-Stokes problem into a viscous-inviscid interaction problem, in two or three dimensions. Author

N87-22153# Scientific Research Associates, Inc., Glastonbury, CT.
COMPUTATION OF TIP AND CORNER REGION FLOWS
T. R. GOVINDAM and H. MCDONALD *In* AGARD Computation of Three-Dimensional Boundary Layers Including Separation 20 p (SEE N87-22145 15-34) Feb. 1987
(AGARD-R-741) Avail: NTIS HC A10/MF A01

The flow field in corner and tip regions of wings and propellers is complex, three-dimensional, and viscous with large secondary/transverse velocities. The large secondary velocities, usually associated with streamwise vorticity development in the flow, preclude the use of conventional boundary-layer solution techniques to compute such flow fields. On the other hand, solution techniques for the full Navier-Stokes equations that adequately resolve the length scales of tip and corner region flow fields would require formidable computer resources for use routinely. Sets of approximate three-dimensional viscous flow equations which are applicable to tip and corner region flow fields and which can be solved economically are sought. Clearly, economy of solution must result from approximations to the governing equations for such procedures to be attractive. A spatial marching computation procedure that solves approximate three-dimensional viscous flow equations economically is presented here and application of the procedure to compute tip and corner region flow fields discussed. Author

N87-27958# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SYMPOSIUM ON APPLICATIONS OF COMPUTATIONAL FLUID DYNAMICS IN AERONAUTICS
W. J. MCCROSKEY (National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.) Mar. 1987 24 p Symposium held in Aix-en-Provence, France, 7-10 Apr. 1986
(AD-A172209; AGARD-AR-240; ISBN-92-835-0416-X) Avail: NTIS HC A02/MF A01

The Fluid Dynamics Panel of AGARD arranged a Symposium in Applications of Computational Fluid Dynamics in Aeronautics on 7 to 10 April 1986 in Aix-en-Provence, France. The purpose of the Symposium was to provide an assessment of the status of CFD in aerodynamic design and analysis, with an emphasis on emerging applications of advanced computational techniques to complex configurations. Sessions were devoted specifically to grid generation, methods for inviscid flows, calculations of viscous-inviscid interactions, and methods for solving the Navier-Stokes equations. The 31 papers presented at the meeting are published in AGARD Conference Proceedings CP-412 and are listed in the Appendix to this report. A brief synopsis of each paper and some general conclusions and recommendations are given Author

N88-11968# Smith (A. M. O.), San Marino, CA. Fluid Dynamics Panel.
TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SYMPOSIUM ON AERODYNAMIC AND RELATED HYDRODYNAMIC STUDIES USING WATER FACILITIES
A. M. O. SMITH, J. W. SLOOFF, and A. ROSHKO (California Inst. of Tech., Pasadena.) Aug. 1987 10 p
(AGARD-AR-225; ISBN-92-835-1556-0; AD-A187957) Avail: NTIS HC A02/MF A01

The results of aerodynamic investigations performed in water facilities were examined and reviewed. These facilities included water tunnels, towing channels, and stationary tanks. It was observed that the use of water as a medium for both aerodynamic and hydrodynamic testing is gradually gaining wider acceptance. This meeting allowed specialists to gather and discuss their results, compare techniques, and find solutions to problems. Author

N88-11970# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
SPECIAL COURSE ON MODERN THEORETICAL AND EXPERIMENTAL APPROACHES TO TURBULENT FLOW STRUCTURE AND ITS MODELLING
Aug. 1987 263 p Course held in Rhode-St.-Genese, Belgium, 16-20 Mar. 1987; sponsored by the von Karman Inst. and AGARD
(AGARD-R-755; ISBN-92-835-0430-5; AD-A198872) Avail: NTIS HC A12/MF A01

The large eddy concept in turbulent modeling and techniques for direct simulation are discussed. A review of turbulence modeling is presented along with physical and numerical aspects and applications. A closure model for turbulent flows is presented and routes to chaos by quasi-periodicity are discussed. Theoretical aspects of transition to turbulence by space/time intermittency are covered. The application to interpretation of experimental results of fractal dimensions and connection of spatial temporal chaos are reviewed. Simulation of hydrodynamic flow by using cellular automata is discussed. For individual titles, see N88-11971 through N88-11978.

N88-11971# Stanford Univ., CA. Dept. of Mechanical Engineering.
FUNDAMENTALS OF TURBULENCE FOR TURBULENCE MODELING AND SIMULATION
W. C. REYNOLDS *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 66 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

A brief review is given of fluid flow fundamentals pertinent to turbulence. Extensive use is made of the Cartesian tensor summation convention, where repeated indices imply that the terms containing them must be summed over all possible coordinate indices. Author

N88-11972# Electricite de France, Chatou. Lab. National d'Hydraulique.
TURBULENCE MODELLING THROUGH ONE POINT CLOSURES-APPLICATIONS-ENLIGHTENING BY LARGE EDDY SIMULATION
D. LAURENCE *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 34 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

Reynolds stress and Low Re models for the modelling of inhomogeneous flows are considered. They are shown to provide satisfactory predictions for engineering flows. Near wall and buoyancy effects are also included. Results of large eddy simulations are used as guidance to the standard one point closures, especially for data that cannot be obtained by experiment. Author

N88-11973# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. of Aerothermodynamics.
HOMOGENEOUS TURBULENCE TWO-POINT CLOSURES AND APPLICATIONS TO ONE-POINT CLOSURES
B. AUPOIX *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 47 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

Homogeneous, i.e., translation invariant, turbulence is discussed. Homogeneous turbulence is an ideal situation in which the mean field is unaffected by the turbulent motion, so that the turbulent motion can be studied solely with a prescribed mean field. Such a flow can nearly be achieved in very simple experimental set-ups. Author

N88-11974# Commissariat a l'Energie Atomique, Gif-sur-Yvette (France). Service de Physique du Solide et de Resonance Magnetique.
DYNAMICS AND ROUTES TO CHAOS FROM *QUASIPERIODICITY*
M. DUBOIS *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 17 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

One of the routes leading to deterministic chaos is the route through the quasiperiodicity; the simplest one involves the presence of two oscillators, whose dynamics may become chaotic by the increase of the amount of the non-linearities between them. Though this dynamic is generally related to nonlinear dynamic systems, it may be found in hydrodynamical flows as soon as the increase of a control parameter initiates the appearance of periodic behaviors. So, in the following, the physical examples will be taken from Rayleigh-Benard experiments, which provide good illustrations of quasiperiodic behaviors in dissipative systems. Author

N88-11975# Commissariat a l'Energie Atomique, Gif-sur-Yvette (France). Service de Physique du Solide et de Resonance Magnetique.
A DETERMINISTIC APPROACH TO TURBULENCE: CHAOS IN RAYLEIGH-BENARD CONVECTION
P. BERGE *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 30 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

Various aspects of chaos in Rayleigh-Benard convection are discussed. Basic concepts concerning dissipative dynamical systems, a definition of chaos, a brief introduction to bifurcations, reconstruction of phase space and quasiperiodicity are among the topics covered. R.J.F.

N88-11976# Commissariat a l'Energie Atomique, Gif-sur-Yvette (France). Service de Physique du Solide et de Resonance Magnetique.
TRANSITION TO TURBULENCE VIA SPATIO-TEMPORAL INTERMITTENCY
PAUL MANNEVILLE *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 18 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

A scenario of transition to turbulence specific to large aspect ratio systems is presented. Starting with simulations on a model chosen for its relevance to the field of convective instabilities, researchers characterized the spatio-temporal intermittent phase. They examined the transition process having recourse to simpler systems: coupled map lattices. This process appeared to involve the propagation of an information, laminar/turbulent which seemed stochastic though it was generated by a deterministic dynamics.
Author GRA

N88-11977# Istituto Nazionale di Ottica, Florence (Italy).
DETERMINATION OF FRACTAL DIMENSION, CONNECTION OF SPACE AND TEMPORAL CHAOS AND APPLICATION TO EXPERIMENTAL RESULTS
S. CILIBERTO *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 15 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

Experiments on time dependent behavior of a horizontal fluid layer, heated from below, that is Rayleigh-Benard convection, are discussed. It is shown that time dependent regimes are characterized by the presence of either traveling waves or localized oscillations. These spatio temporal regimes turn out to be similar to those observed in numerical simulations of Kuramoto-Shivanshisky and Kuramoto-Velarde partial differential equations. Experimental evidence that the properties of the chaotic regimes depend on space coordinates is given. Experiments on surface wave instabilities where the competition between two spatial patterns produces time dependent behavior and chaos are discussed. The results of this experiment are in good agreement with a low dimensional model obtained from Navier-Stokes equations. Author

N88-11978# Brussels Univ. (Belgium). Faculte des Sciences.
LATTICE GAS HYDRODYNAMICS
JEAN PIERRE BOON and ALAIN NOULLEZ *In* Advisory Group for Aerospace Research and Special Course on Modern Theoretical and Experimental Approaches to Turbulent Flow Structure and its Modelling 27 p (SEE N88-11970 03-34) Aug. 1987
(AGARD-R-755) Avail: NTIS HC A12/MF A01

The motivation for using a lattice gas to simulate hydrodynamics stems from the idea that the details of the microscopic properties should be unimportant to the macroscopic behavior of the fluid. So, whether the fictitious microworld one uses is a caricature of a real fluid does not matter as long as it produces correct hydrodynamics. In order to answer the question of whether the lattice gas hydrodynamics meets the goal of producing correct hydrodynamics, the constitutive elements are built up to construct a lattice gas and a model system is put to work. Computational aspects of hydrodynamic simulations are reviewed. Author

N88-16977# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
TECHNIQUES OF FLOW VISUALIZATION
W. MERZKIRCH and K. GERSTEN (Ruhr Univ., Bochum, West Germany) Dec. 1987 100 p
(AGARD-AG-302; ISBN-92-835-0438-0; AD-A194291) Avail: NTIS HC A05/MF A01

The methods of flow visualization are reviewed with particular emphasis on their application in wind tunnels, water tunnels, and experiments related to propulsion research. The discussion of methods starts with those that visualize the flow pattern on a solid surface. Then methods visualizing the whole field, either by introducing a foreign substance (smoke, dye) or by making use of refractive index changes in the flowing fluid (optical methods) are examined. Emphasis is placed on the discussion of the physical background of a method rather than on technical details. B.G.

N88-23125# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
AERODYNAMIC AND RELATED HYDRODYNAMIC STUDIES USING WATER FACILITIES
Jun. 1987 462 p In ENGLISH and FRENCH Symposium held in Monterey, Calif., 20-23 Oct. 1986 Original contains color illustrations
(AGARD-CP-413; ISBN-92-835-0419-4; AD-A199357) Avail: NTIS HC A20/MF A01

Related problems, experiences and advancements in aeronautical and maritime fluid dynamics through the use of water facilities are reviewed. In recent years there has been an increasing use of water facilities for aerodynamic investigations. These include water tunnels, towing channels, and stationary tanks. Examples include basic research problems as well as flow fields around fighter aircraft, inlet flows, recirculation flow patterns associated with VTOL, ramjet simulation, etc., and, in general, 3-D flows with vortices or separated regimes as prominent features. The Symposium was organized to provide an appropriate forum for

the exchange of information within the aeronautical and maritime fluid dynamics community. For individual titles, see N88-23126 through N88-23157.

N88-23127*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
VORTEX BREAKDOWN AND CONTROL EXPERIMENTS IN THE AMES-DRYDEN WATER TUNNEL
F. K. OWEN (Complere, Inc., Palo Alto, Calif.) and D. J. PEAKE *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 10 p (SEE N88-23125 16-34) Jun. 1987 Previously announced as N87-13409
(AGARD-CP-413) Avail: NTIS HC A20/MF A01 CSCL 20D

Flow-field measurements have been made to determine the effects of core blowing on vortex breakdown and control. The results of these proof-of-concept experiments clearly demonstrate the usefulness of water tunnels as test platforms for advanced flow-field simulation and measurement. Author

N88-23130# Eidetics International, Inc., Torrance, CA.
FLOW VISUALIZATION STUDY OF VORTEX MANIPULATION ON FIGHTER CONFIGURATIONS AT HIGH ANGLES OF ATTACK
GERALD N. MALCOLM and ANDREW M. SKOW *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 19 p (SEE N88-23125 16-34) Jun. 1987
(Contract F33615-85-C-3619)
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Experiments were performed in a flow visualization water tunnel on a generic fighter model to explore vortex manipulation as an effective means of aircraft control by altering the natural state of the forebody and LEX vortices in the medium-to-high-angle of attack range with either small surface modifiers or blowing jets. Specifically, the forebody vortex system was examined with the clean forebody, with forebody strakes, and with forebody surface blowing. LEX vortices were examined with a clean LEX, with small geometric modifications near the apex, and with surface blowing, both in upstream and downstream directions at various locations on the LEX surface. The interactive effects of forebody and LEX/wing vortices and their response to the various methods of control were also examined. It was concluded that the forebody vortices can be effectively controlled by either blowing or using strakes, but the effectiveness is very dependent on proper radial placement of the blowing port or strake. Author

N88-23131# Naval Postgraduate School, Monterey, CA. Dept. of Mechanical Engineering.
OSCILLATING FLOW OVER BLUFF BODIES IN A U-SHAPED WATER TUNNEL
TURGUT SARPKAYA *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 15 p (SEE N88-23125 16-34) Jun. 1987
(Contract NSF CEE-82-10246)
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Studies dealing with sinusoidally oscillating separated and unseparated flows over various types of bluff bodies are described. First, the characteristics of a large U-shaped vertical water tunnel are described and then the numerical and experimental results obtained with circular cylinders are presented. It is shown that for 2-D, attached, and laminar-flow conditions the data are, as expected, in good agreement with the previous analysis. The oscillatory viscous flow becomes unstable to axially periodic Taylor-Goertler vortices above a critical Keulegan-Carpenter number K (K=U sub mT/D) for a given Beta (Beta = D sup 2/upsilonT). For larger values of K the effects of separation and vortex shedding become increasingly important, eventually leading to a very interesting half Karman vortex street in the transverse direction in the range 8 less than K less than 13. The discrete vortex model of the separated oscillating flow is shown to provide a reasonably satisfactory explanation of the transverse vortex street. Finally, an attempt is made, through the use of an ideal vortex model, to explain the observed flow modes and the cycle-to-cycle variations in forces and pressures in terms of their sensitivity to small stochastic variations in the position of the vortices Author

N88-23134# Technische Hochschule, Aachen (Germany, F.R.).
SHORT DURATION FLOW ESTABLISHMENT ON A PROFILE IN A WATER-LUDWIEG-TUNNEL
W. KERRES and H. GROENIG *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 12 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

This paper deals with the time-dependent establishment of the flow field on an airfoil in unsteady flow. The impulsive part of the flow is achieved in a Water-Ludwieg-Tunnel. By using a coded particle tracing method for flow visualization, the detailed flow establishment on a NACA 0012 airfoil at 30-deg angle of attack is shown from the beginning where potential flow exists with zero circulation to a quasi-steady formation of the vortex street. Author

N88-23135# McDonnell-Douglas Research Labs., Saint Louis, MO.
EXPERIMENTAL INVESTIGATION OF HOVER FLOWFIELDS IN WATER AT THE MCDONNELL DOUGLAS RESEARCH LABORATORIES
K. R. SARIPALLI, J. C. KROUTIL, and J. R. VANHORN *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 10 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

A new experimental facility, the Hover Research Facility (HRF), is designed to study the flowfields generated by hovering vertical takeoff and landing (VTOL) aircraft and helicopters. Water is used as the working medium because of its inherent advantages in flow visualization and laser Doppler velocimeter (LDV) measurements. The applications of the Hover Research Facility include: (1) experimental investigation of twin-jet impingement flow with application to VTOL aircraft; (2) visualization of the flowfield around a fully contoured, model supersonic fighter/attack short takeoff and vertical landing (STOVL) aircraft; and (3) performance testing of a No Tail Rotor (NOTAR) helicopter in hover mode by use of a scale model. Flow visualization and quantitative LDV data on these experiments are presented. Author

N88-23136# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
AN INVESTIGATION OF DUCTED PROPELLERS IN AXISYMMETRIC SHEAR FLOW
J. A. C. FALCAODECAMPOS *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 15 p (SEE N88-23125 16-34) Jun. 1987 Sponsored in part by Instituto Superior Tecnico
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

To improve the basic understanding of the complex interaction flow phenomena between ducted propeller systems and a ship's hull, the effects of radial nonuniformity of the inflow to the ducted propeller were investigated, both numerically and experimentally. The mathematical model is based on the Euler equations for an inviscid, incompressible axisymmetric flow and on the representation of the propeller by an actuator disk. In a vorticity-stream function formulation, the problem is governed by two coupled integral equations, which express vorticity transport in the flow and the boundary conditions on the duct and hub surfaces. The numerical solution method employs a discretization of the vorticity field into vortex sheets, which are traced iteratively in a fixed grid. The problem was also experimentally investigated in the Large Cavitation Tunnel of the Maritime Research Institute of the Netherlands. A five-bladed propeller model, placed inside a duct, was tested behind wire screens, generating a wake velocity profile with axial symmetry. Laser-Doppler measurements of mean axial and radial velocities were carried out at various axial locations upstream and downstream of the ducted propeller. Detailed comparisons between the results of calculations and the experiments are presented and discussed. Author

N88-23137# Leicester Univ. (England). Dept. of Engineering.
MEASUREMENTS OF AERODYNAMIC FORCES ON UNSTEADILY MOVING BLUFF PARACHUTE CANOPIES
D. J. COCKRELL, R. J. HARWOOD, and C. Q. SHEN *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 7 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Equations which describe the unsteady motion of bluff bodies through fluids contain certain components, termed added mass coefficients, which can only be determined by experiment. From the solutions to such equations the ways in which the shapes of parachute canopies influence the frequency of their oscillatory motion in pitch and their corresponding damping rates are required. Although a full-scale parachute canopy descends through air, oscillating in pitch as it does, experiments necessary to determine these added mass coefficients have been performed under water, using for this purpose a large ship tank from the towing carriage of which the model parachute canopies were suspended. These experiments showed that the added mass coefficients for bluff parachute canopies differed appreciably from their corresponding potential flow values. The latter were obtained from the analysis of inviscid, fluid flow around regular shapes which were representative of those parachute canopies. The significance for the prediction of the parachute's dynamic behavior in pitch is outlined. Author

N88-23138# IMI Summerfield, Kidderminster (England).
WATER FLOW VISUALISATION OF A RAMROCKET COMBUSTION CHAMBER
P. J. BOSZKO and G. S. OWEN *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 11 p (SEE N88-23125 16-34) Jun. 1987 Sponsored in part by Ministry of Defence
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Flow within the combustion chamber of a ramrocket has been investigated using water flow visualization with air bubbles as tracers. Configurations with four axisymmetric intakes entering the combustion chamber at either 45 or 90 deg have been considered. A region of stable recirculatory flow has been identified at the head end of the combustion chamber and estimates have been obtained of the amount flowing through the recirculation region. Based on this information fuel jets have been designed which it is believed will aid ignition, secure flame stability, and improve combustion efficiency. The interaction between fuel jets and the recirculatory air flow has been tentatively investigated on flow visualization tests using jets of colored water. Author

N88-23139# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
THE ONERA WATER TUNNELS TEST POSSIBILITIES FOR FLOW VISUALIZATION IN AERONAUTICAL AND NAVAL DOMAINS
H. WERLE *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 16 p (SEE N88-23125 16-34) Jun. 1987 In FRENCH; ENGLISH summary
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

The ONERA water test tunnels, which for a long time were the pioneers in flow visualization, cover a broad scope of test methods and means, encompassing a wide field of applications. This paper presents an up-to-date description of the experimental techniques used for plane, axisymmetric and three-dimensional flow, and gives a survey of the most notable results achieved in domains as varied as fundamental research and aerodynamics and related hydrodynamic studies. Author

N88-23140# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Experimental Fluid Mechanics.
THE USE OF A WATER TOWING TANK FOR AERODYNAMIC TESTING AND METHODS FOR QUANTITATIVE EVALUATION OF PHOTOGRAPHS
H. BIPPES *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 11 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

The use of the water towing tank of the DFVLR for fluid dynamic testing is briefly described. The capability of measuring techniques is discussed. Among the various techniques the quantitative evaluation of photographs of visualized flow proved to be most effective for use in a water towing tank. Two methods enabling the survey of 3-D flow fields are dealt with in detail. The first method based on photogrammetric techniques has already been applied to the investigation of 3-D disturbances in an unstable laminar boundary layer and to the study of a free vortex flow. The second one is based on holographic techniques. Its feasibility for supplying quantitative data is discussed. Author

N88-23141*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLOW MEASUREMENTS IN A WATER TUNNEL USING A HOLOCINEMATOGRAPHIC VELOCIMETER
LEONARD M. WEINSTEIN and GEORGE B. BEELER *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 7 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01 CSCL 20D

Dual-view holographic movies were used to examine complex flows with full three-space and time resolution. This approach, which tracks the movement of small tracer particles in water, is termed holocinematographic velocimetry (HCV). A small prototype of a new water tunnel was used to demonstrate proof-of-concept for the HCV. After utilizing a conventional flow visualization apparatus with a laser light sheet to illuminate tracer particles to evaluate flow quality of the prototype tunnel, a simplified version of the HCV was employed to demonstrate the capabilities of the approach. Results indicate that a full-scale version of the water tunnel and a high performance version of the HCV should be able to check theoretical and numerical modeling of complex flows and examine the mechanisms operative in turbulent and vortex flow control concepts, providing an entirely unique instrument capable, for the first time, of simultaneous three-space and time measurements in turbulent flow. Author

N88-23142# Centre d'Etudes et de Recherches, Toulouse (France). Dept. dEtudes en Mecanique et Energetique des Systemes.
EXPERIMENTAL STUDY OF VORTEX SHEETS IN PLANE FLOW [ETUDE EXPERIMENTALE DE NAPPES TOURBILLONNAIRES EN ECOULEMENT PLAN]
CHRISTIAN BERGER, MAGALI BOURGEOIS, GERARD LAVERGNE, CHRISTINE LEMPEREUR, and JEAN-MICHEL MATHE *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 7 p (SEE N88-23125 16-34) Jun. 1987 In FRENCH
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

With the aim of conducting an experimental study of shear instability in laminar flow, a vertical water tank was designed which would generate a confluence of two bi-dimensional flows of different velocities. The study consisted of characterizing the instabilities developing downstream from the base starting with the determination of velocity profiles with laser anemometry and various flow visualization and image processing techniques. The Reynolds number calculated across the width of the base and the mean of the two velocities is less than 600. Modeling this type of flow with the aid of vortex sheets emitted at the base extremities permits the construction of emission lines comparable to those observed. Author

N88-23143# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
THREE-DIMENSIONAL FLOW VISUALIZATION USING LASER-SHEET SCANNING
D. M. NOSENCHUCK and M. K. LYNCH *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 13 p (SEE N88-23125 16-34) Jun. 1987
(Contract N00014-85-K-0352; NSF MSM-83-52175)
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

It has been demonstrated that the conventional technique of fixed-laser-sheet flow visualization can be extended to include 3-D visualization by means of a scanning laser sheet. This system was implemented using a rotating mirror in conjunction with appropriate fixed optics. A space-filling 3-D data base was digitally obtained from the imaging and recording units, and was processed to yield a variety of 3-D views of the flow field in addition to obtaining quantitative results regarding mixing levels and velocities. Laser-sheet scanning was first applied in a study of boundary-layer turbulence in which active control was implemented. The flow

visualization readily indicated the near-wall instabilities present in turbulent spots and synthetic turbulent boundary layers. When control was attempted using an array of surface heating elements, the visualization technique graphically illustrated the attenuation of the near-wall sublayer streaks and resultant quiescent outer flow. Author

N88-23144# Institut de Mecanique des Fluides de Lille (France).
APPLICATION OF HIGH SPEED HOLOGRAPHY TO AERODYNAMIC AND HYDRODYNAMIC THREE-DIMENSIONAL VELOCIMETRY
M. STANISLAS, O. RODRIGUEZ, M. DADI, and F. BELUCHE *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 10 p (SEE N88-23125 16-34) Jun. 1987
Sponsored in part by French Ministery for Defense
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

The application of holography to the measurement of fluid velocity in 3-D domains is proposed. After a short description of the method, an example of application to the water flow around a circular cylinder at low Reynolds number is presented. Then, the main limitations of the method are discussed and solutions proposed to overcome them. Author

N88-23146# Universite de Valenciennes et du Hainaut-Cambresis (France). Lab. de Mecanique des Fluides.
WATER TUNNEL MEASUREMENTS BY AN ELECTROCHEMICAL METHOD [MESURES EN TUNNEL HYDRODYNAMIQUE PAR METHODE ELECTROCHIMIQUE]
C. TOURNIER and P. FLORENT *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 14 p (SEE N88-23125 16-34) Jun. 1987 In FRENCH
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

A polarographic method to measure parietal friction is described. With the proper liquid, the technique permits the measurement of 3-D and unsteady flows without perturbations. To employ the method, a large capacity water tank (Re - 1.5 x 10 to the 6th) made entirely of electrically neutral and chemically inert materials was designed. Sample measurements made using the polarographic method are presented. They were selected to illustrate the advantages of this method in typical cases of 3-D or unsteady flows. The possibility of measuring mass transfer using this method is also discussed. Author

N88-23147# California Univ., San Diego, La Jolla.
FLOW VELOCITY MEASUREMENTS BY IMAGE PROCESSING OF OPTICALLY MODULATED TRACES
M. GHARIB, B. DYNE, O. THOMAS, and C. YAP *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 7 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

A computerized flow visualization technique capable of quantifying the flow field automatically is described. The technique uses a time modulated illumination scheme to retrieve vectorial information from the pathlines of particles suspended in the flow. This technique has eliminated a major source of error in velocity reading which is common in conventional particle tracing techniques. Application of the present technique to the recirculating flow field of a 2-D cavity is described. Velocity profiles obtained from the pathlines of the particles through the present techniques show excellent agreement with the velocity profiles obtained using laser Doppler velocimetry. Author

N88-23148# Florida State Univ., Tallahassee.
A NON-INVASIVE EXPERIMENTAL TECHNIQUE FOR THE MEASUREMENT OF UNSTEADY VELOCITY AND VORTICITY FIELDS
L. LOURENCO, A. KROTHAPALLI, J. M. BUCHLIN, and M. L. RIETHMULLER (Von Karman Inst. for Fluid Dynamics, Rhode-Saint Genese, Belgium) *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 9 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

A new velocity measurement technique is described which provides the simultaneous visualization of a 2-D streamline pattern and the quantification of the velocity field. The main advantage of this technique is that the velocity field can be measured with sufficient accuracy and spatial resolution so that the vorticity field can be readily obtained. This technique is ideally suited for the study of unsteady vertical flows, which occur in high angle of attack aerodynamics. The technique, some of the important parameters affecting its use, and some recent examples are described. Author

N88-23149*# Notre Dame Univ., IN. Dept of Aerospace and Mechanical Engineering.
USE OF WATER TOWING TANKS FOR AERODYNAMICS AND HYDRODYNAMICS
MOHAMED GADELHAK *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 11 p (SEE N88-23125 16-34) Jun. 1987
(Contract NAS1-18292; NAS1-18213; N00014-81-C-0453, F49620-82-C-0020; NSF ISI-85-60825)
(AGARD-CP-413) Avail: NTIS HC A20/MF A01 CSCL 20D

Wind tunnels and flumes have become standard laboratory tools for modeling a variety of aerodynamic and hydrodynamic flow problems. Less available, although by no means less useful, are facilities in which a model can be towed (or propelled) through air or water. This article emphasizes the use of the water towing tank as an experimental tool for aerodynamic and hydrodynamic studies. Its advantages and disadvantages over other flow rigs are discussed, and its usefullness is illustrated through many examples of research results obtained over the past few years in a typical towing tank facility. Author

N88-23151# British Aerospace Public Ltd. Co., Bristol (England). Aerodynamics Research Dept.
A COMPARATIVE STUDY OF VORTEX FLOWS IN WIND AND WATER TUNNELS
A. G. DAVIES *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 16 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Characteristics of the flowfield around a generalized missile configuration using two flow visualization techniques in a water tunnel are compared to corresponding wind tunnel data at subsonic and supersonic speeds. It is shown that the flowfields derived from the water tunnel can be representative of those found at subsonic speeds although isolated body vortex locations agree more with those measured at supersonic speeds [illegible] that separation angles on the body can be important. The addition of a cruciform set of fins is shown to modify the body vortex structure dramatically, the degree of modification varying with axial location of the fins. A speed effect is seen to exist in the water tunnel that can change some vortex flowfield characteristics from those of a subsonic flow to those observed at supersonic speeds. Finally, cross flow velocities and circulations are compared between water and wind tunnels. Author

N88-23152# Saab-Scania, Linkoping (Sweden).
INVESTIGATION ON THE MOVEMENT OF VORTEX BURST POSITION WITH DYNAMICALLY CHANGING ANGLE OF ATTACK FOR A SCHEMATIC DELTA-WING IN A WATERTUNNEL WITH CORRELATION TO SIMILAR STUDIES IN WINDTUNNEL
KARL W. WOLFFELT *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 8 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

The requirements for modern military aircraft to maintain good handling qualities at very high angles of attack is one of many reasons why an increased knowledge is necessary regarding the aerodynamic behavior of vortex flows at nonstationary conditions. Linearized theory as it has been utilized in flight mechanics simulation using damping derivatives derived from forced oscillation technique, for example, may no longer be valid at such conditions. With this background some investigations have been made by SAAB-SCANIA with the aim to study the hysteresis effects for nonstationary vortex flows. A schematic delta-wing model which could also be equipped with a similar canard wing has been tested in a water tunnel. The model was supported in the tunnel by a simple mechanism by which it could be forced to move in one of four different modes, pitching or plunging with either ramp or harmonic motion. The flow over the model was visualized with air bubbles and sequences were recorded on videotape. The sequences were analyzed and the movements of the leading edge

vortex burst have been studied with the main interest focused on the hysteresis effects. Author

N88-23153# Technische Hogeschool, Eindhoven (Netherlands).
SOME VISUALIZATION STUDIES ON TURBULENT BOUNDARY LAYERS USING MULTIWIRE HYDROGEN BUBBLE GENERATION
R. BLOKLAND and K. KRISHNA PRASAD *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 12 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Provided are new results obtained using two visualization methods which assist in describing essentially three dimensional phenomena: (1) With two wire pattern correlation the flow field can be described in a large set of sections through a certain structure; (2) Multiple color illumination allows recognition of movements in a direction normal to the plane of the photograph from changes in color. Some countings were made concerning the behavior of low speed streaks as a function of y and the relation between streaks and some other structures. A new detection criterion for streaks is proposed. The distribution for the spanwise velocity of a streak was determined. It is shown that the detection criteria of Blackwelder and Kaplan essentially samples spanwise passages of streaks. A few results of multiple color visualization are shown to establish unambiguously the vertical transport associated with streaks. Author

N88-23154*# Lehigh Univ., Bethlehem, PA. Dept. of Mechanical Engineering and Mechanics.
STRUCTURE OF UNSTEADY FLOWS AT LEADING- AND TRAILING-EDGES: FLOW VISUALIZATION AND ITS INTERPRETATION
D. ROCKWELL, R. ATTA, L. KRAMER, R. LAWSON, D. LUSSEYRAN, C. MAGNESS, D. SOHN, and T. STAUBLI *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 13 p (SEE N88-23125 16-34) Jun. 1987 Sponsored in part by NASA, NSF, Navy, AF, and Volkswagen Foundation
(AGARD-CP-413) Avail: NTIS HC A20/MF A01 CSCL 20D

Unsteady two- and three-dimensional flow structure at leading and trailing edges of bodies can be characterized effectively using recently developed techniques for acquisition and interpretation of flow visualization. The techniques addressed here include: flow image/surface pressure correlations; 3-D reconstruction of flow structure from flow images; and interactive interpretation of flow images with theoretical simulations. These techniques can be employed in conjunction with: visual correlation and ensemble-averaging, both within a given image and between images; recognition of patterns from images; and estimates of velocity eigenfunctions from images. Author

N88-23155# Hamburg Model Basin (Germany, F.R.).
MEASUREMENTS OF THE TIME DEPENDENT VELOCITY FIELD SURROUNDING A MODEL PROPELLER IN UNIFORM WATER FLOW
JOERG BLAUROCK and GERD LAMMERS *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 13 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

As part of a research program, the flow field around an operating ship propeller was investigated in a water tunnel, using laser Doppler velocimetry. The 3-D velocity field was measured in three planes at the suction side and four planes on the pressure side of the propeller at the design thrust coefficient of K sub T = 0.185. In one of the planes in the propeller's slipstream, the measurements were repeated at thrust coefficients of K sub T = 0.12 and 0.25. The velocity profiles measured in the propeller's slipstream are compared with the induced velocities derived from design calculations, and occurring deviations are discussed. Furthermore, the instationary flow field permits study of the tip vortices at different distances behind the propeller. The measurements yield a quantitative description of the vortices, and the influence of propeller load at the blade tips on geometry and intensity of the tip vortices can be seen. Author

N88-23156# Admiralty Research Establishment, Gosport (England).
EXPERIMENTS TO INVESTIGATE THE VORTICES SHED FROM A SUBMARINE-LIKE BODY OF REVOLUTION
A. R. J. M. LLOYD and I. M. C. CAMPBELL (Southampton Univ., England) *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 22 p (SEE N88-23125 16-34) Jun. 1987 Presented at the 59th Meeting of the AGARD Fluid Dynamics Panel Symposium, Monterey, Calif., 20-23 Oct. 1986
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Described are experiments to determine the characteristics of the vortices shed from a submarine-like body of revolution at an angle of attack in a turn. The experiments used a new type of vorticity probe developed by Freestone at the City University in the UK. The probe allows the streamwise vorticity to be estimated from simple pressure measurements and rapid assessments of vortex position and strength can be made. The paper examines the expected performance of the probe using a simulation of an ideal viscous cored vortex and reports experience gained in the design and preliminary testing of the probe. Results of experiments to measure the vortex shed by a hydroplane at an angle of attack and a body of revolution in a turn are reported. Author

N88-23157# Admiralty Research Establishment, Gosport (England). Submarine Hydrodynamics and Experiment Services Div.
A REVIEW OF THE NATO SPECIAL GROUP OF EXPERTS ON NAVAL HYDROMECHANICS AND RELATED PROBLEMS
JOHN CHARLESWORTH and L. JOHN LEGGAT (Defence Research Establishment Atlantic, Dartmouth, Nova Scotia) *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 12 p (SEE N88-23125 16-34) Jun. 1987
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

The Special Group of Experts on Naval Hydromechanics and Related Problems (SGE-HYDRO) was formed following an exploratory meeting on 3 to 4 November 1982. Its formation was spurred to a large degree by the need within NATO for a forum to promote multinational cooperation in the general area of Naval hydromechanics testing and research for problems not adequately covered by other NATO international exchange groups and the International Towing Tank Conference. The Group's mandate allows it to address current aspects of interest to Naval hydromechanics including test and research facilities, test techniques and instrumentation, prediction methods, model to full scale correlations, full scale trials, model tests, math modeling and simulation, and implications of instrumentation development in other fields. Author

N88-27480# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AERODYNAMICS OF HYPERSONIC LIFTING VEHICLES: FLUID DYNAMICS PANEL AGARD SYMPOSIUM
S. M. BOGDONOFF, H. HORNUNG, ed., and R. E. WHITEHEAD, ed. (Office of Naval Research, Arlington, Va.) Apr. 1988 20 p Symposium held in Bristol, United Kingdom, 6-9 Apr. 1987
(AGARD-AR-246, ISBN-92-835-0453-4; AD-A195892) Avail: NTIS HC A03/MF A01

This report reviews and evaluates the Fluid Dynamics Panel AGARD Symposium entitled, Aerodynamics of Hypersonic Lifting Vehicles, held 6 to 9 June 1987 in Bristol, UK. The purpose of the Symposium was to assess the technology status in the field of hypersonics after a comparative lull in the past decade. The author addresses each of the papers separately and makes general comments on the 5 major topic sessions. The limitations of test facilities for experimental studies at high Mach numbers were clearly evident. New developments in computational fluid dynamics provide possibilities that did not exist in the past. The reviewer stressed the areas that need special emphasis in the future. The papers presented at the Symposium are published in AGARD Conference Proceedings CP-429 and are listed in an Appendix to this report. Author

N88-28872# British Aerospace Public Ltd. Co., Weybridge (England). Military Aircraft Div.
DEVELOPMENT AND ANALYSIS OF TURBULENT NON-EQUILIBRIUM BOUNDARY LAYERS
A. G. T. CROSS *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 250-270 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The simulation of flow phenomena involving a boundary layer was already identified as potentially very sensitive to the upstream state of the incoming layer. The state of the layer in the sense of being laminar, transitional, or turbulent is of prime importance. As turbulent flow is usual at full scale it is a main objective of model tests. For turbulent flow an important consideration is departure from equilibrium as, in these cases the similarity solutions so frequently used in calculations no longer apply. Including non-equilibrium effects in the velocity profile is particularly revealing, and is essential for determining the important scale parameters and establishing separation criteria. The turbulent boundary layer is considered specifically in terms of the law of the wall and wake velocity profile which can be used to examine the influence of second order effects including that of departure from equilibrium.
Author

N88-28873# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle Stroemungsmechanik.
SHOCK BOUNDARY LAYER INTERACTION
E. STANEWSKY *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 271-305 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

An essential prerequisite for the viscous simulation of the flow about transonic flight vehicles is the correct simulation of shock boundary layer interaction. The latter requires that the parameters of the incoming boundary layer dominating the interaction are known. An attempt is made to identify such parameters for the characteristic features of shock boundary layer interaction.
Author

N88-28875# Calspan Field Services, Inc., Arnold AFS, TN.
VORTEX FLOWS
EDWARD M. KRAFT *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 338-355 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

For today's high performance aircraft, separation and vortical flow is a fact of life. The design challenge is to control vortex separation and make it work to improve the aircraft performance. Vortical flows are generally complex and correspondingly difficult to model analytically. Consequently subscale simulation remains the primary developmental tool for vehicle optimization, particularly in a high speed maneuver. Therefore, it is essential to understand the physical aspects of vortical flows that effect subscale simulation. A brief summary of some of the key questions and current assessment is provided. The primary types of vortical flows of interests in terms of proper subscale simulation at transonic speeds are forebody vortices, wing leading edge vortex flows, vortex breakdown, and vortex/shock interactions. The fundamental aspects of these types of flow are explored and areas where further research is required, are suggested.
Author

N88-28876# Middle East Technical Univ., Ankara (Turkey). Dept. of Aeronautical Engineering.
ENVIRONMENTAL EFFECTS ON TRANSITION AND BOUNDARY LAYER CHARACTERISTICS
C. CIRAY *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 356-408 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

The environmental effect on transition and some boundary layer characteristics is summarized. Environmental effects seem to be a section of fluid dynamics that was neglected or that was not studied systematically and in an organized manner. Yet with the need or increased accuracies required from recent wind tunnel measurements and the need for reduced discrepancies of the experimental data obtained from different wind tunnels, the wind tunnel environmental effects have to be accurately assessed. Looking at the breadth and delicacy both from an experimental and theoretical point of view, the subject of environmental effect on transition and boundary layer characteristics appears challenging and rewarding for fluid dynamicists.
Author

N88-28877# Calspan Field Services, Inc., Arnold AFS, TN.
BOUNDARY LAYER MANIPULATION
EDWARD M. KRAFT *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 409-446 (SEE N88-28857 23-01) Apr. 1988
(AGARD-AR-224) Avail: NTIS HC A20/MF A01

It is clear that, left to its own development, the boundary layer on a model used in a subscale simulation may have little resemblence, in general, to the boundary layer on the full-scale vehicle. Consequently, it is inevitable that some sort of manipulation of the viscous dominated regions on the model will have to be performed in order that the wind tunnel results can be extrapolated to flight. The elements necessary for a successful viscous simulation are: an understanding of what parameters need to be controlled in the subscale experiment to provide a surprise-free extrapolation to flight; means for manipulating and controlling the required viscous parameters. Methods for determining that the viscous parameters were properly controlled in the wind tunnel; and an understanding of how the wind tunnel data need to be extrapolated to flight from whatever conditions were established in the wind tunnel. It must also be kept in mind that different boundary layer manipulation techniques will be applied for different test requirements. In addition, different requirements may exist for various components of a vehicle. An overview of the elements required for boundary layer manipulation will be presented and some suggested areas for future research will be discussed.
Author

N89-11400# Technische Univ., Regensburg (Germany, F.R.).
COMPUTATINAL FLUID DYNAMICS AND SUPERCOMPUTERS, CHAPTER 6
W. GENTZSCH *In* AGARD, Computational Fluid Dynamics: Algorithms and Super Computers p 141-182 (SEE N89-11395 02-60) Mar. 1988
(AGARD-AG-311) Avail: NTIS HC A09/MF A01

It is important to optimally adapt codes and algorithms to the vector or parallel computer in use. In addition to faster and larger supercomputers, users must be much better trained than for (scalar) general purpose computers. Details on restructuring typical numerical algorithms to achieve superior performance on vector computers. The focus, of course, is on Computational Fluid Dynamics. During the last two decades CFD gained an important position together with experiments in wind tunnels and analytical methods. The main objective of CFD is to simulate dynamic flow fields through the numerical solution of the governing equations, e.g., the Navier-Stokes equations, using high-speed computers. The simulation of 2-D inviscid and viscous flows on vector computers does not represent any difficulties with respect to memory requirements or computation time. In 3-D, however, one has to compute some 20 to 30 variables per mesh point in a 3-D field per time-step or iteration such as the velocity components, density, pressure, enthalpy, temperature, concentrations, dissipative fluxes, local time steps, geometry coefficients, dummy arrays, etc. Computations in the case of 3-D are therefore restricted to fairly coarse meshes as well as to solutions which are often not fully converged solutions. The large amount of CPU time involved and the fact that the data cannot be contained in central memory are the main reasons for the long elapsed times for CFD applications. In these cases, the mapping of the problem onto the architecture of the machine and in particular onto special organizations of the memory must be fully considered to take full advantage of the vector computer.
Author

N89-18610# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
VALIDATION OF COMPUTATIONAL FLUID DYNAMICS. VOLUME 1: SYMPOSIUM PAPERS AND ROUND TABLE DISCUSSION
Dec. 1988 588 p In ENGLISH and FRENCH Symposium held in Lisbon, Portugal, 2-5 May 1988
(AGARD-CP-437-VOL-1; ISBN-92-835-0489-5; ISBN-92-835-0491-7) Avail: NTIS HC A25/MF A01

The specific intent of the examining activities, both computational and experimental, was directed toward validating or

calibrating CFD codes over a broad spectrum of fluid dynamics study areas. The objectives of the Symposium were to identify the level of agreement of numerical solution algorithms and physical models with experimental and/or analytical data, to identify regions of validity for given flow solvers, and to identify flow regions where significant gaps exist and further work is warranted. For individual titles, see N89-18611 through N89-18647.

N89-18611# General Dynamics Corp., Fort Worth, TX.
CFD VALIDATION PHILOSOPHY
RICHARD G. BRADLEY *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 6 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Computational Fluid Dynamics (CFD) is becoming an increasingly powerful tool in design and analysis of fluid dynamic and aerospace systems. Application of CFD to practical design problems requires a high level of confidence, which in turn requires focused experimentation to verify the accuracy of CFD codes. The need for CFD validation is presented from the viewpoint of the user, and a general philosophy for validation of CFD codes is introduced, highlighting the requirements for disciplined experimentation and careful evaluation of the bounds of error in CFD solutions. Author

N89-18612*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ACCURACY REQUIREMENTS AND BENCHMARK EXPERIMENTS FOR CFD VALIDATION
JOSEPH G. MARVIN *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 15 p (SEE N89-18610 11-34) Dec. 1988 Previously announced as N88-21423
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01 CSCL 20D

The role of experiment in the development of Computational Fluid Dynamics (CFD) for aerodynamic flow prediction is discussed. The CFD verification is a concept that depends on closely coordinated planning between computational and experimental disciplines. Because code applications are becoming more complex and their potential for design more feasible, it no longer suffices to use experimental data from surface or integral measurements alone to provide the required verification. Flow physics and modeling, flow field, and boundary condition measurements are emerging as critical data. Four types of experiments are introduced and examples are given that meet the challenge of validation: flow physics experiments; flow modeling experiments; calibration experiments, and verification experiments. Measurement and accuracy requirements for each of these differ and are discussed. A comprehensive program of validation is described, some examples given, and it is concluded that the future prospects are encouraging. Author

N89-18613# National Aerospace Lab., Amsterdam (Netherlands).
NUMERICAL ACCURACY ASSESSMENT
J. W. BOERSTOEL *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 18 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A framework is provided for numerical accuracy assessment. The purpose of numerical flow simulations is formulated. This formulation concerns the classes of aeronautical configurations (boundaries), the desired flow physics (flow equations and their properties), the classes of flow conditions on flow boundaries (boundary conditions), and the initial flow conditions. Next, accuracy and economical performance requirements are defined; the final numerical flow simulation results of interest should have a guaranteed accuracy, and be produced for an acceptable FLOP-price. Within this context, the validation of numerical processes with respect to the well known topics of consistency, stability, and convergence when the mesh is refined must be done by numerical experimentation because theory gives only partial answers. This requires careful design of test cases for numerical experimentation. Finally, the results of a few recent evaluation exercises of numerical experiments with a large number of codes on a few test cases are summarized. Author

N89-18617# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
COMPARATIVE STUDY OF CALCULATION PROCEDURES FOR VISCOUS FLOWS AROUND AIRFOILS IN THE TRANSONIC REGIME
H. W. STOCK, W. HAASE, and H. ECHTLE *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 9 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Comparative studies for the evaluation of flows around airfoils are presented. This problem is solved in two different ways. Flows are computed by: (1) a finite volume Navier-Stokes method; and (2) an iterative calculation procedure using a finite volume method to solve the full potential equation for the inviscid flow and an inverse integral boundary layer method for the viscous part. Using the Navier-Stokes method, two different algebraic turbulence models are investigated. First, the Baldwin-Lomax model is applied followed by the Cebeci-Smith model, in combination with a recently developed approach to evaluate the turbulent length scales in Navier-Stokes method. Concerning the problem of the computation of shock wave boundary layer interaction zones, a numerical study is performed using the finite volume Navier-Stokes method. The influence of mesh refinement, in the surface normal and tangential direction, with respect to the prediction quality is studied. Two different airfoils, the RAE 2822 and the DoAL3, are investigated and compared to experimental findings. Author

N89-18618# Catania Univ. (Italy). Inst. di Macchine.
NUMERICAL SOLUTION OF COMPRESSIBLE NAVIER-STOKES FLOWS
F. BASSI, F. GRASSO, and M. SAVINI (Consiglio Nazionale delle Ricerche, Peschiera Borromeo, Italy) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 14 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A mesh embedding technique for increasing the accuracy of Navier-Stokes computations of compressible flows is presented and fully described. The method proposed is quite robust and the results obtained by appling it to transonic airfoil computations are in fairly good agreement with the experiments and with computations made by other authors using much finer meshes. Thus this technique allows the computation of such flows for practical use even on small computers. Author

N89-18619# National Aerospace Lab., Amsterdam (Netherlands).
THE INTERNATIONAL VORTEX FLOW EXPERIMENT
A. ELSENAAR, L. HJELMBERG, K. BUETEFISCH, and W. J. BANNINK (Technische Hogeschool, Delft, Netherlands) *In* AGARD, Validation of Computational Fluid Dynamics Volume 1 Symposium Papers and Round Table Discussion 26 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Experimental results of the International Vortex Flow Experiment are presented. In this joint program, the vortex flow development on a 65 deg delta wing was studied for Mach numbers between 0.4 and 4. The experimental results include pressure and force measurements, surface flow visualizations and flow field surveys. The influence of leading edge shape (sharp or rounded), a decrease in leading edge sweep (to 55 deg), the addition of a canard wing and yaw effects were measured and analyzed in some detail as far as vortex development, shock wave formation and vortex break-down are concerned. Particular attention was given to experimental details that affect the comparison with theory. Some specific test cases for computer code validation are recommended. Author

N89-18620# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
STATUS OF CFD VALIDATION ON THE VORTEX FLOW EXPERIMENT
B. WAGNER, S. M. HITZEL, M. A. SCHMATZ, W. SCHWARZ, A. HILGENSTOCK, and S. SCHERR (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany, F.R.) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 10 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

The vortex flow phenomena developing at highly swept wings by leading edge separation are of great interest for fighter and missile aerodynamics. While panel methods are already known for more than a decade to satisfactorily model the roll-up of the corresponding vortex sheets at subsonic speed, Euler methods became available in the early 80's for predicting these effects also in the transonic and supersonic speed ranges. Subsequent trials to validate such transonic vortex flow computations revealed the experimental data basis to be very poor for high speeds and, in consequence, the International Vortex Flow Experiment on Euler Code Validation was set up. More recently, also three dimensional Navier-Stokes codes could be applied in order to clarify the role of viscous effects and to investigate in detail the neglect of those in the Euler solutions. A survey is presented on the Euler code validation based on the Symposium on the IVFE in 1986 and additional insight is given into some related Euler and Navier-Stokes work done in West Germany more recently. Author

N89-18621# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
FLOW FIELD SURVEYS OF LEADING EDGE VORTEX FLOWS
T. T. NG, R. C. NELSON, and F. M. PAYNE (Boeing Commercial Airplane Co., Seattle, WA.) *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 13 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

The phenomenon of vortex breakdown over slender delta wings is examined experimentally. Measurements of leading edge vortex structures were obtained using both flow visualization and detailed wake surveys using either a seven hole pressure probe or a laser Doppler anemometer. The structure of the leading edge vortex on a family of delta wings is presented. The delta wing models were sharp-edge flat plates having leading edge sweep angles of 70, 75, 80 and 85 degs. These models were tested at angles of attack of 10, 20, 30 and 40 degs in a Reynolds number range of 8.5 x 10,000 to 6.4 x 100,000. Data is presented on vortex trajectories, wake surveys, and swirl angles before and after vortex breakdown. In addition, the effect of Reynolds number on the vortex surveys is discussed. The data presented represents a portion of a large experimental data base that should be of value to the development and validation of computational models of leading edge vortices. Author

N89-18624*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACCURATE SOLUTIONS, PARAMETER STUDIES AND COMPARISONS FOR THE EULER AND POTENTIAL FLOW EQUATIONS
W. KYLE ANDERSON and JOHN T. BATINA *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 16 p (SEE N89-18610 11-34) Dec. 1988 Previously announced as N88-28892
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01 CSCL 20D

Parameter studies are conducted using the Euler and potential flow equation models for steady and unsteady flows in both two and three dimensions. The Euler code is an implicit, upwind, finite volume code which uses the Van Leer method of flux vector splitting which has been recently extended for use on dynamic meshes and maintain all the properties of the original splitting. The potential flow code is an implicit, finite difference method for solving the transonic small disturbance equations and incorporates both entropy and vorticity corrections into the solution procedures thereby extending its applicability into regimes where shock strength normally precludes its use. Parameter studies resulting in benchmark type calculations include the effects of spatial and temporal refinement, spatial order of accuracy, far field boundary conditions for steady flow, frequency of oscillation, and the use of subiterations at each time step to reduce linearization and factorization errors. Comparisons between Euler and potential flow results are made, as well as with experimental data where available. Author

N89-18625# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
VERIFICATION OF AN IMPLICIT RELAXATION METHOD FOR STEADY AND UNSTEADY VISCOUS AND INVISCID FLOW PROBLEMS
M. A. SCHMATZ, A. BRENNEIS, and A. EBERLE *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 33 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A 3-D Navier-Stokes code (NSFLEX) and an unsteady Euler code (INFLEX3) is described. The fundamental feature of both methods is a Godunov type averaging procedure based on an eigenvalue analysis of the inviscid equations for the calculation of the inviscid fluxes. Up to 3rd order accuracy in space is employed for the flux calculation. The unfactored implicit equations are solved in time dependent form by a Newton method. Relaxation is performed with a point Gauss-Seidel technique. Both codes are highly vectorized. Because the codes are finite volume schemes, they are flexible in handling complex geometries. The NSFLEX is applied to steady viscous 2-D airfoil and 3-D delta wing flows at transonic Mach numbers including vortices. The method compares very well with the experiment. The INFLEX method is applied to the unsteady Euler equations in order to predict time accurate, unsteady, subsonic and transonic flows about 3-D configurations oscillating in the flow. Numerical results are given for a rectangular supercritical wing and the so-called LANN-wing. Comparisons show good agreement with experiments for a wide range of Mach numbers. Viscous effects, especially at the rear of the wing, explain some deviations. Author

N89-18626# Avions Marcel Dassault, Saint-Cloud (France). Div. of Etudes Avancees.
RELIABILITY AND VALIDITY OF CFD CODES: FLIGHT AND WIND TUNNEL COMPARISON [FIABILITE ET VALIDITE DES CODES DE C.F.D. COMPARAISON AU VOL ET A LA SOUFFLERIE]
G. HECKMANN *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 11 p (SEE N89-18610 11-34) Dec. 1988 In FRENCH
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Considerations for the evaluation of CFD (computational fluid dynamics) software are discussed with particular emphasis given to the comparison of code predictions with flight and wind tunnel test data. Overall robustness of the computational procedure, code portability, documentation, maintenance, and error detection/correction are discussed along with other factors that effect general reliability and quality. The use of wind-tunnel pressure data, velocity fields and flow visualization results for code validation is addressed along with the use of flight-test local measurements and drag response data. Author

N89-18627# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SEPARATION AROUND ELLIPSOID-TYPE OBSTACLES: MODELING AND VALIDATION EXPERIENCES [DECOLLEMENT SUR OBSTACLES DE TYPE ELLIPSOIDE EXPERIENCES DE VALIDATION ET MODELISATION]
D. BARBERIS and B. CHANETZ *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 17 p (SEE N89-18610 11-34) Dec. 1988 In FRENCH; ENGLISH summary
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

In the aim of understanding 3-D separation phenomenon and obtaining detailed experimental data for the development and calibration of numerical models, wall measurements (pressures, surface flow visualizations by viscous coating), flow field measurements with pressure probes and 3 directional laser Doppler velocimeter were carried out on blunt bodies of simple form. Vortex flows and boundary layers near the plane of symmetry were investigated. Experimental data were used for the validation of a

numerical method for the separation line. Differences observed between theoretical and experimental results on turbulent quantities indicate some insufficiences of the turbulence model used.
Author

N89-18633# British Aerospace Public Ltd. Co., Bristol (England). Dynamics Div.
DEVELOPMENT AND APPLICATION OF A WEAPONS MULTIBLOCK SUITE
P. A. SHEPHERD and G. R. TOD *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 17 p (SEE N98-18610 11-34) Dec. 1988 Sponsored in part by Ministry of Defence, United Kingdom
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A Multiblock Euler capability for use on weapons in the project environment is described, with comparisons between predicted and experimental data being given for a number of weapons related problems. The present Jameson flow code is shown to produce good agreement with experiment in most cases, covering a wide range of Mach number and incidence. The limitations of the code for more general weapon applications, where viscous effects dominate, is also clear. Extensions of the existing flow solver to higher Mach number and the modeling of viscous phenomena, will form the subject of further development. Author

N89-18634# General Dynamics Corp., San Diego, CA. Convair Div.
ARCJET VALIDATION OF SURFACE CATALYCITY USING A VISCOUS SHOCK-LAYER APPROACH
ALLEN D. ZWAN, RICHARD S. CROOKS, and WALTER J. WHATLEY *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 13 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A 2-D planar, viscous shock layer code was developed to analyze surface catalytic effects on small, leading edge test specimens in an arcjet environment. An arcjet test was performed to generate validation data for the newly developed code. The test program consisted of testing leading edge test specimens with radii of 0.10, 0.25 and 0.35 inches. Test specimens of each radius were coated with silicon carbide, silicon monoxide, or nickel. The code predicted the surface recombination rates for silicon carbide and nickel coatings. These rates agree with other values found in similar literature. Author

N89-18635*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CFD VALIDATION EXPERIMENTS FOR INTERNAL FLOWS
LOUIS A. POVINELLI *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 13 p (SEE N89-18610 11-34) Dec. 1988. Previously announced as N88-16679
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01 CSCL 20D

Computational Fluid Dynamics (CFD) validation experiments at NASA Lewis are described. The material presented summarized the research in 3 areas: Inlets, ducts and nozzles, Turbomachinery, and Chemically reacting flows. The specific validation activities are concerned with shock boundary layer interactions, vortex generator effects, large low speed centrifugal compressor measurements, transonic fan shock structure, rotor/stator kinetic energy distributions, stator wake shedding characteristics, boundary layer transition, multiphase flow and reacting shear layers. These experiments are intended to provide CFD validation data for the internal flow fields within aerospace propulsion system components. Author

N89-18636# Technische Hochschule, Aachen (Germany, F.R.). Inst. for Jet Propulsion and Turbomachinery.
SOLUTION ON UNSTRUCTURED GRIDS FOR THE EULER- AND NAVIER-STOKES-EQUATIONS
W. KOSCHEL, M. LOETZERICH (Dornier-Werke G.m.b.H., Friedrichshafen, Germany, F.R.), and A. VORNBERGER *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 16 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by Deutsche Forschungsgemeinschaft, Fed. Republic of Germany
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

An explicit Finite Element scheme based on a two step Taylor-Galerkin algorithm was developed for solving the Euler and Navier-Stokes equations. The spatial discretization is based on an unstructured Finite Element mesh. The adaptive grid refinement technique which is incorporated in the code, allows a local refinement of the grid by mesh enrichment. For validation, the method is applied to the simulation of the flow around a cylinder and a sphere, a regular shock reflection at a wall, the interaction of an oblique shock wave with a laminar boundary layer and the flow through a scramjet inlet and a turbine cascade. The computed results generally show a satisfying agreement with analytical solutions and experimental data. Author

N89-18637# Ecole Polytechnique Federale de Lausanne (Switzerland). Hydraulic Mechanics and Fluid Mechanics Inst.
VALIDATION OF AN EULER CODE FOR HYDRAULIC TURBINES
F. THIBAUD, A. DROTZ, and G. SOTTAS *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 14 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by Commission d'Encouragement des Recherches Scientifiques, Switzerland, Ateliers de Constructions Mecaniques de Vevey S.A., Switzerland and Suizer-Escher-Syss Ltd., Switzerland
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

Validation of a 3-D internal incompressible stationary Euler flow solver was performed. A finite volume discretization scheme with an explicit time integration is used. The influence of the numerical scheme parameters on the solution and on the convergence is extensively studied. The geometry on which the numerical and experimental comparisons are presented is the runner of an hydraulic Francis turbine. The difference between calculated and experimental integral values is less than 0.2 percent. Author

N89-18638# Pennsylvania State Univ., University Park. Aerospace Engineering Dept.
COMPUTATIONAL TECHNIQUES AND VALIDATION OF 3D VISCOUS/TURBULENT CODES FOR INTERNAL FLOWS
B. LAKSHMINARAYANA, K. R. KIRTLEY, and M. WARFIELD *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 17 p (SEE N89-18610 11-34) Dec. 1988 Sponsored in part by Naval Ship Research and Development Center, Bethesda, MD
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

The computational techniques and codes developed for the prediction of 3-D turbulent flows in internal configurations and rotor passages are described. Detailed calibration and validation of the flow fields in 90 deg curved ducts, cascades, end wall flows and turbomachinery rotors are presented. Interpretation and comments on accuracy, level of agreement with various turbulence models and limitations of the codes are described. The single pass space marching code is found to be efficient for curved duct and 2-D cascade flows. Multipass space marching, time marching and zonal methods are found to be accurate for complex situations. The efficiency and accuracy of a zonal technique, with saving in computational time, is demonstrated. Author

N89-18639# Institut de Mecanique des Fluides de Marseille (France)
WIND TUNNEL VALIDATION OF AERODYNAMIC FIELD CALCULATION CODES FOR ROTORS AND PROPELLERS IN VARIOUS FLIGHT CONDITIONS [VALIDATION A L'AIDE D'ESSAIS EN SOUFFLERIE DE CODES DE CALCUL DU CHAMP AERODYNAMIQUE DE ROTORS ET D'HELICES DANS DES CONDITIONS DE VOL VARIEES]
C. MARESCA, D. FAVIER, M. NSI MBA, and C. BARBI. *In* AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion 16 p (SEE N89-18610 11-34) Dec. 1988. In FRENCH
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

The aerodynamic characteristics of helicopter rotors and propellers operating in various flight modes were studied using both numerical codes and wind tunnel tests. The use of the wind tunnel results to validate and improve three computational codes is discussed. The codes specifically cover helicopter rotors in stationary (hovering) flight, propellers in translational flight, and helicopter rotors in forward flight. Author

N89-18640# Norges Tekniske Hoegskole, Trondheim. Div. of Hydro- and Gas Dynamics.
VALIDATION OF A 3D EULER/NAVIER-STOKES FINITE VOLUME SOLVER FOR A RADIAL COMPRESSOR
LARS-ERIK ERIKSSON and JAN TORE BILLDAL. *In* AGARD, Validation of Computational Fluid Dynamics Volume 1 Symposium Papers and Round Table Discussion 9 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

The application of a time marching Euler Navier-Stokes solution procedure to 3-D compressible turbomachinery flow is described. The method is based on the cell-centered finite volume technique and explicit Runge-Kutta time stepping. A centered and compact difference scheme is used to obtain the velocity and temperature gradients needed in the viscous flux terms and a standard algebraic turbulence model is included in the method. Computational results *for the well known Eckardt impeller* show that the viscous model comes significantly closer to the experimental data than the Euler model. The results of a thin layer version of the viscous solver are in very close agreement with those of the full Navier-Stokes solver. Author

N89-18643# Air Force Systems Command, Wright-Patterson AFB, OH. Aeronautical Systems Div.
EFFORTS TOWARD THE VALIDATION OF A COMPUTATIONAL FLUID DYNAMICS CODE FOR ANALYSIS OF INTERNAL AERODYNAMICS
R. G. SEMMES, D. G. ARBITER, and R. D. DYER. *In* AGARD, Validation of Computational Fluid Dynamics Volume 1 Symposium Papers and Round Table Discussion 13 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

A two-dimensional axisymmetric, Reynolds averaged Navier-Stokes code (PARC2D) was selected to aid in the analysis of internal aerodynamics problems. Before implementing the code in actual systems applications, the code's results were compared with experimental data to determine the extent of its usefulness. The configurations chosen for code validation were: (1) a two-dimensional hypersonic inlet, (2) an axisymmetric convergent-divergent nozzle, and (3) an axisymmetric subsonic diffuser. The ability of the method to readily perform engineering predictions on internal aerodynamics problems is discussed. Sample grids for each configuration as well as comparisons of computational and experimental results are presented. The PARC2D code was able to predict the hypersonic inlet flow field trends and shock structure, but had difficulty in predicting forebody losses. PARC2D provided good agreement with experimental data for both the nozzle as well as the subsonic diffuser. Author

N89-18646# Palermo Univ. (Italy). Dipt. di Ingegneria Nucleare.
TIME-DEPENDENT NUMERICAL SIMULATION OF THE STARTING FLOW OF AN INCOMPRESSIBLE FLUID PAST A DOWNSTREAM-FACING STEP
M. CIOFALO and M. W. COLLINS (City Univ., London, England). *In* AGARD, Validation of Computational Fluid Dynamics Volume 1: Symposium Papers and Round Table Discussion 16 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01

An impulsively generated transient flow of an incompressible fluid past a complex shaped body is investigated numerically using the 2-D Navier-Stokes equations. The geometry is a flat plate with a backward facing step and a blunt trailing edge. Reynolds numbers, based on a free stream velocity and step height, range from 50 to 500. Results are compared with flow visualization data in water. The influence of boundary and initial conditions, differencing scheme, time stepping, pressure velocity coupling algorithms and other computational parameters is discussed. A literature review is included of experimental and predictive studies on laminar and transitional flow past backstep. Author

N89-18647*# National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.
A COMPARATIVE STUDY AND VALIDATION OF UPWIND AND CENTRAL-DIFFERENCE NAVIER-STOKES CODES FOR HIGH-SPEED FLOWS
DAVID H. RUDY, AJAY KUMAR, JAMES L. THOMAS, PETER A. GNOFFO, and SUKUMAR R. CHAKRAVARTHY (Rockwell International Science Center, Thousand Oaks, CA). *In* AGARD, Validation of Computational Fluid Dynamics Volume 1: Symposium Papers and Round Table Discussion 15 p (SEE N89-18610 11-34) Dec. 1988
(AGARD-CP-437-VOL-1) Avail: NTIS HC A25/MF A01 CSCL 20D

A comparative study was made using 4 different computer codes for solving the compressible Navier-Stokes equations. Three different test problems were used, each of which has features typical of high speed internal flow problems of practical importance in the design and analysis of propulsion systems for advanced hypersonic vehicles. These problems are the supersonic flow between two walls, one of which contains a 10 deg compression ramp, the flow through a hypersonic inlet, and the flow in a 3-D *corner formed by the intersection of two symmetric wedges. Three* of the computer codes use similar recently developed implicit upwind differencing technology, while the fourth uses a well established explicit method. The computed results were compared with experimental data where available. Author

N89-18648# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
VALIDATION OF COMPUTATIONAL FLUID DYNAMICS. VOLUME 2: POSTER PAPERS
Dec. 1988 239 p Symposium held in Lisbon, Portugal, 2-5 May 1988
(AGARD-CP-437-VOL-2; ISBN-92-835-0490-9
ISBN-92-835-0491-7) Avail: NTIS HC A11/MF A01

AGARD's Fluid Dynamics Panel has sponsored a Symposium with the specific intent of examining activities, both computational and experimental, directed toward validating or calibrating computational fluid dynamics (CFD) codes over a broad spectrum of fluid-dynamics study areas. The objectives of the Symposium were to identify the level of agreement of numerical solution algorithms and physical models with experimental and/or analytical data, to identify regions of validity for given flow solvers, and to identify flow regions where significant gaps exist *and further work* is warranted. For individual titles, see N89-18649 through N89-18663.

N89-18651# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
FINITE DIFFERENCE METHODS IN RECIRCULATING FLOWS
J. C. F. PEREIRA and F. DURST (Erlangen-Nuremberg Univ., Germany, F.R.). *In* AGARD, Validation of Computational Fluid Dynamics Volume 2: Poster Papers 12 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

Numerical solutions of the two-dimensional Navier-Stokes equations using finite-difference approaches in which different

numerical schemes for the discretization of the convective terms are used are discussed. The errors arising in the solution of the recirculating flows are mainly attributed to the convective discretization schemes and, hence knowledge of different numerical schemes is essential to accurately predict complex recirculating flows. To assess the performance of prediction schemes, it is necessary to carry out predictions in carefully selected laminar flows. For this reason the flows examined are all in the laminar regime and emphasis is given to numerical solutions with laser-Doppler measurements. Author

N89-18656# Erlangen-Nuremberg Univ. (Germany, F.R.).
SOLUTION ERROR ESTIMATION IN THE NUMERICAL PREDICTIONS OF TURBULENT RECIRCULATING FLOWS
R. KESSLER, M. PERIC, and G. SCHEUERER *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 12 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

An efficient method for numerical solution error estimation and its application to numerical predictions of turbulent recirculating flows are presented. A finite volume method with colocated variable arrangement is employed to solve the flow and k-epsilon turbulence model equations. The two-dimensional, turbulent flow over an obstacle in a plane channel is selected to demonstrate the necessity of the error estimation. Recent laser Doppler measurements are available for this geometry. The error estimation method, which is applied to each solution variable, serves two purposes. Firstly, it aids in the construction of an optimum numerical grid. Secondly, the information of the location and magnitude of the numerical errors is essential to draw reliable conclusions from comparisons of numerical results and experimental data. The procedure outlined here is based on Richardson extrapolation and enables an accurate assessment of the performance of the employed turbulence model and, hence, of the complete numerical solution method. Author

N89-18659# Florence Univ. (Italy). Dipt. di Energetica.
ACCURACY AND EFFICIENCY OF A TIME MARCHING APPROACH FOR COMBUSTOR MODELING
A. A. BORETTI and F. G. MARTELLI *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 17 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

Research on numerical modeling of turbulent reactive gas flows is being conducted at the University of Florence Department of Energy Engineering (DEF) to provide improved analytical models of combustion devices. The objective is to develop adequate mathematical models of physical processes and a solution algorithm with suitable numerical properties. Both the flow model and the numerical method adopted are described in detail. Author

N89-18661# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).
INVESTIGATION OF THE ACCURACY OF FINITE VOLUME METHODS FOR 2- AND 3-DIMENSIONAL FLOWS
C. ROSSOW, N. KROLL, R. RADESPIEL, and S. SCHERR *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 11 p (SEE N89-18648 11-34) Dec. 1988
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

The accuracy of finite volume methods for the discretization of the unsteady Euler equations in the cartesian coordinate frame is investigated. For finite volume methods, general requirements are derived for a spatial discretization which yields first order accuracy on arbitrary meshes. An error analysis shows that in two dimensions methods based on a cell vertex scheme meet these requirements whereas methods based on a cell centered scheme do not. Numerical results on different two-dimensional meshes confirm the theoretical statement that only cell vertex schemes perform accurately on grids with slope discontinuities. Using structured coordinate grids for complex three-dimensional flow problems, even cell vertex schemes require additional effort to ensure first order accuracy on arbitrary meshes. The applicability of the cell vertex scheme is demonstrated by the calculation of the flow field in a nozzle and the flow around a powered nacelle. Author

N89-18662# Technische Univ., Brunswick (Germany, F.R.). Inst. fuer Stroemungsmechanik.
DOCUMENTATION OF SEPARATED FLOWS FOR COMPUTATIONAL FLUID DYNAMICS VALIDATION
DIETRICH HUMMEL *In* AGARD, Validation of Computational Fluid Dynamics. Volume 2: Poster Papers 24 p (SEE N89-18648 11-34) Dec. 1988
(Contract DFG-SCHL-5/82; HU254/2; HU254/8; BMVG-T/RF41/90010/81454, BMVG-T/RF41/D0011/01411)
(AGARD-CP-437-VOL-2) Avail: NTIS HC A11/MF A01

In recent years a large number of separated flows have been studied at Institute fur Stromungsmechanik of TU Braunschweig and a lot of experimental data are available. Some flows are well understood in many details and properly documented, so that they can be used as test cases for computational fluid dynamics validation. The topics of separated flows to be treated here are low speed flows around delta wings, double-delta wings and canard configurations as well as hypersonic flows in axial corners of intersecting wedges. The experimental results are summarized. The main results are presented and a detailed documentation is provided on where and in which form these results are available. Author

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INSTRUMENTATION AND PHOTOGRAPHY

Includes remote sensors; measuring instruments and gages; detectors; cameras and photographic supplies; and holography.

N87-20180# Norges Tekniske Hoegskole, Trondheim. Dept. of Physics.
TV-HOLOGRAPHY: A PROMISING INSPECTION TOOL FOR ANALYSIS OF COMPOSITE MATERIALS
OLE J. LOKBERG, JAN T. MALMO, and ARVID STRAND (Conspectum A/S, Trondheim, Norway.) *In* AGARD The Repair of Aircraft Structures Involving Composite Materials 7 p (SEE N87-20174 13-01) Oct. 1986
(AGARD-CP-402) Avail: NTIS HC A11/MF A01

Holographic measuring techniques combined with the speed and convenience of video recording and display, provide a real-time system which can be used to reveal extremely small movements. By various excitation-like heating, pressure and vibrations, we detect object defects and structural weaknesses. The system's construction and its modes of operation are discussed. Finally some examples are given of the applications of the system. Author

N87-20359# MATRA Espace, Toulouse (France). Dept. of Satellite Engineering.
QUALIFICATION OF THE FAINT OBJECT CAMERA
PATRICE AMADIEU *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 13 p (SEE N87-20355 13-18) Jul. 1986
(AGARD-CP-397) Avail: NTIS HC A12/MF A01

The Faint Object Camera (FOC) is presently integrated as one of the five Scientific Instruments in the NASA Space Telescope (ST) which after an extensive integration and tests campaign should be launched in 1986. The Space Telescope is an observatory of 13 metres long, 4.3 metres diameter and 11,000 kilogrammes which will be placed by the Space Shuttle in a 500 kms circular orbit. The Faint Object Camera installed at the ST focal plane is a complex instrument with a total weight of 320 kgs and overall dimensions 1 x 1 x 2.2 metres. A Structural/Thermal Model (STM) and flight model of the FOC have been built. The FOC/STM was subjected to an extensive test program with for the mechanical part, sine and random vibrations, acoustic noise and modal test. On the FOC/PFM, acoustic noise only was applied for workmanship verification. With the FOC integrated now in the Space Telescope and considering the specimen overall dimensions, limited mechanical testing will be applied at ST level which will consist of modal survey and acoustic noise. Then at the end of the test program, the overall assembly will be shipped to Kennedy Space Center and launched. Author

N87-21187# Land Turbine Sensors, Inc., Tullytown, PA.
SOME CONSIDERATIONS RELATING TO AERO ENGINE PYROMETRY
P. J. KIRBY *In* AGARD Advanced Instrumentation for Aero Engine Components 14 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

With turbine blade optical pyrometry rapidly becoming acccpted by the aerospace community as a viable flight control technique, some of the traditional and emerging demands are described, with examples of how they are being addressed. Many of these demands are now being met by skillful application of materials technology, electronic engineering, signal processing and fluid flow techniques, but it is probable that flight conditions will impose a more pragmatic approach than customarily adopted towards test bed installations. Author

N87-21188# Technische Hochschule, Aachen (Germany, F.R.). Inst. for Jet Propulsion and Turbomachinery.
TURBINE ROTOR BLADE MEASUREMENTS USING INFRARED PYROMETRY
W. KOSCHEL, D. SALDEN, and T. HOCH *In* AGARD Advanced *Instrumentation for Aero Engine Components* 16 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-3: ?) Avail: NTIS HC A24/MF A01

An infrared pyrometer system was developed for the noncontacting measurement of metal temperatures on turbine rotor blades. The system with a high bandwidth ratio, a small target size and a high signal-to-noise ratio meets the requirements for the accuracy of temperature measurements to be performed on small gas turbines running at high speeds. The system set-up is described and special features of the probe head design, the lay-out of the detector/amplifier unit and the signal processing are discussed in detail. Results of the automated calibration of an infrared pyrometer system concerning the influence of variations in the target-to-lens distance, in the lens stop diameter and in the observation angle on the detector signal output are reported. Finally some results of temperature measurements obtained for the cooled rotor blades of a small research turbine are presented. Author

N87-21194# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
PROCESSING TECHNIQUES FOR CORRELATION OF LDA AND THERMOCOUPLE SIGNALS
M. N. R. NINA and G. P. A. PITA *In* AGARD Advanced Instrumentation for Aero Engine Components 8 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

A technique was developed to enable the evaluation of the correlation between velocity and temperature, with laser Doppler anemometer (LDA) as the source of velocity signals and fine wire thermocouple as that of flow temperature. The discontinuous nature of LDA signals requires a special technique for correlation, in particular when few seeding particles are present in the flow. The thermocouple signal was analog compensated in frequency and the effect of the value of time constant on the velocity temperature correlation was studied. Author

N87-21202# Warwick Univ. Coventry (England). Dept. of Engineering
THE APPLICATION OF HOLOGRAPHY AS A TRANSONIC FLOW DIAGNOSTIC TO ROTATING COMPONENTS IN TURBOMACHINERY
P. J. BRYANSTON-CROSS *In* AGARD Advanced Instrumentation for Aero Engine Components 22 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

A review is presented of the application of holography as a whole field flow visualization diagnostic in turbomachinery. Starting with two dimensional cascade testing, which required wavelength toleranced optical tables, it has now been found possible to obtain results with bolt-on optical components. In order to achieve this, compromises have been made in optical quality and attention has been given to the nature of the data required. Holographic systems are shown which have been applied to visualize the flow in a linear cascade, an annular cascade, a three dimensional compressor shock in a rotating flow and a diffuser blockage observed in a rotating turbocharger. Author

N87-29478# Marconi Avionics Ltd., Rochester (England). Guidance Systems Div.
A LOW COST GYROSCOPE FOR GUIDANCE AND STABILISATION UNITS
D. G. HARRIS *In* AGARD, Advances in Guidance and Control Systems and Technology 9 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

The potential requirements for a rugged moderate accuracy low cost gyro are very large, especially in smartening simpler weapons. Suitable candidate weapons are identified and a composite specification derived for gyroscopes that would satisfy the guidance and stabilization requirements. A development program is then described which is aimed at producing a suitable gyro by the combination of a well established principle for angular rate measurement and the latest materials and electronic techniques. A considerable effort was expended on basic experimental work before prototype batches of gyros were made. Results from the test of the later can survive cannon firing without performance degradation. This was demonstrated by informal tests with potential customers. The discipline of regular estimates of unit production cost was firmly maintained to avoid a major pitfall of sub-inertial quality gyro design. However, there are many past projects which bear witness to the fact that this is an unforgiving art and the necessity for continuous attention to detail must be maintained if the START design is to be successfully taken through to mass production. Author

N87-29479# Naval Air Development Center, Warminster, PA. Strapdown Navigation Lab.
JOINT DEVELOPMENT OF THE MULTI-FUNCTION INTEGRATED INERTIAL SENSOR ASSEMBLY (MIISA)
JACK JANKOVITZ, DAVID KRASNJANSKI, and ANDREW S. GLISTA, JR. (Naval Air Systems Command, Washington, D. C.) *In* AGARD, Advances in Guidance and Control Systems and Technology 9 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

The U.S. Navy, Air Force, and Army are in the process of formalizing the joint service development and flight evaluation of the Multi-Function Integrated Inertial Sensor Assembly (MIISA). The MIISA concept will provide a reliable, standardized, fault-tolerant, system which will serve as a common source of inertial data. MIISA will provide data for flight control, navigation, weapon delivery, automatic terrain following terrain avoidance, sensor/tracker stabilization, flight instruments, and displays. A primary goal of this joint service activity is to resolve all technical issues and make this capability available for the next generation fighter and attack aircraft and for advanced helicopters. The Navy program to design, build, and evaluate an IIISA Advanced Development Model was begun. To insure that the IIISA is suitable for installation and flight test in an Air Force F-15, extensive laboratory testing will be undertaken at the NAVAIRDEVCEN Strapdown Navigation Laboratory. These tests involve the examination of IIISA system performance for navigation and flight control. These tests are discussed. Author

N88-23145# Case Western Reserve Univ., Cleveland, OH. Dept. of Mechanical and Aerospace Engineering and Chemical Engineering.
MATCHED INDEX LASER ANEMOMETRY SYSTEMS FOR FLOW STUDIES IN COMPLEX GEOMETRIES
A. DYBBS, R. V. EDWARDS, and E. RESHOTKO *In* AGARD, Aerodynamic and Related Hydrodynamic Studies Using Water Facilities 18 p (SEE N88-23125 16-34) Jun. 1987 Sponsored in part by Case Center for Complex Flow Measurements, C3FM
(Contract N00014-84-K-0294; NSF CME-79-13389)
(AGARD-CP-413) Avail: NTIS HC A20/MF A01

Optical access to the flow is necessary if laser anemometry is to be used to map a given flow field. Often this access is difficult or impossible to obtain because of the shape of the object about which (or within which) the flow exists. Examples are flows in porous media, fluidized beds, heat exchangers, or near sinusoidal surfaces. Making the object of transparent material such as of glass or plexiglas is not sufficient to provide a reliable, useable optical environment for laser measurements. It is often necessary to use a fluid whose index or refraction matches that of the object. Author

N88-27525# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
FLIGHT TESTING UNDER EXTREME ENVIRONMENTAL CONDITIONS
CLENDON L. HENDRICKSON (Air Force Flight Test Center, Edwards AFB, Calif.) Jun. 1988 73 p
(AGARD-AG-300-VOL-8; ISBN-92-835-0459-3; AD-A197579)
Avail: NTIS HC A04/MF A01

The major objective of Flight Testing under extreme environmental conditions is to determine to what extent a weapon system, including its essential support equipment and attendant crews can accomplish the design mission in the required climatic extremes, using Technical Order procedures. Such testing has historically often revealed design deficiencies that impact the operational capabilities of the air vehicle involved. This volume in the AGARD Flight Test Techniques Series discusses the philosophy, purpose and methods for conducting ground and flight tests of weapon systems in extreme environment conditions. The areas considered include testing in a controlled artificial environment, as well as cold arctic, hot desert, tropic, and adverse-weather conditions. Also included are the technical and safety aspects of planning, instrumentation, and data acquisition requirements, types of tests conducted and reporting requirements. Author

N88-28287# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THE ANATOMY OF THE GYROSCOPE
FRANK W. COUSINS and JOHN L. HOLLINGTON, ed. (Smiths Industries Aerospace and Defence Systems Ltd., Cheltenham, England.) Feb. 1988 200 p
(AGARD-AG-313; ISBN-92-835-0441-0; AD-A197162) Avail: NTIS HC A09/MF A01

This report on the gyroscope and its applications collates the technical information to be found in the patent literature, augmented by that in text books and technical journals. The report is in three parts: Part 1 is a patent survey arranged in a detailed classification; Part 2 comprises a bibliography of the references in Part 1; and Part 3, published as a separate volume, gives historical notes and comments on the material of Parts 1 and 2. Author

N89-17608# Litton Technische Werke, Freiburg (Germany, F.R.)
PACKAGED FIBER OPTIC GYROS
H.-J. BUESCHELBERGER and W. SCHROEDER *In* AGARD, Guidance and Control of Precision Guided Weapons 7 p (SEE N89-17605 10-15) Nov. 1988
(AGARD-CP-435) Avail: NTIS HC A05/MF A01

An overview of the Fiber Optic Gyroscope (FOG) - Attitude and Heading Reference Systems (AHRS) program and the outlook for the application of FOG for smart munitions are given. The main program is for the development of a FOG with a drift stability of 0.1 o/h, which is the class for strapdown AHRS. Flight tests with the LTR-81, Litton Technische Werke's standard AHRS, are scheduled for the end of 1988. Author

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LASERS AND MASERS

Includes paramagnetic amplifiers

N87-13286# Plessey Co. Ltd., Romsey (England)
A STUDY OF METHODS OF PHASE NOISE REDUCTION OF SEMICONDUCTOR LASERS FOR SENSOR APPLICATIONS
J. P. DAKIN and P. B. WITHERS *In* AGARD Guided Optical Structures in the Military Environment 7 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Many optical sensors based on fiber interferometry have been proposed. The majority of these use interferometers of the Mach-Zehnder or Michelson type, in which the optical path lengths of the two arms are often unequal. Under these conditions, a highly coherent light source is necessary to avoid signal/noise degradation due to fluctuations in the phase or frequency of the source. Single mode gas lasers are sufficiently coherent, but their large size, critical alignment requirements, and cost, limit their appeal as light sources for optical sensors. Semiconductor lasers, *however, are compact, rugged and potentially low-priced devices*, but the magnitude of the phase noise is such that, to obtain microradian sensitivity in interferometric sensors, only path differences less than one millimetre between the signal and reference arms can be tolerated. This imbalance may be increased if the magnitude of the laser phase noise can be reduced using either passive optical feedback or active control of the laser drive current. Both approaches are described. Described first are proposed experiments to examine the feasibility of using an array of suitably spaced mirrors to provide passive optical feedback. Secondly, experiments to measure phase noise reduction produced by active control of the laser drive current are reported together with their results. Author

N87-21177# *Deutsche Forschungs- und Versuchsanstalt fuer* Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Antriebstechnik.
LASER-2 FOCUS VELOCIMETRY
R. SCHODL *In* AGARD Advanced Instrumentation for Aero Engine Components 31 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

A review is given of various publications about L2F-velocimetry. Main emphasis is placed upon the important new advances of *this technique. The manner* of statistical data analysis of turbulent flows including the simplified version which enables a time-saving measuring procedure is described in some detail. The influence of beam diameter - beam separation ratio on the measuring accuracy and on the measuring time is treated. The capability of the L2F-system at close-to-wall measurements could be further improved. Results of measurements in a very *small flow channel* and in a small turbocharger compressor rotor are presented. The 3-D version of the L2F-system was successfully operated recently. The principle, the optical set-up and the signal processing are described and some first results are presented. A comparison between Laser Doppler (LD) - and Laser 2 Focus (L2F) velocimeters gives answers about such signal properties as amplitude and rate, the smallest detectable particles and about the measuring time needed, based on the probe volume dimensions. Author

N87-21178# Cranfield Inst. of Tech., Bedford (England). School of Mechanical Engineering.
SEEDING GAS FLOWS FOR LASER ANEMOMETRY
A. MELLING *In* AGARD Advanced Instrumentation for Aero Engine Components 11 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The seeding of gas flows for laser anemometry is reviewed. *The specification and determination of the size of seeding particles* to ensure both an adequate response to velocity changes of the flowing medium and a sufficient light scattering capability are examined critically. A compromise between these conflicting criteria is generally given as an upper limit on acceptable particle size, expressed as the diameter of an equivalent spherical particle. Problems arise in defining and quantifying this equivalent diameter, generating particles of suitable size from a given material, measuring the particle size distribution at the generator exit, and determining the size distribution actually seen by the laser anemometer. Recommendations are made for particle generators, sizing methods, and interpreting the significance of quoted particle distributions for laser anemometry purposes. Author

N87-21180# Cranfield Inst. of Tech., Bedford (England). School of Mechanical Engineering.
APPLICATION OF DOPPLER AND TRANSIT LASER ANEMOMETRY IN SMALL TURBOMACHINES
R. L. ELDER, C. P. FORSTER, and M. E. C[illegible] AGARD Advanced Instrumentation for Aero Engine [illegible]s 15 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The selection laser anemometry systems and their application *to the particularly hostile environment found in small high speed* rotating turbomachines are discussed. There are several different laser anemometry systems which are used in turbomachinery studies and when selecting a system to carry out specific duties it is necessary to have some prior knowledge of the flows to be measured, the spacial resolution required and any limitations on

optical access. The optical access will often determine the spatial resolution possible and the quality of the scattered signal will generally determine the type of signal processor which can be used. The criteria used for the selection of systems at Cranfield are discussed. The arrangements in use include both the Doppler and transit systems each of which are found to have unique and very distinct advantages. Author

N87-21181# Pratt and Whitney Aircraft, East Hartford, CT.
LASER VELOCIMETRY STUDY OF STATOR/ROTOR INTERACTIONS IN A MULTI-STAGE GAS TURBINE COMPRESSOR
M. CARLSON WILLIAMS *In* AGARD Advanced Instrumentation for Aero Engine Components 10 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The measurement of airflow through multi-stage compressor rigs has generally been limited to the use of flow perturbing pressure and temperature probes. Although limited studies of the dynamics of these flows have been obtained with hot wire and hot film probes, the advent of the laser Doppler velocimeter (LDV) with its non-perturbing nature is expected to develop into the preferred instrumental method. To assess the feasibility of utilizing an LDV in these flows an exploratory program was recently undertaken at Pratt and Whitney. A multi-stage compressor rig, the Energy Efficient Engine high pressure compressor consisting of 6th through 15th compressor stages, was outfitted with windows between the 6th stator-7th rotor, 9th stator-10th rotor, and 13th stator-14th rotor. The windows, extending circumferentially one stator gap wide, permitted the hub to tip traversing midway between the stator trailing edge and the rotor leading edge both in and out of the stator wakes. A confocal two color, two component back scatter LDV system developed for use in gas turbine environs was employed to obtain detailed mappings to velocity magnitude and air angle as a function of rotor position at several spanwise and gapwise positions downstream of the 6th and 9th compressor stators. Although a complete mapping was not obtained, sufficient data was acquired behind the 13th stator to identify the flow's character there as well. The equipment employed in this study and the difficulties encountered are described. Author

N87-21201# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
THE STUDY OF COMBUSTION BY MEANS OF DIODE LASER SPECTROSCOPY
B. ROSIER, P. GICQUEL, and D. HENRY *In* AGARD Advanced Instrumentation for Aero Engine Components 11 p (SEE N87-21170 14-31) Nov. 1986 Original language document was announced as A86-46182
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The experimental apparatus and results with a diode laser spectrometer used to obtain absorption signatures of premixed methane-air burning in a furnace are reported. A tunable laser was used to scan the reaction zone with an acuity of 1900 lines/cm. Absorption data collected from the furnace were compared with reference spectra of known gases. Pulse frequencies of 50 Hz to 1 kHz were explored. The data obtained were useful for characterizing the temperatures and composition of the burning gases, identifying the presence of cold layers, and quantifying the mass concentrations of various gases along the flame front.
Author

N87-29475# Eltro G.m.b.H., Heidelberg (Germany, F.R.).
EYE SAFE RAMAN LASER RANGE FINDER FOR GROUND AND AIRBORNE APPLICATION
J. RUGER *In* AGARD, Advances in Guidance and Control Systems and Technology 9 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

The need for an eye safe laser for military fire control systems, especially in the function as a range finder is described. The performance achieved with a Raman shifted Neodymium-YAG laser with a resulting wavelength of 1.54 microns is given in detail and compared to that of a 1.064 and 10.6 micron laser range finder under various atmospheric conditions. The use of the Raman range finder in prototype equipment contracted by the German MOD is described showing the advantages of eye safety and superior ranging performance as compared to the Neodymium-YAG laser range finder Author

N88-13228# Institut Franco-Allemand de Recherches, Saint-Louis (France). Dept. d'Aerodynamique.
AN ULTRA-HIGH-SPEED CINEMATOGRAPHIC METHOD FOR THE STUDY OF WAKES IN HYPERSONIC BALLISTIC RANGES [UNE METHODE CINEMATOGRAPHIQUE ULTRA-RAPIDE POUR L'ETUDE DES SILLAGES EN TUNNEL DE TIR HYPERSONIQUE]
AXEL KOENEKE, BERNARD CHARLES JAEGGY, and GERMAIN KOERRER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 13 p (SEE N88-13219 05-02) Nov. 1987
In FRENCH
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Optical methods are among the only possibilities to study hypersonic wakes in ballistic ranges. Because of the flow velocities involved the methods employed must permit exposure time well below one microsecond. The ISL has used ultrahigh speed visualization techniques for the study of the transition of hypersonic wakes for quite some time, but the means available up to now did not permit investigation of the time-history of the instabilities in the wake. The use of a laser equipped with an acousto-optical modulator is proposed as a source of ultrashort, highly energetic pulses with high repetition rate to be used to record a certain number of images of the same experiment in order to study the time history of these instabilities. Advantages of the laser as a light source are not only the high energies available together with pulse duration down to 20 nanoseconds, but mostly the free choice of repetition rate independently of exposure time, and the possibility to synchronize the pulses with external events. The laser is a point source and as such can be used in a variety of different optical setups. The coherent nature of the laser light even permits holographic techniques. The reception system capable of recording the images at a sufficient rate is the basic problem in the development and use of the proposed setup. Author

N89-12849# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
LASER APPLICATIONS IN FLOW DIAGNOSTICS
J. D. TROLINGER and J. J. GINOUX, ed. (Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese, Belgium.) Oct. 1988 189 p
(AGARD-AG-296; ISBN-92-835-0480-1, AD-A203450) Avail: NTIS HC A09/MF A01

This is an explanation and update of AGARDograph No. 186, Laser Instrumentation for Flow Field Diagnostics, which was published in 1974. A brief introduction to coherent optics and lasers is given to provide a review and common language to the reader. The material is presented at a level to be understood by engineers who are working in the aerospace field and who are interested in the experimental application of lasers in research and development. An emphasis is placed on applications in aerodynamics, and examples were selected from a number of laboratories in the NATO countries visited while the material was being prepared. The applications include holography, laser velocimetry, spectroscopy, and the use of lasers simply as efficient light sources in conventional measurement methods. Author

N89-17606# Raytheon Co., Sudbury, MA. Equipment Div.
CO2 LASER RADAR SYSTEMS FOR TARGET ACQUISITION AND GUIDANCE
A. V. JELALIAN, G. R. OSCHE, D. R. BATES, and A. J. LEGERE *In* AGARD, Guidance and Control of Precision Guided Weapons 14 p (SEE N89-17605 10-15) Nov. 1988
(AGARD-CP-435) Avail: NTIS HC A05/MF A01

Laser radar systems combine the narrow beam width associated with optical systems with target measurement capabilities of microwave radar systems. The combined attributes of these distinctly different technologies lead to a single sensor capable of measuring range, velocity acceleration and angular location while still providing imaging capability. The best optical source for systems having this capability is the CO2 laser operating in the infrared band at 10.6 microns. Atmospheric propagation, coherent and incoherent detection receivers, and field test data collected over the past two decades are assessed. Author

N89-17714# Royal Signals and Radar Establishment, Malvern (England).
COHERENT SCATTERING FROM RANDOM MEDIA
C. J. OLIVER *In* AGARD, Scattering and Propagation in Random Media 12 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The representation and simulation of clutter textures in coherent scattering is discussed in terms of a correlated noise model initially expressions for the detected intensity when coherent radiation is scattered from a surface with fluctuating cross-section are derived demonstrating how the effects of surface statistics and correlation properties interact with the imaging function. Secondly, a model for the cross-section fluctuations based on negative-binomial or gamma-distributed statistics is propesed. When coherent radiation is scattered by a surface with these properties the resulting intensity distribution can be shown to be K distributed. Having derived theoretical predictions for the correlated noise model with a variety of spectral forms a texture simulation technique is proposed based on linear filtering which duplicates the two-point correlation properties of the observed intensity. Finally, a comparison of original image data, simulated textures, and the theoretical model is made for a number of examples of differing textures of both natural and manmade clutter Author

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MECHANICAL ENGINEERING

Includes auxiliary systems (nonpower); machine elements and processes; and mechanical equipment.

N86-29236# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AIRCRAFT AND BEARING TRIBOLOGICAL SYSTEMS
Feb. 1986 232 p Meeting held in San Antonio, Tex., 22-26 Apr. 1985
(AGARD-CP-394; ISBN-92-835-1509-9; AD-A168241) Avail: NTIS HC A11/MF A01

Advances in aircraft gear and bearing tribology are discussed. Future trends and problems, gear and bearing materials, and lubricants are discussed. For individual titles see N86-29237 through N86-29254

N86-29237# Westland Helicopters Ltd., Yeovil (England)
THE VALUE OF LABORATORY SIMULATION TESTING FOR PREDICTING GEARBOX PERFORMANCE
P. B. MACPHERSON *In* AGARD Aircraft and Bearing Tribological Systems 11 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

The evolution of a successful gearbox design involves much development testing which is both time consuming and expensive. For this reason full advantage should be taken of laboratory simulation tests for which, to be successful, predictions must, obviously, be reliable. Some of the more salient aspects of simulation testing are set out along with a few examples drawn from the author's experience. Heat treatment design rules,future test methods, and testing machines are discussed Author

N86-29238# Schaefer (Georg) and Co., Schweinfurt (Germany, F.R.).
EFFECTS OF UNFAVORABLE ENVIRONMENTAL CONDITIONS ON THE SERVICE LIFE OF JET ENGINE AND HELICOPTER BEARINGS
H. K. LOROESCH *In* AGARD Aircraft and Bearing Tribological Systems 9 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

Aircraft bearings normally operate at high speeds and have to meet demanding reliability requirements. If conventional guidelines for their design are used, the resultant stresses are low. The stresses are particularly low if compared to those customarily applied in testing rolling fatigue. Potential fatigue life, the influence of plastic deformation in the raceways, the influence of surface damage and loading, service life under favorable lubricating conditions, achievable fatigue life at loads above the endurance limit, and the influence of contamination are discussed. Author

N86-29239# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.)
AERO-ENGINE GEARS: MANUFACTURING CRACKS AND THEIR EFFECT ON OPERATION
J. SPECHT *In* AGARD Aircraft and Bearing Tribological Systems 10 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

The effect of cracks in gear splines is discussed. After black-oxidising of case-hardened gears, stress corrosion cracking may occur. This was determined from damage analysis of cracked gears of flight engines and from sample testing. Besides design measures to reduce operational stresses, corrective action may be in the form of modified manufacturing procedures and improved crack inspection. Author

N86-29240# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Inst. for Technical Physics.
TRIBOLOGY IN AIRCRAFT SYSTEMS: BASIC PRINCIPLES AND APPLICATIONS
E. JANTZEN and V. BUCK *In* AGARD Aircraft and Bearing Tribological Systems 13 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

The historical origin of the name tribology is outlined. The trends for the next two decades are reviewed: reduction of fuel consumption, improvement of the ratio of specific output to weight, reduction of maintenance, and further improvement of safety. Then the consequences from these trends are outlined with respect to research in tribology. The current status of research is sketched and some unsolved problems are discussed: interaction of material/lubricant in areas with mixed friction (reaction layers); interaction of material/lubricant in the hydrodynamic region; friction and wear of synthetic bearings with and without lubrication, friction, wear and service time if solid lubricants are used; and topographical features of surfaces. Many government sponsored research to gain the wide spread of basic knowledge necessary for new and better solutions Author

N86-29241# Schaefer (Georg) and Co., Schweinfurt (Germany, F.R.).
DESIGN AND CALCULATION OF HIGH SPEED ENGINE BEARINGS
H. J. KOEBER *In* AGARD Aircraft and Bearing Tribological Systems 12 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HCA11/MF A01

New aspects in design and calculation of high speed ball and roller bearings are discussed in as much as they affect bearing performance in the speed range of DxN = 3.0 x 1 million min-1 and beyond. For roller bearings the guide flange to roller end configuration as well as roller excursion within the cage pocket are linked to the phenomena of skewing and skidding. The need for under-race-lubrication in small diameter engine bearings is derived from this and a special solution (integral scoop) is shown along with related performance data. The influence of incorporating state of the art rolling elements made of silicon nitride on the design and calculation of high speed ball and roller bearings is shown taking into account hardness, density, Young's modulus and the Poisson ratio. Increase speeds coupled with additional design features being incorporated (such as lubrication holes, grooves, slots) require that inner rings of improved fracture toughness be developed with existing materials of known properties thus supplementing the material development activities already under way Author

N86-29243# KHD Luftfahrttechnik G.m.b.H., Oberursel (Germany, F.R.)
MULTIFUNCTIONAL REQUIREMENTS FOR A GEARBOX SECONDARY POWER SYSTEM IN A MODERN FIGHTER AIRCRAFT AND ITS COMPONENTS AND INTERFACE REQUIREMENTS
M. PUCHER *In* AGARD Aircraft and Bearing Tribological Systems 14 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

The basic task of the gearbox in a Secondary Power System (SPS) of an aircraft is to provide and distribute mechanical energy

from the Auxiliary Power Unit (APU) or from the Main Engine (ME) to the accessories, e.g., generators, hydraulic pumps and fuel pumps. The complexity as well as the functional facilities increase by incorperating further functionnal requirements such as main engine start, cross drive operation between redundant systems with the associated control devices, including oil supply to the accessories into the gearbox oil system. The Tornado-SPS is one of the most modern systems flying today. The system shows a high reliability although the aircraft has been in service for only a few years. The experience gained with major components like gearbox housing, gearing, freewheel clutches, dry friction cluthes and components of the oil system is reported. Some aspects from this experience are given for the design of gearboxes for future secondary power systems. Author

N86-29246# Westland Helicopters Ltd., Yeovil (England). Materials Lab.
THE ROLE OF RESIDUAL STRESS IN THE PERFORMANCE OF GEARS AND BEARINGS
A. V. OLVER *In* AGARD Aircraft and Bearing Tribological Systems 16 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

Residual stresses are an inevitable consequence of the manufacture and service conditions to which mechanical components are subjected. A wide range of evidence is presented to show the decisive effect of residual stress, both pre-existing and service induced, on the performance of gears and rolling element bearings. The results of measurement of residual stresses arising from a range of manufacturing procedures are presented, particular emphasis being placed on carburized steels. The effect of such stresses on fatigue performance is demonstrated. Possible causes of residual stress change during service are reviewed and the results of new experimental and theoretical work on the role of residual contact stress in a number of relevant tribological failure modes are presented. Author

N86-29247# Technische Hogeschool, Eindhoven (Netherlands). Dept. of Mechanical Engineering.
THE LUBRICATION OF DYNAMICALLY LOADED CONCENTRATED HARD LINE CONTACTS: TEMPERATURE AND PRESSURE MEASUREMENTS
M. J. W. SCHOUTEN, H. J. VANLEEUWEN, and H. A. MEIJER *In* AGARD Aircraft and Bearing Tribological Systems 12 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

Some results of temperature and pressure measurements in two types of dynamically loaded concentrated contacts are reported, viz., a cam-flat follower contact and a cylindrical roller - outer race contact. The measurement technique utilizes miniature vapour deposited thin layer transducers and a counter current circuit and an amplifier. These first results are very encouraging. The transducers worked well, even under very adverse conditions of pure sliding and dynamic loads. Author

N86-29248# Atlantic Industrial Research Inst., Halifax (Nova Scotia).
WEAR OF HIGH SPEED ROLLER BEARINGS
T. SAVASKAN, E. E. LAUFER (Nova Scotia Technical Coll., Halifax), and D. E. VEINOT (Defence Research Establishment Atlantic, Dartmouth, Nova Scotia) *In* AGARD Aircraft and Bearing Tribological Systems 12 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

A laboratory bearing test rig was constructed to study wear in three high-speed roller bearings simultaneously under different conditions of loading and lubrication. A test run of 355 hours duration was performed during which wear of the bearings was monitored using DR ferrography. The test bearings from the rig were examined using metallography and microhardness measurements. Wear debris particles were collected from oil samples using ferrography. These were studied using bichromatic microscopy, scanning electron microscopy and energy dispersive X-ray analysis. The results of ferrography were correlated with the metallographic results. Author

N86-29254# Blok (Harmen), Rijswijk (Netherlands).
CRITICAL ANALYSIS OF ACHIEVEMENTS AND MISSING LINKS IN GEAR AND BEARING TRIBOLOGY IN RELATION TO POWER ENVELOPES
H. BLOK *In* AGARD Aircraft and Bearing Tribological Systems 15 p (SEE N86-29236 20-37) Feb. 1986
(AGARD-CP-394) Avail: NTIS HC A11/MF A01

Power envelopes provide a convenient and informative basis of comparison for the development of gear transmissions towards higher power densities. Each such envelope consists of a sequence of segments representing power barriers due to a variety of critical phenomena. Most of these phenomena and barriers are tribologically affected. They may be exemplified by the occurrence of contact between the rubbing surfaces whenever a fully separating lubricant film can no longer be maintained and, further, by pitting and scuffing. For every gear transmission at least two power envelopes have to be considered in conjunction, i.e., for the most vulnerable pair of gears and rolling-element bearing, respectively. The trends of these two envelopes, as well as their mutual position, depend on the configuration of the major elements in the transmission concerned and on certain tribologic characteristics of the solid rubbing materials and the lubricant. The power envelopes, being tribologically affected, prove useful for developing tribology into tribotechnology, so as to enable its integration into the design of gear transmissions. Once certain missing links have been filled in, tribology may provide breakthroughs for developing the technology of both gears and bearings to the high-tech level required for creatively increasing the power densities permissible in gear transmissions. Here, the concentration is upon those segments of the two power envelopes that are called contact barriers. Author

N86-31064# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
DESIGN OF BOLTED JOINTS IN COMPOSITES
1985 27 p Presented at the 60th Meeting of the Structures and Materials Panel of AGARD, San Antonio, Tex., 21-26 Apr. 1985
(AGARD-R-727; ISBN92-835-1531-5; AD-A171308) Avail: NTIS HC A03/MF A01

This publication contains three papers heard by the Structures and Materials Panel Sub-Committee on Mechanically Fastened Joints in Composites. The papers survey the various parameters governing the behaviour of bolted joints, and give some experimental data representative of behaviour under load. It is concluded that poor static strength, rather than good fatigue strength, is a characteristic of this type of joint; a Panel Specialists Meeting is to review the topic. Author

N87-17051# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
ADVANCED JOINING OF AEROSPACE METALLIC MATERIALS
Jul. 1986 270 p in ENGLISH and FRENCH Meeting held in Oberammergau, West Germany, 11-13 Sep. 1985
(AGARD-CP-398; ISBN-92-835-0397-X; AD-A173979) Avail: NTIS HC A12/MF A01

The papers contained in this report provide a review of the state-of-the-art of advanced joining techniques currently available to the manufacturers of aerospace equipment and identify newly emerging techniques and joining problems. Computational weld mechanics, diffusion bonding and superplastic forming, electron-beam welding, tungsten inert gas welding, inspection methods, and repair techniques are addressed. For individual titles see N87-17052 through N87-17071.

N87-17052# Carleton Univ., Ottawa (Ontario). Dept. of Mechanical and Aeronautical Engineering.
COMPUTATIONAL WELD MECHANICS
JOHN GOLDAK, BALVANTRAI PATEL (Engineering Mechanics Research, Inc., Troy, Mich.), MALCOLM BIBBY, and JAMES MOORE *In* AGARD Advanced Joining of Aerospace Metallic Materials 32 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

An overview of the aims and methods of computational weld mechanics is presented. In particular, relevant literature and recent developments in the authors' laboratory are described. The

presentation emphasizes an exposition of the computational principles and the application of computational weld mechanics to practice. In fact, the primary aim of the work is to transfer this technology from the research specialists who are developing it to the engineers who must apply it in the design and production of welded structures. The numerical methods, algorithms, software and computer hardware needed for computing the temperature, displacement, strain and stress fields associated with the welding process are described. While computer methods are widely applied in the engineering community, thermal strain-stress transients are rarely calculated in welding because of the complexity of the problem. Finite element analysis (FEA) together with the equations of continuum mechanics and irreversible thermodynamics forms the basis for a successful analysis of welding processes. The special problems encountered when FEA is used for weld analysis are discussed in detail. Particular attention is focussed on transient temperature field computations. Modelling heat sources, nonlinear thermal properties, the heats of fusion and transformation, and workpiece geometry and boundary conditions are discussed. Predicting relevant properties (strength, hardness, etc.) of weld joints from computed temperatures is included. In addition, thermo-elasto-plastic analysis for calculating residual strain, stresses and workpiece deformation is described. Measured thermal and distortion changes are compared to computed values as a means of verifying the accuracy of the computational methods. Finally, the computing environment (hardware and software) for computational weld mechanics is discussed at some length.
Author

N87-17053# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris (France). Lab. Assemblage Metallurgique.
STUDY OF THE ELECTRON BEAM WELDABILITY OF SUPERALLOYS THROUGH THE ANALYSIS OF MELT ZONE MORPHOLOGY
F. PIERQUIN and J. LESGOURGES *In* AGARD Advanced Joining of Aerospace Metallic Materials 22 p (SEE N87-17051 09-37) Jul. 1986 *In* FRENCH; ENGLISH summary
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Characterized by high specific energy, the electron beam allows a high welding velocity. The melted zones and heat affected zones are narrow and the thermal cycles involved are short, and therefore, the weld joints are submitted to high stresses. Thus, welding of high strength superalloys raises hot cracking problems, due to their low ductility. The configuration of the melted pond is logically recognized as an important factor in the generation of defects and on their type: vertical cracks, horizontal cracks, axial cracks, spike cracks, etc. To extend the applications of the process, a technique was developed to investigate the melted pond morphology and establish a correlation with the type of defects observed. The process, based on the pollution of the melted pond at a given time during welding, reveals, through micrographic examination, the solidification front configuration.
Author

N87-17054# Welding Inst., Cambridge (England). Solid Phase Welding Group.
THE APPLICATION OF DIFFUSION BONDING AND LASER WELDING IN THE FABRICATION OF AEROSPACE STRUCTURES
S. B. DUNKERTON and C. J. DAWES *In* AGARD Advanced Joining of Aerospace Metallic Materials 12 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

A review is given of work undertaken in both diffusion bonding and laser welding which is relevant to the aerospace industry. The wide use of superplastic forming/diffusion bonding of titanium alloys is mentioned with reference to particular applications. This is extended to include the newly developed superplastic aluminum alloys and data are presented on the diffusion bonding of conventional aluminum materials. The laser welding of aluminum, steel, nickel alloys and titanium alloys is covered with detail given on mechanical properties such as tensile and fatigue. The weld quality is shown to be tolerant to changes in process parameters by means of weldability lobes while dimensional tolerances such as beam/joint alignment and component fit-up can be critical. Finally, the development of laser beam spinning is mentioned with data on the increased tolerance to joint mismatch.
Author

N87-17055# Messerschmitt-Boelkow-Blohm G.m.b.H., Augsburg (Germany, F.R.). Materials and Technologies.
ECONOMICAL MANUFACTURING AND INSPECTION OF THE ELECTRON-BEAM-WELDED TORNADO WING BOX
JUERGEN BERGGREEN *In* AGARD Advanced Joining of Aerospace Metallic Materials 7 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

The Tornado wing box is an extensively electron-beam-welded titanium 6Al4V-alloy component. The design and the manufacturing steps are described with emphasis on joining and inspection techniques. As EB-welding requires expensive investments and operations the manufacturing costs have been cut by several means which are shown. The advantages of EB-welding on the material's side and the experience gained with this technique meanwhile allow the use of EB-welding for major titanium structures even with thick cross sections as a well-known and established and no longer uneconomic advanced joining method.
Author

N87-17056# Aeritalia S.p.A., Turin (Italy). Space System Div.
THE WELDING OF ALUMINUM ALLOYS: A NEW TECHNOLOGY IN SPACE APPLICATION
P. MARCHESE and G. BANING *In* AGARD Advanced Joining of Aerospace Metallic Materials 11 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

The optimization of the structural weight of the Spacelab structure, the first European manned laboratory designed according to shuttle requirements, led to the choice of 2219-T851 aluminum alloy, T.I.G. welded with the process completely developed and qualified from Aeritalia as briefly described is this paper. To demonstrate the high quality and reliability of the welded primary structure, new inspection techniques, many different tests on the welded joint, and expensive fracture mechanics analysis were applied. The main assumptions and results are presented. The main efforts were concentrated on the reduction of number and size of welding defects, improving, on the one side, the welding technique and on the otherside, inspecting single defects after fracture mechanics analysis based on sophisticated measurement of their dimensions, on the schematization of embedded flaw in tension and bending, and on carefull measurement of material properties. Possible improvements of T.I.G. application for future space programs (space station) or its substitution with plasma welding processes are also mentioned.
Author

N87-17057# British Aerospace Aircraft Group, Bristol (England). Civil Aircraft Div.
DIFFUSION BONDING IN THE MANUFACTURE OF AIRCRAFT STRUCTURE
D. STEPHEN and S. J. SWADLING *In* AGARD Advanced Joining of Aerospace Metallic Materials 17 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Over the last twenty years, considerable aerospace research and development effort has been directed to the development of the diffusion bonding (DB) process as a means of manufacture of low cost structures. To date the main thrust of these developments have been associated with titanium which has inherent metallurgical characteristics which make this material ideally suited for joining by this technique. For these titanium alloys which exhibit superplastic properties, the combined processes of superplastic forming (SPF) and DB considerably extend the range of low cost and structurally efficient titanium aerospace components which can be manufactured, even as replacements for conventionally fabricated aluminum alloy components. Recent developments in the SPF of high strength aluminums and metal matrix composites has stimulated work in the field of DB of aluminum. It is thought that in the longer term this field of DB could have the highest levels of application. This paper details the range of aerospace structural forms which can and are currently being manufactured using the diffusion bonding process. The process options, bond integrity, and nondestructive test (NDT) aspects are discussed.
Author

N87-17058# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.

DIFFUSION BONDING OF AL-ALLOYS IN THE SOLID STATE

P. G. PARTRIDGE, J. HARVEY, and D. V. DUNFORD. *In* AGARD Advanced Joining of Aerospace Metallic Materials 23 p (SEE N87-17051 09-37) Jul. 1986

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Solid state diffusion bonds have been produced between clad Al-alloy sheets in alloys 7010, 2024, SUPRAL 220 and LITAL A. The sheet surface was first ion plated with a 1 micron layer of silver before bonding at 280 C or 450 C under 130 MPa or 7 MPa pressure. Lap shear strengths were in the range 140 MPa to 180 MPa and peel strengths were more than 40 N/mm. The effects of test piece design, surface finish, clad layer thickness and of oxide films on diffusion bond strengths are described. The results suggest that a combination of thin silver coating and a clad layer should enable any Al-alloy to be diffusion bonded.

Author

N87-17059# Technische Univ., Munich (Germany, F.R.).

BONDING OF SUPERALLOYS BY DIFFUSION WELDING AND DIFFUSION BRAZING

P. ADAM and L. STEINHAUSER. *In* AGARD Advanced Joining of Aerospace Metallic Materials 6 p (SEE N87-17051 09-37) Jul. 1986

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Several developments of diffusion welded and diffusion bonded *superalloy* turbine engine parts, blades, vanes, and blisks, are summarized. The description of results comprises nondestructive testing of parts and mechanical testing of material samples. Results *are mainly presented* as conclusions on the expense of detailed test results which would require individual parts/material problem presentations.

Author

N87-17060# Societe Nationale Industrielle Aerospatiale, Suresnes (France). Dept. Production-Recherches.

APPLICATION OF DIFFUSION BONDING COMBINED WITH SUPERPLASTIC FORMING (SPF/DB) TO THE FABRICATION OF TAGV METAL SHEET STRUCTURES [APPLICATION DU SOUDAGE PAR DIFFUSION ASSOCIE AU FORMAGE SUPERPLASTIQUE (SPF/DB) A LA REALISATION DE STRUCTURES EN TOLES MINCES DE TA6V]

M. BOIRE and P. JOLYS. In AGARD Advanced Joining of Aerospace Metallic Materials 14 p (SEE N87-17051 09-37) Jul. 1986 In FRENCH

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

The potential applications of combined superplastic forming and diffusion bonding (SPF/DB) technology to the fabrication of TA6V titanium alloy structures are discussed. *The conditions for the* application of this technology are summarized as well as the impacts of certain material properties. Examples of structural fabrication processes are presented and an *economical technique* is suggested. Finally, the main problems which need to be resolved for a fully-developed industrial process are examined.

M.G.

N87-17066# National Research Council of Canada, Boucherville (Quebec)

A REAL TIME VISION SYSTEM FOR ROBOTIC ARC WELDING

M. DUFOUR, P. CIELO, and F. NADEAU. *In* AGARD Advanced Joining of Aerospace Metallic Materials 14 p (SEE N87-17051 09-37) Jul. 1986

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Fast real-time vision systems for robotic arc welding have been developed and successfully implemented for seam tracking and adaptive welding functions (mass and heat balance). Typical seam tracking errors of 0.3 mm were achieved for single pass type joints (lap, butt, fillet). In one system the weld preparation profile is first enhanced by a projected laser target formed by a line and dots. A standard TV camera is used to observe the target image at an angle. The rapid preprocessor developed by NRCC and Leigh Instruments Inc. as part of the visual aid system of the space shuttle arm is then used to analyse the video signal in real time. Another active vision system was developed in order to process more complex types of joints. It is based on laser flying spot scanning with a mechanically synchronized scanning system for projection and range finding. With a passive system the weld preparation temperature is mapped in front of the arc using a fiber optic bundle. *The temperature profile of the joint is then* analysed by a microcomputer. Because no single sensor is *universal, the combination of active and passive systems* on the same robot arm allows the arc welding robot to perform complex tasks. Furthermore, the use of an off-line programming system *greatly simplifies the programming* task of *an arc welding* robotic workcell equipped with vision sensors.

Author

N87-17067# *Hughes Helicopters*, Culver City, CA. Materials, Processes and Standards Dept.

INERTIA WELDING OF NITRALLOY N AND 18 NICKEL MARAGING 250 GRADE STEELS FOR UTILIZATION IN THE MAIN ROTOR DRIVE SHAFT FOR THE AR-64 MILITARY HELICOPTER PROGRAM

A. G. HIRKO and L. L. SOFFA. In AGARD *Advanced Joining of* Aerospace Metallic Materials 9 p (SEE N87-17051 09-37) Jul. 1986

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Preproduction feasibility studies were performed on laboratory type inertia welded specimens of Nitralloy N and 18 Nickel Maraging 250 Grade Steel prior to a *full-scale engineering development* program. The full-scale program consisted of producing scaled down drive shaft components to produce engineering test parts and to develop process control parameters for *guide lines in the* production program. Initial studies consisted of a metallurgical development program to arrive at a satisfactory post aging cycle for the composite or *dual alloy drive shaft. In addition, metallurgical* and static and dynamic tests were made from coupons excised from inertia-welded assemblies to establish structural behavior. Several sub-scale inertia-welded test specimens were tested in torsion loading to develop flight structural performance. Torsion tests showed the inertia weld exhibited strength characteristics equal or better than the parent metal for the Nitralloy N alloy component. The improved two-alloy, inertia-welded components show an approximate weight saving of 10 to 15 pounds over a drive shaft produced from Nitralloy N. This is due to a higher strength/weight ratio of 18 Nickel Maraging 250 Grade Steel as compared to Nitralloy N.

M.G.

N87-17068# Swiss Aluminum Ltd., Neuhausen am Rheinfall. Materials Technology Dept.

WELDING OF ALUMINIUM CASTINGS

J. LEUPP, A. MAITLAND, and K. SCHELLENBERG. *In* AGARD Advanced Joining of Aerospace Metallic Materials 8 p (SEE N87-17051 09-37) Jul. 1986

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Developments in the field of electronics have recently made available new methods and power sources which enable even the most difficult aluminium casting alloys to be welded economically. Each method has specific applications where it is optimally employed. The best results in fabrication welding are obtained with the TIG-PLASMA-KEYHOLE process. With this method the normal classification of casting alloys into those which weld easily and those which weld badly no longer applies. Excellent welds can be obtained for example with the high strength AlCu *alloys. The flawless*, fine grained weld bead provides mechanical properties equivalent to those of the parent metal - both under static and fatigue loading conditions. The best results in finish *and repair welding have been* obtained using TIG welding with variable polarity. If due care is taken, this method also enables excellent results to be achieved under all types of loading *conditions. Examples where the described methods are* successfully employed include not only aircraft constructions but also parts for railway vehicles and electrical switch-gear.

Author

N87-17069# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris (France). Lab. Assemblages Metallurgiques.

THE APPLICATION OF THE RBD PROCESS TO THE DEPOSITION OF ANTI-WEAR ALLOYS

J. LESGOURGUES. *In* AGARD Advanced Joining of Aerospace Metallic Materials 11 p (SEE N87-17051 09-37) Jul. 1986

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Initially, the rechargement-brasage-diffusion (RBD) was developed by SNECMA to solve problems occurring during assembly and repair of cast superalloy turbine parts. Beyond the metallurgical possibilities it offers, this process has proved to be economical. Subsequent developments in this field have shown it was *possible to apply alloys with specific characteristics*, e.g.

antiwear properties. This paper presents various applications of The RBD process, mainly in the field of wear protection. Author

N87-17071# Liburdi Engineering Ltd., Burlington (Ontario).
REPAIR TECHNIQUES FOR GAS TURBINE COMPONENTS
J. LIBURDI and P. LOWDEN *In* AGARD Advanced Joining of Aerospace Metallic Materials 12 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Areas in which the state of the art in gas turbine repair technology needs to be advanced are discussed. A large part of the discussion deals with current inadequacies of weld repair techniques for high strength superalloys and with possible areas for improvement. In particular, the problems of poor weldability and the low strength of conventional weld repairs are examined, with emphasis on areas for further development including; welding with matching filler metals, pre-weld heat treatment and preparation, modification of welding techniques and post-weld hot isostatic pressing (HIPing) and heat treatment. Another area of discussion is the need for improved techniques for resurfacing and repair of airfoil damage. Two techniques appear to be promising for this application; diffusion brazing and vacuum plasma spraying. The importance of NDT limitations and mechanical analysis with regard to the development and implementation of novel repair techniques is emphasized. Disregard of these factors can lead to repairs which are substantially cosmetic in nature. Author

N87-21190# Cranfield Inst. of Tech., Bedford (England). Signal Processing and Applications Group.
ACQUISITION AND ANALYSIS OF DYNAMIC ROTATING MACHINERY DATA
R. WALLACE *In* AGARD Advanced Instrumentation for Aero Engine Components 11 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

During the development and design of new engines, vast quantities of vibration data are acquired. An efficient analysis system designed to analyze dynamic rotating machinery data (accels, decels, etc.) is described. The system is built round a general purpose multi-tasking computer which not only analyses the data directly from pre-recorded tapes or rigs but allows engineers to post-analyze data at the same time. Examples of different types of presentation are given which enable easy interpretation of measured data. General acquisition rates and methods are also discussed. Author

N87-21191# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
ACQUISITION AND PROCESSING OF NON-STATIONARY PRESSURE MEASURMENTS IN STUDIES OF AIR INTAKE DISTORTION [ACQUISITION ET TRAITEMENT DES MESURES DE PRESSIONS NON STATIONNAIRES DANS LE CADRE DES ETUDES DE DISTORSION DENTREES DAIR]
J. L. EYRAUD, F. AUZOLLE, and M. WAGNER (Office National d'Etudes et de Recherches Aerospatiales, Paris, France) *In* AGARD Advanced Instrumentation for Aero Engine Components 7 p (SEE N87-21170 14-31) Nov. 1986 In FRENCH
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Investigations of compatibility between an aircraft air intake and the engine constitute an essential stage in the improvement of new concepts. This work is based on an experimental activity which, for full exploitation of the conditions, requires that the most complete data acquisition and processing techniques be employed. The methods described illustrate the full range of presently operational analog and digital systems. Particular emphasis is given to the importance of continuous real time analysis. Author

N87-21195# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
THE UTILIZATION OF THIN FILM SENSORS FOR MEASUREMENTS IN TURBOMACHINERY [UTILISATION DES CAPTEURS PELLICULAIRES POUR LA MESURE SUR TURBOMACHINES]
A. BRUERE, M. PORTAT, J. C. GODEFROY, and F. HELIAS *In* AGARD Advanced Instrumentation for Aero Engine Components 9 p (SEE N87-21170 14-31) Nov. 1986 In FRENCH Original language document was announced as A86-46180
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Sensor features and data analysis principles for thin films used as pressure and temperature transducers for flowfield measurements in turbomachinery are described. The devices were developed to collect data without affecting the flowfield around fixed and rotating turbine blades. The concept has been extended to thermal fluxmeters for measuring convection of the thermoelectric effect and to measuring the aerodynamics of boundary layer flows by exploiting temperature-induced changes in the resistivity of certain metals. The films have a maximum thickness of 80 microns, can be integrated into the walls of the area under investigation by vapor phase deposition, and require adhesive layers of only 2 to 4 microns. Numerical models are furnished for solid and gaseous dielectric sensor films for pressure measurements and for relating data from a thermal fluxmeter to temperature fields of flow. Author

N87-21196# Oxford Univ. (England). Dept. of Engineering Science.
INTERFEROMETRIC MEASUREMENT OF STRAINS AND DISPLACEMENTS IN ENGINE COMPONENTS
C. RUIZ, P. H. WEBB, and D. POST (Virginia Polytechnic Inst. and State Univ., Blacksburg) *In* AGARD Advanced Instrumentation for Aero Engine Components 13 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

The strains and displacements in engine components, and in particular in interlocking joints, have been measured by means of two interferometric methods: (1) high sensitivity Moire interferometry, using gratings with 1200 lines/mm; and (2) a coarser grating of 40 lines/mm. The two methods are described and the results compared to the predictions of a finite element program for a typical dovetail joint. The application of the technique to the assessment of fretting damage and to the lifing dovetail joints is discussed. Author

N87-21198# Rolls-Royce Ltd., Bristol (England). Advanced Projects Dept.
THE APPLICATION OF RADIATION PHYSICS AND PHOTOGRAMMETRIC TECHNIQUES FOR THE DIAGNOSIS AND SOLUTION OF MECHANICAL ENGINEERING PROBLEMS AND PERFORMANCE IMPROVEMENTS IN THE DEVELOPMENT OF AERO GAS TURBINE ENGINES AT ROLLS ROYCE
P. A. E. STEWART *In* AGARD Advanced Instrumentation for Aero Engine Components 19 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

Research into the applications of penetrating radiations or particles for the non-invasive imaging and measurement of events within aero gas turbines on dynamic test at Rolls Royce is discussed. High Energy (8 MeV) X-rays are used to determine metal component movements for engine performance improvements and integrity configuration. Low energy X-rays with high speed cine fluoroscopy have been used to analyze molten metal flows in the turbine blade casting process. Cold neutrons and low energy X-rays have been used to analyze two phase flows and oil distribution in the Gem engine oil scavenge system. Positron emitting isotope techniques are being developed to determine fuel and lubrication system dynamics. The images captured by these systems are then processed by digital techniques and pattern recognition and crosscorrelation is carried out. Measurements are made from the film and video images using two and three dimensional photogrammetric methods. Author

N87-21199# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.).
TIP CLEARANCE MEASUREMENT IN MODERN COMPRESSOR COMPONENTS
HARTWIG KNOELL and KURT DING *In* AGARD Advanced Instrumentation for Aero Engine Components 70 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

With regard to maximum efficiency of gas turbine compressors, small blade tip clearances during all engine operating conditions should be achieved. In order to determine the tip clearance during compressor tests, a reliable measuring technique has been developed. Using this temperature-insensitive capacitive probe system (Coulomb system), tip clearance can be monitored even during fast transient conditions. The sensors of the multichannel equipment can operate up to high temperature without cooling. Application to compressor testing is described in two examples; a high-speed centrifugal compressor rig and the intermediate-pressure compressor of a jet engine. Author

N87-29646# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
DIFFUSION BONDING OF METALS
P. G. PARTRIDGE *In* Advisory Group for Aerospace Research and Superplasticity 23 p (SEE N87-29641 24-26) Aug 1987
(AGARD-LS-154) Avail: NTIS HC A10/MF A01

The need to reduce the cost and weight of aerospace metallic structures has led to an increased interest in solid state and liquid phase diffusion bonding processes, especially in combination with superplastic forming. The bonding mechanisms and bonding techniques are reviewed and the process variables that affect bond quality and strength are described with reference to bonds between Ti-alloys, Al-alloys and dissimilar metals. The importance of quality control and the limitations of current nondestructive evaluation techniques for diffusion bonding are emphasized. Finally, some trends and priorities in diffusion bonding technology are indicated. Author

N89-17686# National Aeronautical Establishment, Ottawa (Ontario). Structures and Materials Lab.
LITERATURE REVIEW ON THE DESIGN OF MECHANICALLY FASTENED COMPOSITE JOINTS
C. POON *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 28 p (SEE N89-17685 10-31) Mar. 1988 Previously announced as N87-12872
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

This report presents a literature review of the state-of-the-art analytical and experimental methodologies adopted in the aerospace industry for the design of mechanically fastened joints in composite structures. Results and conclusions obtained from the published literature relating to the effects of critical parameters, which include composite material system, fastener configuration and joint geometry, on the mechanical behavior and failure modes of composite mechanically fastened joints are discussed. Further research required to improve the design of composite mechanically fastened joints is identified as a result of this review. Author

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QUALITY ASSURANCE AND RELIABILITY

Includes product sampling procedures and techniques; and quality control

N87-17061# Messerschmitt-Boelkow-Blohm G.m.b.H., Lemwerder (Germany, F.R.).
ULTRASONIC TESTING TECHNIQUES FOR DIFFUSION-BONDED TITANIUM COMPONENTS
GUSTAV TOBER and STEFAN ELZE *In* AGARD Advanced Joining of Aerospace Metallic Materials 10 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Diffusion-bonded titanium specimens with bonding defects were tested by ultrasonic techniques. In order to improve the defect detectability, high-frequency ultrasound was applied, the echo signals were analyzed in both the time and frequency domains. Author

N87-17062# Army Construction Engineering Research Lab., Champaign, IL.
WELD QUALITY MONITOR AND CONTROL SYSTEM
F. KEARNEY, DAWN WHITE, and WILLIAM RICCI (Army Materials and Mechanics Research Center, Watertown, Mass.) *In* AGARD Advanced Joining of Aerospace Metallic Materials 8 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

A non-contact weld quality monitor (WQM) system is being developed to detect, identify, and correct for deviations from established welding procedures and conditions which lead to weld defects in real time. The WQM continually measures with conventional transducers all primary process parameters such as current, voltage, and travel speed, and computes weld quality parameters such as heat input and weld bead geometry. In addition, the WQM monitors the spectral signature of the welding arc by means of a high resolution microprocessor controlled spectrograph. Here, the presence of weld pool and arc atmosphere contaminants, flux and shield gas effectiveness, arc energy input, and penetration/dilution into the base material can be determined. The spectral response from the welding arc and measurements of process parameters are then normalized, compared to preset operating limits, and processed in real time. Necessary adjustments to primary process parameters are made by automated compensation devices to eliminate weld defects in real time. When necessary, the specific location of discontinuities are provided to facilitate further inspection. Author

N87-17063# Rolls-Royce Ltd., Derby (England)
NDT OF ELECTRON BEAM WELDED JOINTS (MICRO-FOCUS AND REAL TIME X-RAY)
R. G. TAYLOR *In* AGARD Advanced Joining of Aerospace Metallic Materials 4 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

The introduction of electron beam welding (EBW) into the aero engine industry in the early 1960's has presented many new problems for non-destructive testing (NDT). Highlighted among these are the following particular problems: (1) accessibility the use of EBW has resulted in the design of many box-like components which makes it difficult, or impossible, to apply conventional NDT methods satisfactorily; (2) center-line defect orientation; and (3) extremely narrow welds which makes the detection of defects by normal radiography very unreliable. The traditional NDT methods such as conventional X-ray, fluorescent penetrant, magnetic particle, together with the occasional use of eddy current and, where accessibility permits, ultrasonics, have been extensively used for the inspection of EBW fabrications. However, the use of these methods has created considerable limitations in defect detection where extremely small defects (under 1mm) must be detected to guarantee a successful life cycle. Initially, these limitations only applied to parts manufactured by EBW, but during recent years, EBW has been increasingly used during the repair and overhaul of aero engine engine components and the NDT limitations now extend into these areas. Recently, significant developments have taken place which has enabled micro-focus X-ray techniques to be used in place of conventional X-ray on EBW and this has resulted in a considerable improvement in defect detection capabilities. An additional bonus has been the reduction in inspection costs and an improvement in productivity. Author

N87-17064# National Research Council of Canada, Boucherville (Quebec).
THERMOELASTIC TESTING OF STRATIFIED MATERIALS
PAOLO CIELO and MARC DUFOUR *In* AGARD Advanced Joining of Aerospace Metallic Materials 15 p (SEE N87-17051 09-37) Jul. 1986
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

A non-contact thermoelastic technique for the non-destructive testing of layered materials such as aluminum-epoxy laminates or metallurgical coatings is described. A pulsed laser beam heats a small area on the surface of the layer to be tested, and the thermoelastic deformation of the layer is monitored by a sensitive optical probe. Unbonded areas can be recognized from the abnormally high deformation of the unbonded layer. Localized pulsed heating is shown to be far superior than the extended

heating approach which is followed in holographic thermal stressing. The possibility to detect cohesive and adhesive defects by this technique is discussed. Two experimental configurations are described: in the first configuration the probing beam directly monitors the thermoelastic displacement of the heated area, while in the second a thermoelastically-generated annular stress wave converges towards the central probed point. Author

N87-17070# National Aerospace Lab., Amsterdam (Netherlands).
EVALUATION OF DDH AND WELD REPAIRED F100 TURBINE VANES UNDER SIMULATED SERVICE CONDITIONS
A. J. A. MOM, N. M. MADHAVA (Chromalloy Div.-Oklahoma, Midwest City), G. A. KOOL, and M. DEAN (Turbine Support Europa, Tilburg, Netherlands) *In* AGARD Advanced Joining of Aerospace Metallic Materials 9 p (SEE N87-17051 09-37) Jul. 1986 Previously announced as N86-32762
(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Cost and delivery times of high technology turbine components are a strong impetus for the development of advanced repair processes with the ability of complete restoration of unserviceable components. One of such advanced processes, diffusion densification healing (DDH), was applied for repair of cracked and unserviceable F100 turbine vanes. The DDH process was evaluated under simulated service test conditions with respect to the conventional weld/patch coat repair procedure. The evaluation shows that the DDH process is a remarkably effective restoration process, resulting in strongly improved test behavior in relation to the original weld/patch coat procedure. Additional advantages are that scrap rates during repair are likely to be considerably reduced and that for the future some relaxation of current repair limits might even be considered. Author

N89-17253# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
AGARD/SMP REVIEW: DAMAGE TOLERANCE FOR ENGINE STRUCTURES. 1: NON-DESTRUCTIVE EVALUATION
Nov. 1988 125 p In ENGLISH and FRENCH Meeting held in Luxembourg, 1-6 May 1988
(AGARD-R-768; ISBN-92-835-0484-4; AD-A203451) Avail: NTIS HC A06/MF A01

The AGARD Structures and Materials Panel is coordinating a series of workshops within the framework of a review of damage tolerance for engine structures. The review aims to address the areas critical to the acceptance of an approach based on damage tolerance concepts as an alternative lifing philosophy to that of safe-life for the design of engine components. Engineering assumptions, component design, life prediction of turbine disk and the need for common AGARD approaches to nondestructive evaluation are among the topics covered. For individual titles, see N89-17251 through N89-17261.

N89-17254# Rolls-Royce Ltd., Derby (England). Dept. of Materials and Mechanical Technology.
THE IMPACT OF ENGINEERING ASSUMPTIONS ON NDE REQUIREMENTS
R. H. JEAL *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 6 p (SEE N89-17253 09-38) Nov. 1988
(AGARD-R-768) Avail: NTIS HC A06/MF A01

Geometrical aspects - including surface finish - have the advantage that they can be directly measured on the individual parts for comparison with those originally set. The designer can calculate the size of acceptable deviations from the norm and production is accepted or rejected on the basis of these tolerances. Material condition is a more difficult concept to deal with. It covers a wide range of phenomena ranging from cracks, scratches and porosity to the details of material microstructure which represent a deviation from the designers' assumption of a material as a continuous, isotropic, homogeneous media free from defects. These deviations are both difficult to find and their effect on performance is difficult to assess. Designers in the past used to assume safety factors to account for the unseen presence of defects. As more efficient use of available materials has been sought, these factors have been reduced but at the price of greater perfection in the materials. This has led to increasing demands upon the ability of the designer to assess the behavior of discontinuities and set the defect standards, and for the inspection engineer to establish techniques that will find smaller and smaller defects in more and more difficult situations on ever increasing degree of certainty. The way these changing design requirements have impacted upon the problem presented to the inspection engineer is discussed.
Author

N89-17255# University Coll., London (England). Dept. of Mechanical Engineering.
REVIEW OF EXISTING NDT TECHNOLOGIES AND THEIR CAPABILITIES
LEONARD J. BOND *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 15 p (SEE N89-17253 09-38) Nov. 1988
(AGARD-R-768) Avail: NTIS HC A06/MF A01

A review of selected nondestructive test (NDT) technologies is presented with regard to their reliability and capability to detect and characterize defects in critical aero-engine components such as discs and blisks (integrally bladed discs), both in production and after service. The performance of non-destructive testing is considered both at the time of manufacture and after service for parts fabricated from powder metals including AP1 and with particular consideration given to the needs of the European Fighter Aircraft (EFA). Various NDT technologies have been considered with the aim of establishing the current capability of each technology in terms of defect detection capability and probability of detection rates. The cause of the limits on performance are reviewed and areas where development can be expected in these and other NDT technologies within the next 5 to 10 years have been identified. Author

N89-17256# Pratt and Whitney Aircraft, West Palm Beach, FL. Dept. of Materials Engineering.
RELATIONSHIPS OF NONDESTRUCTIVE EVALUATION NEEDS AND COMPONENT DESIGN
JOHN A. HARRIS, JR. and M. C. VANWANDERHAM *In* AGARD AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 8 p (SEE N89-17253 09-38) Nov. 1988
(AGARD-R-768) Avail: NTIS HC A06/MF A01

Several well publicized engine and airframe failures which occurred in the late 1960 to mid 1970's time frame resulted in emphasis on development, application and quantification of nondestructive evaluation (NDE) as opposed to reliance on a Zero Defects design philosophy. As the use of fracture mechanics as a basis for damage tolerance and retirement analysis of components became established, additional emphasis was placed on screened flaw sizes, NDE and quantification of reliability. In the late 1970's a structural assessment was conducted on the design of the F100 engine which resulted in a series of relatively sophisticated safety inspections for selected critical components. The Retirement for Cause philosophy also coupled NDE and component lifing analyses to enable return to service decisions for engine components. These activities were (and are) performed usually after the component designs have been finalized. The establishment of Engine Structural Integrity Programs (ENSIP) for new U.S. military engine systems has now made NDE considerations an integral part of the design process. Classification of components, fracture mechanics analyses, critical flaw sizes, material quality, NDE and quantification of inspection reliability are now incorporated in the initial design process and directly influence the resultant component designs. Statistically based probabilistic approaches are supplementing the deterministic methods previously used. The relationships of NDE needs and component design in light of the evolution of the ENSIP approach for gas turbine engine component designs are discussed. Author

N89-17257# National Research Council of Canada, Ottawa (Ontario). Structures and Materials Lab.
IMPORTANCE OF SENSITIVITY AND RELIABILITY OF NDI TECHNIQUES ON DAMAGE TOLERANCE BASED LIFE PREDICTION OF TURBINE DISCS
A. K. KOUL, A. FAHR, G. GOULD, and N. BELLINGER (Carleton Univ., Ottawa, Ontario.) *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 22 p (SEE N89-17253 09-38) Nov. 1988
(AGARD-R-768) Avail: NTIS HC A06/MF A01

The results of a demonstration program carried out to determine the influence of the sensitivity and reliability of nondestructive inspection (NDI) techniques on the damage tolerance based life assessment of aero engine turbine discs are discussed. The program was carried out on the 5th stage compressor discs of the J85-CAN40 engine, made from the AM-355 stainless steel. The sensitivity and reliability of several NDI techniques, in detecting service induced low cycle fatigue (LCF) cracks in the disc bolt hole regions, are assessed on the basis of detectable crack sizes at 90 percent probability of detection (POD) and 90 percent POD with 95 percent confidence level. The NDI techniques examined are the liquid penetrant inspection (LPI) technique, a manual eddy current inspection (ECI) technique using two gain settings and an ultrasonic leaky wave (ULW) technique using an automated C-scan system. The safe inspection intervals (SIIs) for the 5th stage compressor disc are calculated using deterministic fracture mechanics (DFM) and probabilistic fracture mechanics (PFM) principles. These calculations involve the use of the NDI data, finite element analysis and the experimental fatigue crack growth rate (FCGR) data generated on compact tension specimens machined from discs. The results indicate that the manual ECI technique with a high gain setting and the automated ULW technique are the most sensitive and reliable in detecting LCF cracks. Author

N89-17258# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).
SHORT TERM DEVELOPMENTS IN NON-DESTRUCTIVE EVALUATION APPLICABLE TO TURBINE ENGINE PARTS [LES DEVELOPPEMENTS A COURT TERME DES CONTROLES NONDESTRUCTIFS APPLICABLES AUX PIECES DE TURBOMACHINES]
J. VAERMAN. *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 29 p (SEE N89-17253 09-38) Nov. 1988. In FRENCH
(AGARD-R-768) Avail: NTIS HC A06/MF A01

An analysis of the principles forming the basis of non-destructive evaluation (NDE) techniques is presented. Excitation energy sources, medium interaction (perturbation), and sensors and signal processing are examined. Factors affecting the evolution and adaptation of NDE methods are discussed and recent developments in acoustic microscopy, ultrasonic techniques, Foucault current methods, and X-ray tomography are described. Author

N89-17259# Naval Air Development Center, Warminster, PA.
LONG TERM POSSIBILITIES FOR NONDESTRUCTIVE EVALUATION FOR US NAVY AIRCRAFT
W. R. SCOTT. *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 13 p (SEE N89-17253 09-38) Nov. 1988
(AGARD-R-768) Avail: NTIS HC A06/MF A01

The majority of nondestructive inspection (NDI) techniques currently in use for U.S. Navy aircraft are labor intensive, operator dependent and result in excessive aircraft down-time. For this reason NDI R and D efforts currently are directed toward developing rapid automated systems capable of remote or unattended inspection of large areas and inaccessible structures. Ongoing programs of this type that are discussed include laser ultrasonics, acoustic emission, and quantitative imaging. The primary thrust of the presentation will cover the advantages of each technique and the technical obstacles preventing its implementation. Author

N89-17260# Rolls-Royce Ltd., Derby (England). Dept. of Non-Destructive Testing Applications.
NEED FOR COMMON AGARD APPROACH AND ACTIONS
R. G. TAYLOR. *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 3 p (SEE N89-17253 09-38) Nov. 1988
(AGARD-R-768) Avail: NTIS HC A06/MF A01

While there is no direct evidence that the different approaches used in nondestructive tests (NDT) have affected airworthiness, there are many pressures, both technical and commercial, for requiring a common approach within the community in the future. The technical pressures arise from a need to achieve the same technical standard of product, irrespective of the place of manufacture, in order to meet the stringent damage tolerance requirements now being placed on NDE, while the commercial pressures arise from the need for industry to rationalize the methodolgy, so that components are processed in the same way, irrespective of the customer. An example of the problems associated with the lack of a common approach, is shown in the differing requirements of the major aero engine manufactures, for the ultrasonic inspection of turbine discs. A study of the physics of the different methods demanded by the engine companies, shows that the same technical standard cannot be achieved, and the commercial problems are obvious when it is recognized that these different techniques are imposed on a common forging supplier. As a result of recent collaboration activities with a number of other engine manufacturers, Rolls-Royce has carried out a survey of the differences that currently exist and these are summarized. Author

N89-17261# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France).
STATE-OF-THE-ART IN NON-DESTRUCTIVE EVALUATION OF TURBINE ENGINE PARTS [L'ETAT DE L'ART EN CONTROLE NONDESTRUCTIF DES PIECES DE TURBOMACHINE]
J. L. MEIFFREN. *In* AGARD, AGARD/SMP Review: Damage Tolerance for Engine Structures. 1: Non-Destructive Evaluation 16 p (SEE N89-17253 09-38) Nov. 1988. In FRENCH
(AGARD-R-768) Avail: NTIS HC A06/MF A01

An overview of non-destructive evaluation (NDE) methods used in aeronautical engineering is presented. The use of NDE during the fabrication of turbine engine components is discussed, with particular emphasis on the ultrasonic evaluation of compressor and turbine disks, thickness measurement of turbine blades, and the evaluation of welds in compressor rotors. In addition, the application of NDE techniques to the evaluation of in-service engines is discussed. The detection of fatigue cracks and ruptures in operational engine parts is addressed along with statistical approaches to NDE. Author

N89-18477# Rolls-Royce Ltd., Derby (England).
USE OF MARKOV PROBABILITY AND RELIABILITY MODEL GENERATION METHODS IN THE ANALYSIS OF RELIABILITY OF A FAULT TOLERANT, HARDWARE AND SOFTWARE BASED SYSTEM WITH FLEXIBLE REPAIR POLICIES
PAUL WHITE. *In* AGARD, Software Engineering and Its Application to Avionics 23 p (SEE N89-18446 11-06) Nov. 1988. Previously announced as N88-28706.
(AGARD-CP-436) Avail: NTIS HC A18/MF A01

Problems in the application of traditional reliability methods to fault-tolerant systems, particularly with the fault trees approach are reviewed. The application of the Markov state-flow equation to reliability analysis is considered and it is shown how many problems disappear with this approach and how the basic equation can be manipulated to include repair policies, discrete events and to calculate system reliability. How to set up a reliability model from system design information in such a way as to ensure the Markov states and transitions are correct and so as to ensure that the reliability analysis gives an upper bound for the system failures is outlined. Formulation of design information and automatic generation of a reliability model for any given system is explained and an example analysis is given based on a typical jet engine control system. ESA

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STRUCTURAL MECHANICS

Includes structural element design and weight analysis; fatigue; and thermal stress.

N86-27678# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

STATIC AEROELASTICITY IN COMBAT AIRCRAFT

Jan. 1986 42 p

(AGARD-R-725; ISBN-92-835-1516-1; AD-A167595) Avail: NTIS HC A03/MF A01

A review of *fighter aircraft development programs over the* past three decades indicates a trend of increasing emphasis on the consideration of static aeroelastic effects. While early concerns addressed only the impact on air vehicle structural integrity, current design philosophy recognizes and addresses aeroelasticity as a primary design parameter *affecting structural optimization*, vehicle aerodynamic stability, control effectiveness, and overall *performance*. Examples from wind tunnel testing, analytical studies, and operational applications are presented to justify this emphasis, illustrate current methodology and analysis techniques, and make a case for an integrated approach to the *consideration of* static aeroelastic effects at all stages of the design process. Author

N86-31083# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

THE PROSPECTS FOR FINITE ELEMENT ANALYSIS METHODS FOR STRUCTURAL QUALIFICATION

Apr 1986 15 p *Presented at the 61st Meeting of the Structures* and Materials Panel of AGARD, Oberammergau, West Germany, 8-13 Sep. 1985.

(AGARD-R-736; ISBN92-835-1526-9; AD-A171304) Avail: NTIS HC A02/MF A01

As part of its 61st *Meeting the AGARD Structures and Materials* Panel considered whether or not it should set up an activity to *examine* the possibilities of Structural Qualification by using Finite Element Analytical Methods in place of testing. As a preliminary to its discussions it heard the two papers printed here. The first of these looks in general terms at the capabilities of existing organisations and systems vis- a-vis the standards which must *necessarily be established* before FEM qualification procedures can be implemented. The second paper looks in rather more detail at how non-linear FEM may be applied in support of structural tests. Author

N87-16376# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). *Structures and Materials* Panel.

PRACTICAL APPLICATION OF FINITE ELEMENT ANALYSIS TO AIRCRAFT STRUCTURAL DESIGN

Aug. 1986 138 p Lectures held in Geilo, Norway, 11-12 Sep. 1986, in Lisbon, Portugal, 15-16 Sep. 1986, at *McClellan AFB*, Calif., 29-30 Sep. 1986, at Kelly AFB, Tex., 2-3 Oct. 1986, and at *Wright-Patterson* AFB, Ohio, 6-7 Oct. 1986

(AGARD-LS-147; ISBN-92-835-1536-6; AD-A173823) Avail: NTIS HC A07/MF A01

This lecture introduces the main aspects of finite element analysis and modeling with emphasis placed on the solution of *practical design problems*. An *outline* is given of the broad principles of the finite element method with some emphasis on the limitations of the technique. This is followed by an explanation of the modeling problems encountered in the analysis of real structures together with their resolution. The use of the finite element system is included. For individual titles *see N87-16377 through N87-16380*.

N87-16378# British Aerospace Aircraft Group, Warton (England).

STATING THE PROBLEM: THE STEP BEFORE F. E. MODELLING

IAN C. TAIG *In AGARD Practical Application of Finite Element* Analysis to Aircraft Structural Design 11 p (SEE N87-16376 08-39) Aug. 1986

(AGARD-LS-147) Avail: NTIS HC A07/MF A01

Structural analysis is concerned with finding practical solutions of physical problems in the real world; *finite element analysis* is one powerful tool used as part of this process. Before starting to set up a finite element analysis the task should be planned and the essential features of the real world problem should be identified. Seven steps are studied: planning the analysis in relation to resources available, definition of the real structure, *description of* the real structure, description of the structural context, definition *of the facilities* and resources available, and prescription of the solution requirements. In all cases, except formulation, these topics are dealt with discursively, without recourse to mathematics. In discussing formulation, a simple engineers theory of matrix structural analysis is presented as an everyday medium for defining *and understanding the finite element* solution process. Author

N87-16379# British Aerospace Aircraft Group, Warton (England). Military Aircraft Div.

MODELLING FOR THE FINITE ELEMENT METHOD

IAN C. TAIG *In* AGARD Practical Application of Finite Element Analysis to Aircraft Structural Design 18 p (SEE N87-16376 08-39) Aug. 1986

(AGARD-LS-147) Avail: NTIS HC A07/MF A01

Finite element modeling is not synonymous with mesh generation. *The complex structures typical of aerospace*, and many other industries give limited choice for clever mesh definition but contain a host of features which need to be represented, either explicitly or implicitly within the finite element model. Topics covered herein include general modeling strategy, definition of a basic mesh, local modeling of *structural features including those which* are below the basic mesh scale, element selection, load and inertial representation, kinematic constraints and symmetry. All topics are treated in a non-mathematical way, relating decisions which the analyst must make to the known facts about the analysis in the way that experienced people make such judgements. *This naturally* leads to references to expert systems which are seen as having *a major impact in this field*. Author

N87-16380# Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.

THE USE OF THE FINITE ELEMENT METHOD

V. B. VENKAYYA *In* AGARD Practical Application of Finite Element Analysis to Aircraft Structural Design 39 p (SEE N87-16376 08-39) Aug. 1986

(AGARD-LS-147) Avail: NTIS HC A07/MF A01

These lecture notes are primarily intended to provide a quick *overview of the solid mechanics* problem for engineers using a *general purpose finite element* system in the solution of aerospace structures problems. It gives a brief outline of the solid mechanics problem and some the available options for its solution. The finite element method is explained in more detail with particular emphasis on the use of *membrane element in aerospace* structural analysis. Author

N87-17065# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).

INFLUENCE OF WELDING FLAWS ON THE FATIGUE STRENGTH OF ELECTRON BEAM WELDMENTS IN TI AL6 V4

WALTER SCHUETZ and WOLFRAM OBERPARLEITER In AGARD Advanced Joining of Aerospace Metallic Materials 11 p (SEE N87-17051 09-37) Jul. 1986

(AGARD-CP-398) Avail: NTIS HC A12/MF A01

Electron beam (EB) welding is a well known joining method in *aircraft construction*. Although a lot of data is available on the fatigue behavior of EB-welded Ti Al6 V4 alloy, only a few data on the effect of flaws in these weldments exist. Therefore artificial flaws of different size were produced in EB-weldments and the effect of these flaws on static strength, fatigue, fracture toughness and crack *propagation was studied*. Experience has shown, that existing flaws may be not found or heavily underestimated by non-destructive inspection (NDI). Also NDI cannot distinguish

between sharp-edged flaws (which may behave like cracks) and spherical cavities. In the present investigation they reduced the static strength up to 35%, the fatigue strength up to 50% (at N = 10(5) cycles), and the fracture toughness up to 10%. Such reductions therefore must be accounted for in the design phase of Ti A16 V4 components containing Eb-welds. Author

N87-20372# Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost. *Space Div.*

ACOUSTIC EFFECTS ON THE DYNAMIC OF LIGHTWEIGHT STRUCTURES

J. J. WIJKER *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 15 p (SEE N87-20355 13-18) Jul. 1986 (AGARD-CP-397) Avail: NTIS HC A12/MF A01

The influence of the acoustic effects (surrounding air) on the dynamic behavior of lightweight structures is discussed. Emphasis is given to: the unexpected dynamic characteristics as shown during test; simulation of the acoustic loading within the finite element representation (linear domain); and comparison of the measured dynamic characteristics (modal survey) with the adapted finite element results.

N87-21197# Motoren- und Turbinen-Union Muenchen G.m.b.H. (Germany, F.R.)

VIBRATION ANALYSIS BY SPECKLE INTERFEROMETRY

HARTWIG KNOELL *In* AGARD Advanced Instrumentation for Aero Engine Components 9 p (SEE N87-21170 14-31) Nov. 1986 (AGARD-CP-399) Avail: NTIS HC A24/MF A01

The vibrational modes of complex systems can be visualized with high sensitivity by laser light speckle interferometry. Electronic speckle pattern interferometry (ESPI), in contrast to holography, does not use photo-chemical storage media but, shows a live image of the vibrational modes created by the time-average method directly on a monitor screen. The particular advantage of this very useful and now almost conventional procedure of vibration analysis is demonstrated by two applications to aero-engine parts: a compressor blade and an impeller of a small centrifugal compressor. Author

N88-11139# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

RELIABILITY OF FINITE ELEMENT METHODS IN NORTH AMERICA

JERZY J. KACPRZYNSKI Jul. 1987 25 p (AGARD-R-748; AD-A187157) Avail: NTIS HC A03/MF A01

The reliability of finite element analysis techniques in place of structural tests are discussed in the context of airworthiness assessment. Using an example as illustration, it is shown that in order to obtain meaningful results, the analysis must be performed with extreme care by an experienced analyst. The reliance on the finite element analysis alone may result in serious misdiagnosis. The verification and the certification of programs and the certification of users are discussed. Some of the most important tests for validation of finite element programs are presented. Author

N88-12818# Advisory Group for Aerospace Research and Development, Paris (France). Structures and Materials Panel.

STANDARD FATIGUE TEST SPECIMENS FOR FASTENER EVALUATION

ROBIN COOK (Royal Aircraft Establishment, Farnborough, England) Nov. 1987 66 p (AGARD-AG-304; ISBN-92-835-0429-1; AD-A189002) Avail: NTIS HC A04/MF A01

An AGARD coordinated program which examines the fatigue performance and joint characteristics of a number of mechanically fastened joints with: (1) no or low secondary bending, and (2) with high secondary bending. In part 1, three types of joint are assessed which exhibit no, low, and high amounts of load transfer by the fastener. The no-load transfer joint was rejected and low and high load transfer joint were considered to be equivalent in rating fastener systems. In part 2, three types of single shear joint are considered. They are compared on the basis of load transfer and secondary bending characteristics and also on the fatigue endurance with a range of fastener systems installed. Only one joint, the UK designed Q-joint, adequately fulfilled the requirements of a standard joint for fastener evaluation purposes. Author

N88-26695# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).

AUTOMATED MEASUREMENT OF CRACK LENGTH AND LOAD LINE DISPLACEMENT AT ELEVATED TEMPERATURE

H. P. VANLEEUWEN, F. F. GROEP, L. SCHRA, and N. DAM (National Aerospace Lab., Emmeloord, Netherlands.) Feb. 1988 14 p Presented at the 65th Meeting of the Structures and Materials Panel of AGARD, Cesme, Turkey, 4-9 Oct. 1987 (AGARD-R-751; ISBN-92-835-0446-1; AD-A194402) Avail: NTIS HC A03/MF A01

Test results reported in the literature show that in creep cracking tests at elevated temperature under steady load, the crack growth rate correlates best with the contour integral C* (also called J*) in comparison to other possible parameters. In the case of the fatigue at elevated temperature, the crack growth rate correlates best with C* if cracking is predominantly time dependent. If, however, cracking is predominantly cycle dependent the crack growth rate correlates best with the range Delta J of the contour integral J. It is discussed that in such testing C* and J are fairly easily determined if, apart from load and crack length, the load line displacement is measured. A description is given of a test setup developed for elevated temperature creep cracking tests in which crack length was measured with the electrical potential drop method and load line displacement measured with two inductive transducers located inside the furnace. Measurement was automated with the aid of a personal computer which controlled the measurements and processed the results automatically. This setup can be adapted for elevated temperature fatigue testing. Author

N89-10007# Imperial Coll. of Science and Technology, London (England). Dept. of Mechanical Engineering.

BASIC STRUCTURAL DYNAMICS

D. J. EWINS *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 14 p (SEE N89-10006 01-02) Jun. 1988 (AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

Concepts are introduced which are dynamics aspects and the properties of interest as well as summarizing the appropriate analysis method, available for deriving the required information in specific cases. The task of formulating a suitable mathematical model is discussed. The use of finite element methods for this modeling task is examined. Some of the special analysis methods which are especially appropriate for dealing with the particular structural forms common in bladed assemblies are outlined. Author

N89-10016# Detroit Diesel Allison, Indianapolis, IN.

FORCED VIBRATION AND FLUTTER DESIGN METHODOLOGY

LYNN E. SNYDER and DONALD W. BURNS *In* AGARD, AGARD Manual on Aeroelasticity in Axial-Flow Turbo Machines. Volume 2: Structural Dynamics and Aeroelasticity 28 p (SEE N89-10006 01-02) Jun. 1988 (AGARD-AG-298-VOL-2) Avail: NTIS HC A12/MF A01

The aeroelastic principles and considerations of designing blades, disks, and vanes to avoid high cycle fatigue failure is covered. Two types of vibration that can cause high cycle fatigue, flutter, and forced vibration, will first be defined and the basic governing equations discussed. Next, under forced vibration design the areas of source definition, types of components, vibratory mode shape definitions, and basic steps in design for adequate high cycle fatigue life will be presented. For clarification a forced vibration design example will be shown using a high performance turbine blade/disk component. Finally, types of flutter, dominant flutter parameters, and flutter procedures and design parameters will be discussed. The overall emphasis is on application to initial design of blades, disks, and vanes of aeroelastic criteria to prevent high cycle fatigue failures. Author

N89-17287# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). *Structures and Materials Panel.*

SHORT-CRACK GROWTH BEHAVIOUR IN AN ALUMINUM ALLOY: AN AGARD COOPERATIVE TEST PROGRAMME

J. C. NEWMAN, JR. and P. R. EDWARDS (Royal Aerospace Establishment, Farnborough, England) Dec. 1988 106 p (AGARD-R-732; ISBN-92-835-0493-3; AD-A205648) Avail: NTIS HC A06/MF A01

An AGARD test program on the growth of short fatigue cracks was conducted to define the significance of the short-crack effect, to compare test results from various laboratories and to evaluate an existing analytical model to predict the growth of such cracks. The first phase of this program, the Core Program was aimed at test procedure and specimen standardization and calibration of the various laboratories. A detailed working document has been prepared and is included in this report. It describes the testing fundamentals and procedures and includes the analysis procedures used for handling the test data. The results from the test program showed good agreement among the participants on short-crack growth rates, on fatigue life to various crack sizes and breakthrough (surface- or corner-crack became a through crack), and on crack shapes. For individual titles, see N89-17288 through N89-17297.

N89-17288*# National Aeronautics and Space Administration. *Langley Research Center,* Hampton, VA.

SHORT-CRACK GROWTH BEHAVIOUR IN AN ALUMINUM ALLOY: AN AGARD COOPERATIVE TEST PROGRAM

J. C. NEWMAN, JR. and P. R. EDWARDS (Royal Aircraft Establishment, Farnborough, England) *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 1-60 (SEE N89-17287 09-39) Dec. 1988 (AGARD-R-732) Avail: NTIS HC A06/MF A01 CSCL 20K

An AGARD Cooperative Test Program on the growth of short fatigue cracks was conducted to define the significance of the short-crack effect, to compare test results from various laboratories, and to evaluate an existing analytical crack-growth prediction model. The initiation and growth of short fatigue cracks (5 micrometer to 2 mm) from the surface of a semi-circular notch in 2024-T3 aluminum alloy sheet material were monitored under various load histories. The cracks initiated from inclusion particle clusters or voids on the notch surface and generally grew as surface cracks. Tests were conducted under several constant-amplitude (stress ratios of -2, -1, 0, and 0.5) and spectrum (FALSTAFF and GAUSSIAN) loading conditions at 3 stress levels each. Short crack growth was recorded using a plastic-replica technique. Over 250 edge-notched specimens were fatigue tested and nearly 950 cracks monitored by 12 participants from 9 countries. Long crack-growth rate data for cracks greater than 2 mm in length were obtained over a wide range in rates (10 to the -8 to 10 to the -1 mm/cycle) for all constant-amplitude loading conditions. Long crack-growth rate data for the FALSTAFF and GAUSSIAN load sequences were also obtained. Author

N89-17289# National Aerospace Lab., Amsterdam (Netherlands).

MICROSTRUCTURAL EXAMINATION OF CORE-PROGRAMME MATERIAL

R. J. H. WANHILL *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 61-65 (SEE N89-17287 09-39) Dec. 1988 (AGARD-R-732) Avail: NTIS HC A06/MF A01

This annex describes the microstructure of the 2.3 mm thick 2024-T3 aluminum alloy sheet used in the core program. The significance of microstructure for fatigue crack growth in the low stress intensity regime is briefly discussed. The results are based on an extensive compilation and analysis of data for five different batches of 2024-T3 and T351. Author

N89-17290*# National Aeronautics and Space Administration. *Langley Research Center,* Hampton, VA.

PRELIMINARY FATIGUE TESTS ON SHORT-CRACK SPECIMENS

J. C. NEWMAN, JR., E. P. PHILLIPS, and M. H. SWAIN (Planning Research Corp., Hampton, VA.) *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 66-69 (SEE N89-17287 09-39) Dec. 1988 (AGARD-R-732) Avail: NTIS HC A06/MF A01 CSCL 20K

The objective of the preliminary fatigue tests was to determine the stress levels to be used by the participants in the Cooperative Test Program. As previously mentioned, the United States Air Force Wright-Patterson Aeronautical Laboratory machined about 700 single-edge-notched tension (SENT) specimens from material supplied by the NASA Langley Research Center. In addition, NASA Langley machined about 50 SENT specimens from the same material. Comparison of fatigue tests conducted on the two sets of specimens indicated a large difference in fatigue behavior under constant-amplitude loading. A recovery program was initiated to resolve this difference before the specimens were distributed to participants. The following sections describe the recovery program and the preliminary fatigue tests and analyses conducted to determine stress levels for constant-amplitude, FALSTAFF, and GAUSSIAN loading. Author

N89-17291*# National Aeronautics and Space Administration. *Langley Research Center,* Hampton, VA.

ALIGNMENT VERIFICATION PROCEDURES

P. R. EDWARDS (Royal Aircraft Establishment, Farnborough, England), E. P. PHILLIPS, and J. C. NEWMAN, JR. *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 70-71 (SEE N89-17287 09-39) Dec. 1988 (AGARD-R-732) Avail: NTIS HC A06/MF A01 CSCL 20K

In alignment verification procedures each laboratory is required to align its test machines and gripping fixtures to produce a nearly uniform tensile stress field on an un-notched sheet specimen. The blank specimens (50 mm w X 305 mm l X 2.3 mm th) supplied by the coordinators were strain gauged. Strain gauge readings were taken at all gauges (n = 1 through 10). The alignment verification procedures are as follows: (1) zero all strain gauges while specimen is in a free-supported condition; (2) put strain-gauged specimen in the test machine so that specimen front face (face 1) is in contact with reference jaw (standard position of specimen), tighten grips, and at zero load measure strains on all gauges. (epsilon sub nS0 is strain at gauge n, standard position, zero load); (3) with specimen in machine and at a tensile load of 10 kN measure strains (specimen in standard position). (Strain = epsilon sub nS10); (4) remove specimen from machine. Put specimen in machine so that specimen back face (face 2) is in contact with reference jaw (reverse position of specimen), tighten grips, and at zero load measure strains on all gauges. (Strain - epsilon sub nR0); and (5) with specimen in machine and at tensile load of 10 kN measure strains (specimen in reverse position). (epsilon sub nR10 is strain at gauge n, reverse position, 10 kN load). Author

N89-17292# Royal Aircraft Establishment, Farnborough (England).

ON-LINE SPECTRUM LOADING ACCURACY VERIFICATION

P. R. EDWARDS *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 72-74 (SEE N89-17287 09-39) Dec. 1988 (AGARD-R-732) Avail: NTIS HC A06/MF A01

Eight laboratories carrying out variable-amplitude load tests using the FALSTAFF spectrum were visited by one of the coordinators (P.R. Edwards) and measurements taken to assess the accuracy with which the loading sequences were being applied. The measurements were taken on a portable Rainflow counting device which had a resolution of 64 levels. Thus the device was able to measure 64 x 64 triangular Rainflow matrices. All measurements were made on an alignment specimen with central strain gauges on each side of the specimen because these measurements would be more convincing than any taken from the load cell of the servohydraulic fatigue machine. The assessment of the accuracy of loading and whether the actual sequence of loads was correct was done initially by a comparison of Rainflow matrices. However, it was found that all of the conclusions that

could be drawn from such comparisons could equally be drawn from simple measurements of peaks and troughs. These measurements were extracted from the Rainflow matrix and are presented. Author

N89-17293# Planning Research Corp., Hampton, VA.
SUGGESTED PLASTIC-REPLICA METHOD
M. H. SWAIN *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative test Programme p 75 (SEE N89-17287 09-39) Dec. 1988
(AGARD-R-732) Avail: NTIS HC A06/MF A01

The Cooperative Test Program participants received their test specimens in the chemically-polished condition. Prior to testing, the notch area was cleaned with acetone and then ethanlol was applied with a swab. It was then etched, which removed a very thin layer of material revealing the grain structure. A replica of the notch surface was made after each cyclic interval. The cyclic interval was selected so that some 25 to 30 replicas were taken during a test. Acetyl cellulose replica film was used. Author

N89-17294*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPROXIMATE STRESS-INTENSITY FACTORS FOR A SURFACE CRACK AND THROUGH CRACK AT A SEMI-CIRCULAR NOTCH
J. C. NEWMAN, JR. *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative test Programme p 76-77 (SEE N89-17287 09-39) Dec. 1988
(AGARD-R-732) Avail: NTIS HC A06/MF A01 CSCL 20K

An approximate stress-intensity factor equation for a semi-elliptical surface crack located at the center of a semi-circular edge notch subjected to remote uniform stress is given. Author

N89-17295*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LONG-CRACK GROWTH RATE DATA: CONSTANT AMPLITUDE AND FALSTAFF LOADING
E. P. PHILLIPS *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 78-83 (SEE N89-17287 09-39) Dec. 1988
(AGARD-R-732) Avail: NTIS HC A06/MF A01 CSCL 20K

This annex describes test procedures and presents the results from the tests for conventional, long-crack growth rate data. These data were used for comparisons with the short-crack growth rate data. Data were generated in tests with constant stress ratio load sequences (R = -2, -1, 0, and 0.5) and with the FALSTAFF load sequence. Results for long-crack tests with the GAUSSIAN load sequence are discussed. The constant stress ratio tests included decreasing, increasing, and constant load amplitude sequences. All cracks exceeded 6 mm in length when data were taken. All tests were conducted on center-cracked specimens of 2024-T3 aluminum alloy sheet taken from a large stock of this material held at the NASA Langley Research Center for fatigue research programs. The baseline long-crack growth rate data for this AGARD program were generated using 50 mm wide center-cracked specimens which were cut from some of the same sheets that were used to make the edge-notched, short-crack specimens. At growth rates below about 10 to the -5 mm/cycle, the baseline data were supplemented by data generated using 76 mm wide specimens made from sheets other than those used for the short-crack program. At growth rates above about 10 to the -5 mm/cycle, the baseline data were supplemented by data generated using 305 mm wide specimens made from sheets other than those used for the other two specimen sizes. The results from the 305 mm specimens were published in 1969. All specimen configurations are shown. Author

N89-17296# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
LONG-CRACK GROWTH RATE DATA: GAUSSIAN LOADING
P. HEULER *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 84-85 (SEE N89-17287 09-39) Dec. 1988
(AGARD-R-732) Avail: NTIS HC A06/MF A01

Conventional long-crack growth rate data under GAUSSIAN loading were generated at IABG within the AGARD short crack program on 2024-T3 sheet specimens. Test procedures and results are briefly reviewed in the following. Tests were carried out on 50 mm wide center-cracked specimens of 2024-T3 aluminum alloy sheet obtained from NASA Langley Research Center. A central slot of 0.4 by 3 mm was used as the crack starter. Specimen dimensions are shown. Author

N89-17297# P. P. Data Ltd., Fleet (England).
DATABASE PROGRAM FOR CRACK PROPAGATION DATA ACQUIRED IN THE AGARD SHORT CRACKS COLLABORATIVE EFFORT
P. R. EDWARDS *In* AGARD, Short-Crack Growth Behaviour in an Aluminum Alloy: An AGARD Cooperative Test Programme p 86-96 (SEE N89-17287 09-39) Dec. 1988
(AGARD-R-732) Avail: NTIS HC A06/MF A01

The operation of a database program developed for use in the AGARD short cracks collaborative effort is described. Data are stored as files of crack length against number of cycles. If desired, sets of polynomial coefficients describing curves fitted to the data in each file are available. Any of the sets of data can be plotted, either a plot of crack length against number of cycles or a log-log plot of delta K (alternating stress intensity factor) against da/dN (crack growth rate), with adjustable scales in both cases. The object of the program is to enable easy cross-plotting of different sets of data on the same graph. The plots can be output to an external plotter if required, either for incorporation into technical reports or to produce viewgraphs. These features have been extensively used in this report. Least squares fit straight lines on log-log plots can be calculated and plotted for any set or sets of data. Provision exists for the fitting of polynomials to each set of data. This can be carried out interactively, because polynomials are plotted quickly on the graphics screen, and different orders of polynomial curve fit compared. If a suitable digitizing tablet is available then additional points can be added to the length against cycle curves, so as to force the polynomial to follow a desired curve, in particular, to follow the correct slope at the beginning and end of defined crack propagation curves. The program will run on Hewlett-Packard 9836/9816 or 9817/217/310/320 computers with virtually any kind of disc storage. Author

N89-17687# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Airplane Div.
COMPARISON OF EXPERIMENTAL RESULTS AND ANALYTICALLY PREDICTED DATA FOR DOUBLE SHEAR FASTENED JOINTS
J. BAUER and E. MENNLE *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 8 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

Experimental tests were carried out to investigate the strength of open holes and pin loaded holes, as well as the combination of both. The material used was 914 C/T300. The tests delivered enough information to represent the basis for the development of an analytic prediction method. The prediction method is based on a linear analysis, which provides the stress field around a hole loaded with any type of loading. To make use of this information, in order to predict the strength, some empirical influence has to be taken into account to produce good correlation between experimental and theoretical data. The obtained accuracy is shown, as well as diagrams representing theoretically derived notch sensitivity and the double shear pin pearing strength. Author

N89-17688# Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.
RECENT STUDIES ON BOLTED JOINTS IN COMPOSITE STRUCTURES
V. B. VENKAYYA, R. L. RAMKUMAR (Northrop Corp., Hawthorne, CA.), V. A. TISCHLER, B. D. SNYDER, and J. G. BURNS *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 14 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

A brief review of recent Air Force programs in bolted joints in composite structures is given. The review includes analytical methods development and experimental verification. Analytical methods address both single fastener and multifastener joints. A number of joint design variables, such as, finite geometry, fastener arrangement, joint service environment, and a number of relevant parameters are addressed. The test programs include static and

fatigue specimens. Single fastener and multifastener joint tests were conducted to correlate the analysis results. Full scale test specimens were used to verify the overall analysis strategy. A comprehensive design guide was developed for the design and analysis of bolted joints in composite structures. This design guide is supported by four computer programs. Author

N89-17689# Politecnico di Milano (Italy). Dipartimento di Ingegneria Aerospaziale.
DAMAGE GROWTH IN COMPOSITE BOLTED JOINTS
V. GIAVOTTO, C. CAPRILE, and G. SALA *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 12 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

Static and fatigue failures of composite joints are dominated by the growth and propagation of typical damages, up to some catastrophic condition. Starting from experimental observations some typical damage propagation patterns are identified and analyzed with simple models and finite element schemes. This extension of the fracture mechanics approach, to a broader class of damages allows some insight into the intricate behavior of joints, and gives some suggestion for interpreting and correlating experimental data. Author

N89-17690# Technische Hogeschool, Delft (Netherlands). Faculty of Aerospace Engineering.
STRESSES IN PINLOADED ANISOTROPIC PLATES
TH. DEJONG *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 17 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

A method is presented for the calculation of stresses in an anisotropic plate with a row of equally spaced, pin-loaded holes. The pin-plate configuration represents a practical joint in a composite laminate where load is transferred from a row of mechanical fasteners into the laminate. The pins fit without clearance in the holes and they are supposed to be infinitely rigid. Numerical results are presented showing various effects of geometrical and material parameters on the stress distribution. The problem of a row of pin-loaded holes in an anisotropic plate is a complicated one of the mixed-boundary type. Several solutions can be found in literature based on simplifying assumptions regarding symmetry and geometry of the problem. The present solution is more general in those respects. It can be considered to be an application of Lekhitskii's theory on stress distributions in anisotropic plates with holes. With this theory the determination of the stresses is reduced to the determination of two complex functions which must satisfy the specified boundary conditions of the problem. Author

N89-17692# Northrop Corp., Hawthorne, CA. Aircraft Div.
STRENGTH ANALYSIS OF MECHANICALLY FASTENED COMPOSITE STRUCTURES
R. L. RAMKUMAR, E. S. SAETHER, K. APPA, and V. B. VENKAYYA (Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.) *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 22 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

An analysis is presented for the strength prediction of bolted composite structures, based on the average stress failure criterion. The analysis incorporates analytically derived special finite elements (loaded hole, unloaded hole, plain and effective fastener elements) into the Strength Analysis of Multifastener Composite Joints (SAMCJ) computer code. The loaded hole, unloaded hole and plain elements are derived from a doubly-connected laminate analysis that accounts for the effects of finite plate dimensions via a least squares boundary collocation solution procedure. The effective fastener element is derived from a fastener analysis that accounts for fastener shear and bending effects and through-the-thickness effects in the bolted laminates. The special finite elements in the SAMCJ code are developed using Argyris' natural mode method. The bolted plates are modeled using these elements, a conventional solution procedure yields the fastener loads and the stress state in each plate, and average stress failure criteria are used for strength prediction. The characteristic distances for net section, shear-out and bearing failures are assumed to be material constants obtained through limited testing. Author

N89-17694# Service Techniques des Programmes Aeronautiques, Paris (France).
IMPROVEMENT OF SPECIFIC FASTENING ELEMENTS FOR ASSEMBLING COMPOSITE STRUCTURES [MISE AU POINT D'ELEMENTS DE FIXATION SPECIFIQUES POUR ASSEMBLAGES DES STRUCTURES COMPOSITES]
RAYMOND LOUIS *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 31 p (SEE N89-17685 10-31) Mar. 1988 In FRENCH
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

The development of composite material assemblages must take into account the inherent singularities of the materials used, for example, delamination, damage from impact and/or expansion, galvanic corrosion, etc. Several activities have been undertaken to improve specific fastening elements susceptable to the problems encountered with these structures. Specifically, these activities concern the development of a semi-tubular anti-peeling rivet of titanium T-40 for non-working structures; the development of interchangeable nuts that are used in association with an intermediary glass-fiber strip; and the modification of existing fasteners (structural screws and rivets). Author

N89-17697# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
BEARING-BYPASS LOADING ON BOLTED COMPOSITE JOINTS
J. H. CREWS, JR. and R. A. NAIK (PRC Kentron, Inc., Hampton, VA.) *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 13 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

A combined experimental and analytical study has been conducted to investigate the effects of simultaneous bearing and bypass loading on a graphite/epoxy (T300/5208) laminate. Tests were conducted with a test machine that allows the bearing-bypass load ratio to be controlled while a single-fastener coupon is loaded to failure in either tension or compression. Test coupons consisted of 16-ply quasi-isotropic graphite/epoxy laminates with a centrally-located 6.35 mm bolt having a clearance fit. Onset-damage and ultimate strengths were determined for each test case. Next, a finite element stress analysis was conducted for each test case. The computed local stresses were used with appropriate failure criteria to analyze the observed failure modes and strengths. An unexpected interaction of the effect of the bypass and bearing loads was found for the onset of compression-reacted bearing damage. This interaction was caused by a decrease in the bolt-hole contact arc and a corresponding increase in the severity of the bearing loads. The amount of bolt-hole contact had a significant effect on local stresses and, thus, on the calculated damage-onset and ultimate strengths. An offset-compressible failure mode was identified for laminate failure under compression bearing-bypass loading. This failure mode appears to be unique to compression bearing-bypass loading and, therefore, cannot be predicted from simple tests. Author

N89-17698# Construcciones Aeronauticas S.A., Madrid (Spain).
BOLTED JOINTS IN COMPOSITES PRIMARY STRUCTURES
A. RUTZ *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 8 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

In the design of composite parts in primary structures, it is necessary to use bolted joints because of inspection requirements and the need for partial disassembly, repairability, access to the structure and for manufacturing breaks. The proven methodology for bolted joints in metallic structures cannot directly be applied to bolted joints in composites because of material anisotropy, susceptibility to the environment and, specially, due to the brittle behavior of typical epoxy joint members up to ultimate failure. In typical loaded multirow joints, a tension type failure generally occurs. The [illegible] cial stresses at the edge of fastener hole produces fiber [illegible] Stress concentration factors governs the failure, as in metals under fatigue loads. A methodology for composite bolted joint analysis must be able to size any particular joint design, avoiding the need for detail design tests. The approach under the present work correlates stress concentration factors in elastic-isotropic materials with those which appear in composites, by means of an empirically determined relief

factor. CASA has developed a test plan which includes several hundreds of coupons. Basically, bearing strength allowables and stress concentration factors, are investigated. Author

N89-17700# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Airplane Div.
MECHANISM OF SINGLE SHEAR FASTENED JOINTS
J. BAUER *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 6 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

The problems arising with the strength of single shear fastened joints are considerably greater than those of double shear joints. The additional (or secondary) bending moment loads not only the cover plates, but also causes considerably bending in the fasteners. If one of the cover plates is of composite material its brittleness and relatively low bearing strength lead to new problems. Experimental data were produced with a 100 percent load transfer specimen using a carbon fiber reinforced plastic (CFRP) to metal joint. Taking the specimen configuration as a basis, the interaction of bolt bending and local load introduction into the two plates is shown in form of diagrams based on theoretical investigations. Author

N89-17703# Fraunhofer-Inst. fuer Betriebsfestigkeit, Darmstadt (Germany, F.R.).
EFFECT OF ENVIRONMENT AND IMPROVEMENT MEASURES ON STATIC AND FATIGUE STRENGTH OF BOLTED CFRP-JOINTS
J. J. GERHARZ and H. HUTH *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 16 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

Effects of environment, preloading, bushings, local reinforcements and joint laminate tailoring on the efficiency of carbon fiber reinforced plastic (CFRP) joints are documented. Thereby, joint efficiency at static, residual and fatigue strength is considered. The laminate lay-up, the fastener system, fastener fit and clamping stresses were not changed. The material used was 914 C/T300 or Fiberite 976/T300. Critical hot/wet condition expected in service reduced joint efficiency but preloading on fatigue design load level with superimposed temperature cycle per flight did not. Installation of metal bushings into fastener holes, local reinforcement by adding layers to the hole section, and joint laminate tailoring through strip design were introduced to reveal their ability to improve composite joint efficiency. They proved to be successful depending on design constraints and required joint performance. Author

N89-17704# Politecnico di Milano (Italy). *Dipartimento di* Ingegneria Aerospaziale.
STIFFNESS AND RESIDUAL STRENGTH VARIATIONS ON MECHANICAL JOINTS IN CFRP SPECIMENS IN CYCLING LOADING
C. CAPRILE and G. SALA *In* AGARD, Behaviour and Analysis of Mechanically Fastened Joints in Composite Structures 24 p (SEE N89-17685 10-31) Mar. 1988
(AGARD-CP-427) Avail: NTIS HC A14/MF A01

An experimental study of the fatigue behavior of jointed specimens made of carbon fiber reinforced plastic has been carried out. Four different configurations and four laminations have been taken into account, to point out the influence of by-pass load/transfer load ratio and stacking sequence on specimen fatigue behavior. Loading frequency has been maintained at 20 C.P.S. in tension-tension tests at room temperature with dry test conditions. Fatigue loads have consisted in an alternate component (20 pct of failure load) superimposed on a constant tensile force (60 pct of failure load). The influence of different sequences of constant amplitude load blocks were also investigated. Residual strength and stiffness versus number of load cycles have been compared for the same stacking sequence by varying specimen configuration, and for different stacking sequences and equal configuration. Elastic and tensile characteristics have been monitored on-line by means of load-cells, LVDT transducers and strain gauges. Damage growth was inspected by making use of nondestructive tests like X-rays radiography with opaque enhanced penetrant liquids and electronic microscope photography. The final results have consisted of a correlation between damage growth and residual strength and stiffness of jointed specimens. Author

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EARTH RESOURCES AND REMOTE SENSING

Includes remote sensing of earth resources by aircraft and spacecraft; photogrammetry; and aerial photography.

N87-24950# Marconi Avionics Ltd., Rochester (England). Guidance Systems Div.
THE DIGITAL COLOUR MAP SIMPLIFIES GROUND ATTACK OPERATIONS
DAVID W. HUSSEY *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 8 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

A pilot flying low and fast needs to know where he is at all times, the nature of the local terrain, and his actual track. The pilot needs help in identifying waypoints, threats, and targets without distraction of his attention from the safety of the aircraft and the overall demands of the mission. The ideal way to provide this information is as a continuous color map, oriented track up, with all associated information overlayed. It must also be usable by day and by night. No currently available equipment can achieve all these aims satisfactorily, other than a digital color map generator providing video to a multifunction color CRT display. Interest is now focussing on increasing the benefits that accrue from the use of the equipment in helicopter and fixed wing aircraft, in training, operationally, and as an aid to mission planning. The ease with which the digital map database can be updated and overlayed is a factor. It is as useful during mission planning as it is to the pilot in the air. How such a computer aid might be used and some of the increases in effectiveness that follow are identified. Author

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GEOPHYSICS

Includes aeronomy; upper and lower atmosphere studies; ionospheric and magnetospheric physics; and geomagnetism.

N87-26938# Institut d'Aeronomie Spatiale de Belgique, Brussels.
THE QUIET AND DISTRIBUTED PLASMASPHERE
J. LEMAIRE *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 7 p (SEE N87-26937 21-18) May 1987
Previously announced as N87-22498
(AGARD-CP-406) Avail: NTIS HC A13/MF A01 CSCL 22B

The plasmasphere and plasmapause are described from an observational point of view. The main properties of this inner magnetospheric region are recalled. The dynamical response of the plasmasphere to enhancements of geomagnetic activity is considered. The peeling off of the nightside plasmasphere at the onset of enhanced magnetospheric convection events is discussed. The dayside refilling mechanism is addressed. Author

N87-26939# Utah State Univ., Logan. Center for Atmospheric and Space Sciences.
MAGNETOSPHERIC CONTROL OF THE BULK IONOSPHERIC PLASMA
J. J. SOJKA and R. W. SCHUNK *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 14 p (SEE N87-26937 21-18) May 1987
(Contract NSF ATM-84-17880)
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

The temperature, composition, and circulation of high latitude ionosphere display a marked variation with altitude, longitude, universal time, season, solar cycle and geomagnetic activity. To a

large degree this variation is a consequence of the effect that magnetospheric electric fields, particle precipitation, and heat flows have on the ionosphere. These and other aspects of the ionosphere's response to changing magnetospheric conditions are discussed using a time dependent ionospheric model. Author

N87-26940# Institut d'Aeronomie Spatiale de Belgique, Brussels.
A MODEL FOR AN ELECTROMOTIVE FORCE GENERATOR IN THE MAGNETOSPHERE: A SOURCE OF DISCRETE AURORAL ARCS
M. ROTH, D. S. EVANS (National Oceanic and Atmospheric Administration, Boulder, Colo.), and J. LEMAIRE *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 12 p (SEE N87-26937 21-18) May 1987 Previously announced as N87-17421
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

Results obtained from solving Maxwell's and Vlasov's equations to obtain the electrical structure of the sheath that separates magnetospheric particle populations of different densities and temperatures are presented. It is shown that for reasonable magnetospheric plasma populations, an electric potential difference of several kilovolts exists across such a boundary. The potential can serve as the necessary electromotive force for the auroral current circuit. The colocation between a magnetospheric boundary and a discrete aurora is a natural consequence of this picture. Author

N87-26941# Los Alamos National Lab., NM.
HOSTILE ENERGETIC PARTICLE RADIATION ENVIRONMENTS IN EARTH'S OUTER MAGNETOSPHERE
D. N. BAKER, R. D. BELIAN, P. R. HIGBIE, R. W. KLEBESADEL, and J. B. BLAKE (Aerospace Corp., El Segundo, Calif.) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 16 p (SEE N87-26937 21-18) May 1987 Previously announced as N86-32018
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

Particular emphasis is given to highly relativistic electrons (3 approx. 10 MeV). Electron fluxes and energy spectra are shown that were measured by two high energy electron sensor systems at 6.6 R sub E from 1979 through 1984. Large, persistent increases in this population were found to be relatively infrequent and sporadic in 1979 to 1981 around solar maximum. During the approach to solar minimum (1981 to present) it is observed that the highly relativistic electrons occur with a regular 27-day periodicity and are well associated with the reestablished solar wind stream structures. The present analysis suggests that the Jovian magnetosphere is a recurrent source of this significant electron population in the outer terrestrial magnetosphere and that these electrons have a very deleterious effect on spacecraft systems due to deep dielectric charging and low-dose susceptibility effects. Author

N87-26942# Royal Aircraft Establishment, Farnborough (England). Radio and Navigation Dept.
THE USE OF PI2 PULSATIONS AS INDICATORS OF SUBSTORM EFFECTS AT GEOSTATIONARY ORBIT
M. LESTER *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 9 p (SEE N87-26937 21-18) May 1987
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

Some of the characteristics of Pi2 pulsations observed at mid-latitudes on the ground are reviewed and the use of certain characteristics in indicating various magnetic and particle perturbations occurring during substorms are assessed. Spacecraft charging and its effects at geosynchronous orbit are also reviewed. There is a brief discussion of how Pi2 pulsations might be used to predict intervals of spacecraft charging at geosynchronous orbit. Author

N87-26943# Stanford Univ., CA. STAR Lab.
WAVE-INDUCED PARTICLE PRECIPITATION FROM THE MAGNETOSPHERE AND THE ASSOCIATED IONOSPHERIC PERTURBATIONS
U. S. INAN *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 10 p (SEE N87-26937 21-18) May 1987
(Contract NSF DPP-82-17820; NSF DPP-80-22282)
(AGARD-CP-406) Avail: NTIS HC A13/MF A01

A brief review of the gyroresonant wave-induced precipitation of energetic radiation belt particles is presented using the particular case of interactions involving lightning-generated whistler waves as an example. The interaction physics is first discussed in the context of results from a recently developed theoretical model of the whistler-particle scattering process occurring in the magnetosphere. This is followed by a discussion of the Trimpi effect, a particularly sensitive ground-based technique that has recently been used for detecting ionospheric perturbations produced by whistler-induced energetic particle precipitation from the magnetosphere on L-shells of 2 to 5. Author

N89-11933# Lancaster Univ. (England). Dept. of Environmental Science.
THE HIGH-LATITUDE IONOSPHERE: GEOPHYSICAL BASIS
J. K. HARGREAVES *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 27 p (SEE N89-11931 03-32) Sep. 1988
(AGARD-LS-162) Avail: NTIS HC A10/MF A01

This introductory lecture summarizes concepts of the ionosphere and the magnetosphere that are fundamental to our understanding of high-latitude ionosphere. It begins with the basic theory of the ionosphere, particularly the processes of production and loss which lead to the existence of a permanent ionosphere and render the upper atmosphere electrically conducting. The structure of the magnetosphere, which strongly affects the polar regions because of coupling along the geomagnetic field lines, is then reviewed, including the form of the magnetosphere, and the plasma and energetic particles that are contained within the magnetosphere. Author

N89-11938# Lancaster Univ. (England). Dept. of Environmental Science.
THE HIGH-LATITUDE IONOSPHERE: DYNAMICAL ASPECTS, AND MODELS
J. K. HARGREAVES *In* AGARD, Media Effects on Electronic Systems in the High Latitude Region 22 p (SEE N89-11931 03-32) Sep. 1988
(AGARD-LS-162) Avail: NTIS HC A10/MF A01

Whereas the inner magnetosphere co-rotates with the Earth, the outer region circulates in a pattern determined by the solar wind. These motions are communicated along the geomagnetic field-lines to the high-latitude ionosphere, causing F-region plasma to drift bodily and producing electric currents in the E region. The dynamics of the polar ionosphere are characterized by trans-polar drift from day to night and a return flow around the auroral zone. The neutral thermospheric wind is driven by solar heating, and this also flows across the polar caps from day to night sectors. Models are becoming increasingly important in upper-atmosphere geophysics. The extensive data sets now available have enabled empirical models to be compiled. These are essentially mathematical representations of the data in a form suitable for a computer. Where the theory is sufficiently well developed, it is worthwhile to develop a mathematical model based on the fundamental equations governing the phenomenon. The output from such models obviously needs to be checked against data, and they offer a useful technique for studying the fundamentals of complex phenomena. Models - some empirical, some mathematical, and some mixed - have been produced for the structure of the neutral atmosphere, the winds and tides of the thermosphere, the ionosphere, the magnetosphere, and for ionospheric radio propagation. Author

N89-17750# Boston Univ., MA. Dept. of Astronomy.
MAGNETIC STORM EFFECTS ON F LAYER IRREGULARITIES NEAR THE AURORAL OVAL
JULES AARONS and ALAN S. RODGER (British Antarctic Survey, Cambridge, England) *In* AGARD, Scattering and Propagation in Random Media 10 p (SEE N89-17706 10-31) Mar. 1988 Sponsored in part by ONR, Washington, DC and National Environment Research Council, United Kingdom
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The effect of F layer irregularities on transionospheric transmissions and fading at HF at the equatorial, auroral, and polar latitudes was documented. Little was done on morphology and physics of irregularities noted at subauroral latitudes, in the vicinity of the plasmapause. The intensities of the irregularities are considerably less than those observed at equatorial and high latitude regions. A study was made of F layer irregularities for the month of October 1981 using a series of scintillation and spread F measurements between 0 and 70 W. This included F layer intersections at subauroral as well as auroral latitudes. In the data set a comparison was made of scintillation on one propagation path, in the Northern Hemisphere, and spread F data at a Southern Hemisphere conjugate position, the Argentine Islands. Correlation was obtained on those nights when scattering was noted over several hours. The major irregularity activity periods were separated. The separation of irregularity occurrence at subauroral latitudes into cases associated with magnetic activity and cases when magnetic activity was quiet does not allow for simple modeling or statistical ordering. Ordering by Dst rather than Ap yields the best results. During magnetic activity, the irregularities may be convected from high latitudes or created by penetration of the electric field to lower latitudes. During the recovery phase it is proposed that ring current energies supply the ultimate source of the irregularity production at F layer heights. Author

N89-17751# Lowell Univ., MA. Center for Atmospheric Research.
SPECULAR SCATTER: A NEW MECHANISM FOR IONOSPHERIC BACKSCATTER
GARY S. SALES *In* AGARD, Scattering and Propagation in Random Media 8 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Recent investigation into backscatter from ionospheric irregularities at high frequencies (3 to 30 MHz) has indicated that the usual scatter mechanism requiring orthogonality with the field-aligned irregularities in the E and F region of the ionsophere is not sufficient to explain all the observations. Assuming field aligned electron density irregularities, ray tracing shows that clutter originates in the region where the ray becomes perpendicular to the earth's magnetic field lines within the ionosphere. The intensity of these irregularities can be described in terms of delta N/N, the fractional deviation from the ambient electron density. The actual distribution of electron density fluctuations is described using a power law spectrum with an exponent of n = 2. As will be shown, the orthogonality condition can always be satisfied in the F region of the ionosphere at mid and high latitudes near the reflecting point where the rays have become near-horizontal. The orthogonal clutter mechanism is restricted to F-region altitudes near the reflection point for obliquely propagating HF signals. In the auroral ionosphere, in addition, the E-region irregularities are expected to be intense and can contribute to the overall ionosphenc clutter through the mechanism of specular scatter. This scattering mechanism was not considered before and will be described in detail. Finally, the specular scatter mechanism permits effective scatter at a wide range of altitudes throughout the F and E regions of the ionosphere. Author

N89-17752# Air Force Geophysics Lab., Hanscom AFB, MA.
IONOSPHERIC SCINTILLATIONS AND IN-SITU MEASUREMENTS AT AN AURORAL LOCATION IN THE EUROPEAN SECTOR
SANTIMAY BASU, SUNANDA BASU, EILEEN MACKENZIE, and DAN WEIMER (Regis Coll., Weston, MA.) *In* AGARD, Scattering and Propagation in Random Media 12 p (SEE N89-17706 10-31) Mar. 1988 Sponsored in part by Defense Nuclear Agency, Washington, DC
(Contract F19628-86-K-0038)
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The orbiting HiLat satellite launched by the Defense Nuclear Agency in 1983 offered an opportunity for studying the ionospheric scintillation parameters in relation to the in-situ measurements of ionization density, drift velocity, field-aligned current, and particle precipitation during the sunspot minimum period. The results of such a morphological study performed by the Air Force Geophysics Laboratory based on their observations at the auroral oval station of Tromso, Norway are discussed. The dynamics of the spatial and temporal extent of this region are illustrated in the invariant latitude/magnetic local time grid. The geometrical enhancement of scintillations observed during the alignment of the propagation path with the local magnetic L-shell is shown to be the most consistent and conspicuous feature of scintillations in the nighttime auroral oval. The steepening of phase spectral slope in this region is indicative of the presence of L-shell aligned sheet-like irregularities at long scale lengths. The seasonal variation of total electron content (TEC) determined from the differential Doppler measurements of HiLat transmissions is discussed in relation to in-situ density measurements at 830 km. The results are also utilized to illustrate the dependence of ionospheric structure parameters on short-term variability of solar activity during the sunspot minimum period. Special effort is made to illustrate that the joint study of scintillation/TEC and in-situ parameters provides an insight into the nature of magnetospheric coupling with the high latitude ionosphere. Author

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METEOROLOGY AND CLIMATOLOGY

Includes weather forecasting and modification

N88-27669# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ATMOSPHERIC TURBULENCE RESEARCH AT DFVLR
ANNE M. JOCHUM (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling, West Germany) Jul. 1988 19 p
(AGARD-R-752; ISBN-92-835-0462-3; AD-A198045) Avail: NTIS HC A03/MF A01

A brief overview is given of work on atmospheric turbulence at DFVLR (German Aerospace Research Establishment), and describes the research tools, which include instrumented aircraft and numerical models. Some results of research on turbulence characteristics are given; these are mostly in the convective boundary layer. The report discusses their application to the study of aircraft response and airframe loadings. Author

N88-29727*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SUMMARY OF ATMOSPHERIC TURBULENCE MEASUREMENTS WITH SPECIALLY-EQUIPPED AIRCRAFT IN THE US
H. N. MURROW *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of the Art in the Description and Modelling of Atmospheric Turbulence 11 p (SEE N88-29725 24-01) Dec. 1987
(AGARD-R-734) Avail: NTIS HC A09/MF A01 CSCL 04B

The technique of measurement of atmospheric turbulence in the form of true gust velocity is summarized. Specific aspects pointed out are related to NASA programs conducted over the last 15 years. Liberal use is made of references for details. Some recommendations resulting from a Spring 1986 workshop on atmospheric turbulence are also presented. Author

N88-29728# Royal Aircraft Establishment, Bedford (England).
MEASUREMENT AND ANALYSIS OF LOW ALTITUDE ATMOSPHERIC TURBULENCE OBTAINED USING A SPECIALLY INSTRUMENTED GNAT AIRCRAFT
G. W. FOSTER and J. G. JONES *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the Art in the Description and Modelling of Atmospheric Turbulence 45 p (SEE N88-29725 24-01) Dec. 1987
(AGARD-R-734) Avail: NTIS HC A09/MF A01

Detailed measurements of atmospheric turbulence made by a specially instrumented Gnat aircraft at altitudes below one thousand feet over a variety of terrains are described. A program of flying yielded about 400 runs for which time histories of the three components of turbulence are available. These runs are analyzed to give parameters which summarize the statistical characteristics of the turbulence encountered. A very strong relationship between two parameters from the Statistical Discrete Gust Analysis technique and one from the Power Spectral Density technique is identified. Author

N88-29733# National Aerospace Lab., Amsterdam (Netherlands).
ACQUISITION OF GUST STATISTICS FROM AIDS-RECORDED DATA
J. B. DEJONGE, A. J. P. VANDERWEKKEN, and R. NOBACK *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 14 p (SEE N88-29725 24-01) Dec. 1987 Previously announced as N88-14586
(AGARD-R-734) Avail: NTIS HC A09/MF A01

The procedures applied to reduce B-747 acceleration data from greater than 100,000 flight hours to derived gust velocities are described. The results are presented and compared with other data sources. The validity of the assumptions made in the derivation are discussed. Author

N88-29734# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EXTREME GUSTS DISTRIBUTION
GABRIEL COUPRY *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 9 p (SEE N88-29725 24-01) Dec. 1987 In FRENCH; ENGLISH summary Original language document was announced in IAA as A87-44328
(AGARD-R-734) Avail: NTIS HC A09/MF A01

A model of extreme atmospheric turbulence is proposed based on 5 years of commercial flight data for events with load factors in excess of 0.5. The Pratt formula is found to lead to incoherent atmospheric descriptions, while the Hall formula, with appropriate choice of scale, is found to lead to a coherent turbulence description which is relatively independent of the type of aircraft considered. For strong turbulences, the average number of overshoots by a nautical mile are found to decrease exponentially with gust amplitude. The incidences of gusts exceeding a threshold value are found to obey a Poisson distribution whose mean decreases exponentially with amplitude, indicating that the probability of the occurrence of big gusts can be represented by Gumbel's extreme value theory. Author

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LIFE SCIENCES (GENERAL)

N87-25715# Cologne Univ. (Germany, F.R.). Neurobiologische Forschung.
PHARMACOLOGICAL APPROACHES TO PERFORMANCE ENHANCEMENT IN ANIMALS
D. G. SPENCER, JR., T. SCHUURMAN, U. BENZ, E. HORVATH, and J. TRABER *In* AGARD Biochemical Enhancement of Performance 11 p (SEE N87-25709 19-52) Mar. 1987
(AGARD-CP-415) Avail: NTIS HC A07/MF A01

Drug effects were studied on learning and working memory performance in young, normal rats, as well as on reactions to hypoxia and stress. While some of the treatments reduced cognitive parameters under normal conditions, none improved them in a meaningful way. However, several substances were found to improve performance disrupted by exposure to hypoxia. These substances included piracetam, nimodipine, and ipsapirone (TVX Q 7821). An additional characteristic of ipsapirone was an amelioration of negative responses to stress. Due to the well-understood mechanisms of action of nimodipine and ipsapirone, their low toxicity, and their lack of negative effects on normal cognitive performance, it is suggested that these drugs could prove to be useful therapeutic agents under conditions of high information processing loads. Author

N88-27683# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
ELECTRIC AND MAGNETIC ACTIVITY OF THE CENTRAL NERVOUS SYSTEM: RESEARCH AND CLINICAL APPLICATIONS IN AEROSPACE MEDICINE
Feb. 1988 404 p In ENGLISH and FRENCH Symposium held in Trondheim, Norway, 25-29 May 1987 Original contains color illustrations
(AGARD-CP-432; ISBN-92-835-0447-X; AD-A195265) Avail: NTIS HC A18/MF A01

The physical and mental demands imposed on aircrew operating high performance combat aircraft will be severe. The heavy loads of information received from the aircraft sensors must be assimilated and managed in a timely and efficient manner. Severe physiological stresses will be imposed by the environment of rapid onset, high sustained G-acceleration. The purpose of this symposium was to explore the feasibility of using electrical potentials and magnetic fields of the central nervous system as objective measures of the human condition. Topics addressed include: the computer-aided imaging of background and evoked brain electrical activity; magnetoencephalography; the functional significance of P300, contingent negative variation (CNV), and electroencephalogram (EEG) events as indices of behavior; the use of physiological measures for indexing in-flight and simulator mission effectiveness; and the effects of acceleration, drugs, and diseases on CNS activity. For individual titles, see N88-27684 through N88-27721

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AEROSPACE MEDICINE

Includes physiological factors; biological effects of radiation; and effects of weightlessness on man and animals.

N87-13932# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
BACKACHE AND BACK DISCOMFORT
Jun. 1986 274 p In ENGLISH and FRENCH Meeting held in Pozzuoli, Italy, 8-10 Oct. 1985
(AGARD-CP-378; ISBN-92-835-0392-9; AD-A171226) Avail: NTIS HC A12/MF A01

Backache and back discomfort are serious economic and operational problems in aerospace environments. The objective of the meeting was to bring military and civilian specialists together to discuss ways and means of alleviating back problems in the cockpit. The papers address both the seating posture and the vibrational environment as contributory factors. Other topics addressed and discussed include the conditions of the spine which predispose individuals to backache, methods for evaluating and predicting back pain, educational programs for the prevention and treatment of recurrent back pain, and strategies for reducing backache in current and advanced cockpit environments. For individual titles see N87-13933 through N87-13960.

N87-13933# Liverpool Univ. (England) Dept. of Orthopaedic and Accident Surgery.
EPIDEMIOLOGY OF THE DRIVER'S BACK
J. D. G. TROUP In AGARD Backache and Back Discomfort 4 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Back pain is one of the most prevalent of modern symptoms and backache which comes on after sitting is a typical complaint, particularly among drivers. But drivers' backache is not confined to those who seek treatment; it is common throughout the population whether patients or non-patients. Yet both the etiology and the pathomechanism remain unknown. Symptoms are related to the time spent at the wheel thus it may be be inferred that they arise from the concomitant postural restraints. But static stresses in the spine arise both from the seated posture itself and from the muscular work of driving; while dynamic stresses, including vibration, arise from the motion of the vehicle. The epidemiological studies so far have not differentiated between the potential causative factors and few, if any, have taken account of other physical activities undertaken by drivers. Author

N87-13937# Israeli Air Force Aeromedical Center, Tel Hashomer.
LOW BACK PAIN AND NARROWED DISC SPACES IN FIGHTER PILOTS
P. FROOM, S. MARGALIOT, and M. GROSS *In AGARD Backache and Back Discomfort* 4 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Compressive forces may play a role in the development of disc degeneration. The disc spaces were measured on lateral x-rays of the lumbar spine in fighter pilots with and without a history of sciatica, and compared them to those of asymptomatic transport pilots. An arbitrary cutoff point for normal was defined and the proportion of each group with narrowed disc spaces determined. Fighter pilots with a history of sciatica had a significantly higher proportion of those with narrowed disc spaces than did asymptomatic transport pilots. Fighter pilots without low back pain had an intermediate proportion with narrowed disc spaces. It is concluded that disc degeneration may be accellerated by repeated G(z) forces experienced by pilots of fighter aircraft. Author

N87-13938# Institute of Aviation Medicine, Fuerstenfeldbruck (Germany, F.R.).
RELATIONSHIP BETWEEN BACKACHE AND FLYING DUTY IN JET- AND PROP-PILOTS DEMONSTRATED BY A FLYING WING
K. BURMEISTER and W. K. THOMA *In AGARD Backache and Back Discomfort* 16 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

A questionnaire assessment was performed in a collective of 88 jet- and prop-pilots. Approximately half of the pilots suffer from backache. A significant connection between the number of flying hours, annual flying stress and sports activities can not be ascertained. The duration of the sitting posture and G-loads are subjectively classified as being the highest body stress, whereas vibrations play a secondary role. The cold pilot's seat in winter and the uncomfortable harness are objects of particular complaints. Concrete facts indicate that in an effort to avoid vertebral pain the seat must be constructed in such a manner as to avoid excessive posterior pelvis tilt. 50% of the pilots questioned are of the opinion that their flying duty causes health damages. Author

N87-13940# Institute of Work Physiology, Oslo (Norway).
MUSCULO-SKELETAL ILLNESSES AMONG WORKERS EXPOSED TO LOW-INTENSITY WORK LOAD OF LONG DURATION
R. H. WESTGAARD, T. JANSEN, R. BJORKLUND, and M. WAERSTED *In AGARD Backache and Back Discomfort* 9 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Low-level, continuous muscle load of long duration has received increasing attention as a potential source of musculo-skeletal injury. This paper presents evidence which indicates a quantitative relationship between the level of static load on shoulder muscles and the risk of developing musculo-skeletal illnesses in the shoulder and neck. Constrained working postures are probably the most frequent cause of low-level, continuous muscle load, but such loads may also develop for other reasons as illustrated by an example of a probable stress-related development of muscle tension. It is pointed out that aircraft pilots are exposed to a number of a factors which can contribute to the development of muscle tension. Low-level muscle tension may therefore be an important health problem for this profession, but this remains to be demonstrated in more specific projects. Author

N87-13941# *Centre d'Etudes et de Recherches de Medecine* Aerospatiale, Paris (France).
THE BIOMECHANICAL CHARACTERISTICS OF THE SPINAL COLUMN: BIBLIOGRAPHIC REVIEW [ANALYSE BIBLIOGRAPHIQUE DES CARACTERISTIQUES *BIOMECANIQUES DE LA COLONNE VERTEBRALE*]
P. QUANDIEU *In AGARD Backache and Back Discomfort* 28 p (SEE N87-13932 05-52) Jun. 1986 In FRENCH
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

In order to improve dynamic models of the spinal column, it is necessary, not only to apply to the various coefficients (stiffness, damping and mass) values which are as accurate as possible, but to understand the mechanical behavior of the different biological materials. After a diagrammatic review of the anatomy of the vertebral unit, a bibliographic survey of references addressing the mechanical characteristics of the disk, the ligaments, and the vertebral body is presented. Generaly accepted values of creep, relaxation and intranuclear compression, obtained during tests of flexion, extension, lateral inflexion, torsion, and disk shearing are discussed. Parameter values for ligaments are likewise addressed. Data obtained by the propagation of vibrational waves within the column are presented along with an example kinematic study. M.G.

N87-13942# *Paris V Univ. (France).*
AUTOMATIC RESEARCH ON OPTIMAL POSTURE [RECHERCHE AUTOMATIQUE DE POSTURE OPTIMALE]
A. M. COBLENTZ, J. F. COBLENTZ, P. GUENEAU, and N. BONJOUR *In AGARD Backache and Back Discomfort* 4 p (SEE N87-13932 05-52) Jun. 1986 In FRENCH
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

A new perspective on conceptual ergonomics is presented. Specifically, an automatic method for the analysis of optimal posture for a human model in a given environment is described. Algorithms incorporating dynamic programming and artificial intelligence techniques are discussed which model body position and articulation and an ideal reference. M.G.

N87-13943# Paris V Univ. (France). Lab. dAnthropologie Appliquee.
BIOSTEREOMETRIC STUDY OF THE OUTWARD CURVE OF THE SPINE FOR VARIOUS REFERENCE POSITIONS [ETUDE BVIOSTEREOMETRIQUE DE LA COURBURE EXTERNE DUE RACHIS POUR DIFFERENTES POSITIONS DE REFERENCE]
A. M. COBLENTZ, J. C. PINEAU, G. IGNAZI, and R. MOLLARD *In AGARD Backache and Back Discomfort* 5 p (SEE N87-13932 05-52) Jun. 1986 In FRENCH
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

An analysis of the outward curve of the spine was conducted starting with a survey of biostereometric data for a group of male subjects in standing and various sitting positions. The outward curvatures of the spine were determined from the following parameters: radius of the dorsal and lumbar curves, positions of the centers of curves, and localization of the inflexion point. Modifications of the shapes of outward contour were then studied for various sitting positions. The results of these efforts are utilized for three-dimensional modeling of the human body and applied in the analysis of positions in C.A.O. They can likewise contribute to a better understanding of the relations between the forms of the back in a functional posture and the constrained posture of seated operators. M.G.

N87-13944# Finsen Inst., Copenhagen (Denmark).
INVESTIGATION OF THE LUMBAR FLEXION OF OFFICE WORKERS
A. C. MANDAL *In AGARD Backache and Back Discomfort* 10 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Modern furniture in schools, factories and offices is constructed in such a way that no one can use it properly. Each day people

sit for many hours hunched over their tables in postures extremely harmful to the back. A considerably better sitting posture can be obtained if the table is constructed higher and if it is tilted about 10 deg. In this way a book or item is brought closer and is at a better angle to the eye. The worst bending of the neck is thus avoided. Furthermore, the seat can, with advantage, be tilted 20 deg forward to reduce the flexion of the lumbar region. By both these means the extra 30 deg flexion, which is the most strenuous part of the flexion, is avoided. This can be demonstrated by means of an automatic camera. To control the flexion of various parts of the body, well defined anatomical points were marked on the skin or on the clothes. Author

N87-13948# Laboratoire Central de Biologie Aerospatiale, Paris (France).

NUMERICAL CONTROL OF A VIBRATING TANK FOR THE STUDY OF TRANSIENT SIGNALS IN BIOMECHANICS (*COMMANDE NUMERIQUE DUN POT VIBRANT POUR LETUDE DES SIGNAUX TRANSITOIRES EN BIOMECANIQUE*)

L. PELLIEUX and B. PIEDECOCQ *In* AGARD Backache and Back Discomfort 13 p (SEE N87-13932 05-52) Jun. 1986 In FRENCH

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

In order to study the propagation of mechanical shock applied to the spinal column of a bioinstrumented *primate, a system for* the numerical control of the shock signal was developed. When using an implanted accelerometer it is necessary to consider, at the time of implantation, the temporal character of the acceleration selected by the experimenter. The mechanical excitation is effected with the aid of an electrodynamic vibration tank, on which is a fixed seat for the animal. The electric signal transmitted to the vibration tank is numerically calculated by a minicomputer. The system calculates, through filter components, the characteristics of the vibration generating system. It also deterines the dynamic *characteristics of the biological structure.* The technique rests on the hypothesis of linearity and time invariance of the biological structure. However, time invariance is not necessary when the time intervals are short. Likewise, because of the retroactive algorithm used, perfect linearity is not necessary. The method and its limitations are explained and results are reported. M.G.

N87-13949# Sunnybrook Medical Centre, Toronto (Ontario).

PREDICTION OF LUMBAR SPINAL SEGMENT INSTABILITY BY CENTRODE PATTERNS

S. D. GERTZBEIN, M. TILE, J. J. SELIGMAN, N. OGSTON, K. H. CHAN, G. KING, R. HOLTBY, and J. D. RUBENSTEIN *In* AGARD Backache and Back Discomford 9 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

The center of rotation defines motion of the lumbar spinal segment; it is an indicator of spinal instability but since the motion segment does not move about a single axis, a locus of instaneous axes of rotation or a centrode is defined. Centrodes in normal cadaveric spines as well as those with degenerative disc disease have been indentified using more techniques as well as by computer analysis of small angles of motion. In this study 47 spines were assessed, 22 of which were evaluated with axial loading. The normal centrode lies within the posterior half of the disc space, averaging 22 mm in 10 specimens. In the earliest stages of degenerative disc disease the centrode lengthens significantly (average 116 mm). Moderate disc disease shifts the centrode inferiorly. Axial loading did not appear to influence the *centrode lengths or position.* The technique is highly sensitive detecting 94% of the abnormal spines as compared with only 25% *detected by means of measuring* excessive motion on flexion/extension radiographs. This method is a highly reliable and quantifiable method of detecting early changes in spinal motion in degenerative disc disease prior to the well recognized radiographic abnormalities. Author

N87-13950# Uppsala Univ. (Sweden). Dept. of Rehabilitation *medicine*

EVALUATION AND PREDICTION OF BACK PAIN DURING MILITARY FIELD SERVICE

B. NORDGREN, R. SCHELE, and K. LINROTH *In* AGARD Backache and Back Discomfort 7 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Questions regarding back pain in different body positions and earlier sicklisting due to back disorders have been answered by 5,093 men aged 23 to 47 (average age 37) who were about to do military field service. Fifty-three per cent reported that they had had back pain at some time and 14 per cent stated that they had been sick-listed for more than one month in all due to back trouble. A subsample was subjected to a standardized physical examination of the back; *average examination time 9 min,* and the frequency and location pain, stiffness or other impairments are given. Subjects who experienced back pain during field service and whose military post was physically heavier than their civilian occupation had on an average lower isometric strength in abdominal muscles as well as in back muscles than other subjects. The physical examination of the lumbar spine was more efficient in separating subjects who experienced back pain during military field service, than information on earlier sick-listing due to back trouble and heaviness of the military post as compared to civilian *occupation.* Author

N87-13951# Uppsala Univ. (Sweden). Dept. of Rehabilitation Medicine.

INDIVIDUAL PREDICTABILITY OF BACK TROUBLE IN 18-YEAR OLD MEN: A PROSPECTIVE STUDY DURING MILITARY SERVICE

A. L. HELLSING, B. NORDGREN, R. SCHELE, B. AHLBORG, and L. PAULSSON *In* AGARD Backache and Back Discomfort 8 p (SEE N87-13932 05-52) Jun. 1986 Submitted for publication

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

At enlistment 6,824 young men (mean age 18 years) answered a questionnaire concerning back trouble (BT). Out of these 999 passed a standardized physical examination. A follow-up one to *four years later during the military service* was done, including the same physical examination and questionnaire. The aim was to study the possibility for predicting BT during this time course and the correlations between the variables at enlistement and at discharge. Several significant correlations were found. From the first physical examination, the pain tests (springing test, coin test) correlated with the degree of back trouble at discharge. The questions concerning (1) absence *from school or work and* (2) effect of BT on every day life before enlistement correlated with the degree of BT at discharge. The highest predictive value, 39%, was shown from the answer to the second question. The answer to the first question showed a predictive value of 25%. None of the examination variables showed predictive value over 20%. Smoking more than 20 cigarettes/day showed a predictive value of 23%. Physical data like height, weight and muscle strength had a predictive value of less than 20%. Author

N87-13952# National Defence Medical Centre, Ottawa (Ontario). *Physical Therapy Div.*

A REVIEW OF THE NDMC BACK CARE EDUCATION PROGRAMME

B. P. WARRINGTON-KEARSLEY *In* AGARD Backache and Back Discomfort 12 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

The Back Care Education Program (BCEP) at the National Defense Medical Center, directed to the prevention of recurrent low back pain (LBP) is described from its development in 1978 to the present. The course content is also described, and the vicissitudes governing the transformation of the BCEP from a 10-hour five day course conducted twice a month, to the 8.5-hour two day course, to the present 7-hour one day course. Patients were *surveyed through initial questionnaires and review* questionnaires sent to them 6 months after education. Results show that little demonstrable difference was found between the 5-day and one-day courses. The BCEP has proven very effective in preventing the LBP condition from worsening; less effective in reducing continuous pain; very effective in controlling further attacks of LBP. The BCEP also resulted in 71.5% patients requiring no further treatment and in reducing activity limitation. The BCEP

has enabled its clientele to be more responsible for continuing care of their backs by persuing a regime of regular exercise, activity and behavior modification and postural control. The BCEP has also proved cost effective in increasing the overall effectiveness of military personnel in reducing the number of days lost due to back injury. Author

N87-13957# *Liverpool Univ. (England). Dept. of Orthopaedic and Accident Surgery.*
MEASUREMENTS OF CHANGE OF STATURE IN THE ASSESSMENT OF STATIC AND DYNAMIC SPINAL LOADING
J. D. G. TROUP. *In* AGARD Backache and Back Discomfort 4 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

The height of the body in the erect position varies by about 1% during the course of the day. It decreases rapidly on getting up and, depending on the pattern of work and rest, continues to reduce during the day, but recovers overnight. With conventional methods of measuring stature, these changes would go unrecognised. Apparatus has therefore been developed allowing measurement to an accuracy of at least 1 mm. Studies have been made of static loading, lifting, running, in different types of seating and in resting postures. In general, height losses are proportional to the magnitude of lumbosacral compression. In addition, height losses from exercise are related to the perception of the exertion involved; and the gains in height produced in positions of rest are proportional to ratings for relaxation or comfort. For ergonomist, therefore, the method offers a reliable means of assessing the effects of work and recovery on the spine. Author

N87-13958# Royal Air Force Inst. of Aviation Medicine, North Luffenham (England).
BACKACHE IN AIRCREW
D. G. READER. *In* AGARD Backache and Back Discomfort 6 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Aircrew have long complained of backache. The backache is seldom severe, but frequently interferes with flying performance and is very distracting. A survey was conducted among UK aircrew in 1971 which showed that aircrew suffer from backache twice more frequently than groundcrew, pilots suffer more than other aircrew members and that ejection seats caused more backache than other types of seats. The survey also showed that half the aircrew never suffered from backache on the ground. The incidence of backache was high, 13% of pilots suffered on every flight, 22% suffered once a week while 45% suffered once a month. The backache is caused by the sitting position and design of the seat, which leads to loss of the lumbar curve. When the lumbar curve is restored by means of a curved rigid pad applied to the back, 50% of aircrew report that the backache is greatly improved and in 32% of cases completely resolved. A scheme has been underway for some years in the UK to provide lumbar pads for aircrew complaining of backache. The pads are simple and cheap to produce and are easy to use. However, the major disadvantage is that they require a mold for the individual's lumbar curve and then they cannot be used by other aircrew. Aircraft seat designs both for ejection seats and helicopter crew seats now incorporate lumbar support curves to prevent both loss of the lumbar curve and the subsequent backache in aircrews. The incidence of backache in aircraft incorporating these new designs is considerably lower. Author

N87-13959# Royal Air Force, Netheravon (England).
BACK PAIN IN GAZELLE AIRCREW
M. BRAITHWAITE. *In* AGARD Backache and Back Discomfort 8 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

The prevalence of backache among helicopter aircrew has long been known to be unacceptably high. The introduction of the Gazelle helicopter to UK service has resulted in an apparent increase in this prevalence. This paper is based on a questionnaire issued to Gazelle aircrew serving in Germany during 1981. The aim was to produce numerical evidence of the prevalence of backache in Gazelle aircrew, to delineate the factors responsible in the aircraft and to make recommendations for re-design. The major findings of the survey are that 82% of aircrew complained of Gazelle related backache, the taller pilots being worst affected. Flights lasting longer than are one hour gave rise to backache in 70% of the subjects. The seat design features considered responsible were the design of the seat cushion, inadequate lumbar support, routing of the shoulder harness and the angle of seat rake. Since the completion of this survey, a trial of a new Gazelle seat has been carried out. The new design includes an improved seat cushion, inflatable lumbar support, and increased height of the harness take off point from the inertia reel. The results of the initial trial are conclusive in their support for the new seat. These improvements have been incorporated into the design of the Gazelle armoured seat currently under development. Author

N87-13960# CAE Electronics Ltd., Saint Laurent (Quebec).
SEAT ISOLATION SYSTEM
M. VANVLIET, M. MCKINNON, and R. V. KRUK. *In* AGARD Backache and Back Discomfort 12 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Sustained low-frequency vibrations in helicopters, combined with poor posture imposed by control configuration, can affect the health and performance of aircrew. The attenuation of vibration is recognized as a critical problem in the design of future helicopters, and new (sidearm) control configurations under development may permit better posture. Conventional approaches isolate a pilot with a seat suspension which attenuates the dominant (vertical) axis of vibration. Such seats are typically passive, relying on a system of springs and dampers to attenuate the most critical combinations of expected frequency and g level. The bulk of such seats often precludes retrofitting them to existing air vehicles. Active shock/vibration isolation seats which offer advantages in terms of attenuation and frequency response have been proposed but no successful system has been developed to date. Some flight simulators employ g-seats to simulate g-forces acting on the pilot in high-performance aircraft. The expertise gained in developing, testing, and manufacturing the g-seat provides an ideal basis for developing an active antivibration seat. The frequency range of the g-seat includes the critical band of damaging and fatiguing vibrations in the vertical axis. Laboratory trials have demonstrated that the seat can attenuate the vibration to which the pilot is exposed. Concurrently, development of a displacement multi-axis hand controller for helicopter application is under way. Successful flight tests have been conducted with this unit configured as a side arm controller, permitting pilot to maintain an upright posture. This paper describes an approach and methodology for development of an active antivibration seat within the context of an integrated cockpit seat/control system. The intent is to achieve a high level of crew safety and comfort in concert with improved control performance. Author

N87-24070# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
SHORT COURSE ON CARDIOPULMONARY ASPECTS OF AEROSPACE MEDICINE
Mar. 1987 130 p. Course held in Fuerstenfeldbruck, West Germany, 18-20 May 1987, in Athens, Greece, 21-23 May 1987, in Copenhagen, Denmark, 9-11 Jun. 1987, and in Eskisehir, Turkey, 15-17 Jun. 1987
(AGARD-R-758; ISBN-92-835-1544-7; AD-A181671) Avail: NTIS HC A07/MF A01

Lectures and case presentations delivered as part of a course on the cardiopulmonary aspects of aerospace medicine are compiled. The major thrust of the course was directed toward aeromedical decision making. Medical problems such as arrhythmias, coronary disease, valvular disease, hypertension, and bronchiopulmonary disease are addressed. Diagnostic and screening techniques are also discussed. For individual titles, see N87-24071 through N87-24079.

N87-24071# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AEROMEDICAL EVALUATION AND DISPOSITION OF ELECTROCARDIOGRAPHIC ABNORMALITIES
WILLIAM B. KRUYER. *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 8 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Electrocardiographic abnormalities are discussed with regard to their aeromedical significance, evaluation, and disposition. Sinus

bradycardia, sinus and ventricular tachycardia, atrioventricular block, axis deviation, right and left bundle branch block, ventricular hypotrophy, tachyarrhythmias, atrial abnormalities, and short PR syndromes are addressed. Evaluation of the significance of these abnormalities is based on aviator cardiographic records in the USAF Central Electrocardiographic Library. The importance of natural history follow-up studies is emphasized. M.G.

N87-24072# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Clinical Sciences Div.
NONINVASIVE METHODS FOR THE DETECTION OF CORONARY ARTERY DISEASE IN AVIATORS: A STRATIFIED BAYESIAN APPROACH
JAMES R. HICKMAN, JR. *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 11 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

The detection of asymptomatic coronary disease is a major goal of most aeromedical services, especially those associated with high-performance aircraft. Unfortunately, the pursuit of silent coronary artery disease with contemporary noninvasive diagnostic methods has been disappointing. This lecture discusses the epidemiological principles which underlie this rather poor performance of contemporary diagnostic tools in a population where coronary artery disease is of low prevalence. The underlying statistical problem is best explained by analysis of Bayes' theorem, which applies conditional probability analysis to diagnostic tests which are not perfect. The predictive power of a positive diagnostic test is very heavily dependent upon the prevalence of the disease in the population being tested. Unlike sensitivity and specificity, which are independent of disease prevalence, predictive value is strongly influenced by stratification of the test population into subsets with high pretest probability of disease. Strategies to improve the poor performance of contemporary noninvasive tools in the testing of otherwise healthy individuals are discussed. The USAF School of Aerospace Medicine Risk Index is offered as a theoretical, but unvalidated, stratification tool. M.G.

N87-24073# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
VALVULAR AND CONGENITAL HEART DISEASE IN THE AVIATOR
WILLIAM B. KRUYER and ROBERT S. SCHWARTZ *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 12 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Many valvular and congenital heart lesions can have major impact in the aviation environment. In the flying population, such lesions are typically asymptomatic and may be subtle enough that their presence can be detected only by very careful physical or laboratory examination. Thus, valvular or congenital cardiac disease is often found in a flier in whom there is a great deal of time, effort, and monetary investment. The loss of such an individual from flying status should thus be avoided if at all possible. As in all aeromedical decisions, these considerations must be weighed against the likelihood of significant impairment while performing aviation duties resulting either directly or indirectly from the cardiac lesion of concern. In light of these conflicting considerations, a discussion of regulations and medical aspects of specific valvular and congenital problems as approached by the USAF School of Aerospace Medicine is presented. Author

N87-24074# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Clinical Sciences Div.
AEROMEDICAL ASPECTS OF MITRAL VALVE PROLAPSE
JAMES R. HICKMAN, JR. *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 7 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Mitral valve prolapse (MVP) continues to be a major aeromedical problem. Current issues revolve around diagnostic criteria, aeromedical thresholds for disqualification and the lack of definitive natural history studies upon which to base aeromedical decisions. Currently, there are no existing natural history studies of incidentally discovered mitral valve prolapse in the asymptomatic male. The USAF School of Aerospace Medicine is following over 300 mitral valve prolapse subjects on a recurrent basis in order to determine this natural history. The comparison of this natural history group with age-matched controls should be completed in approximately 1988. Preliminary data offered in this report enumerate the most common grounding causes of mitral valve prolapse in the first 202 aviators with prolapse in the study. A suggested scheme for clinical evaluation, aeromedical disposition of MVP and suggested aeromedical diagnostic criteria are offered. Author

N87-24075# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PULMONARY PHYSIOLOGY AND PULMONARY FUNCTION TESTING IN AEROSPACE MEDICINE
G. W. GRAY *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 8 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Respiratory diseases may have serious consequences in the aviation environment, ranging from life threatening incapacitation (e.g., tension pneumothorax) to aggravation of hypoxia, acceleration atelectasis and perhaps lowered G tolerance in individuals with relatively minor degrees of small airways disease. Some concepts of respiratory physiology which are of particular relevance in the aviation environment are reviewed and current methods of pulmonary function testing which can be applied to detect asymptomatic disease in aircrew are discussed. Author

N87-24076# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Central Medical Establishment.
AEROMEDICAL DISPOSITION OF PULMONARY SARCOIDOSIS, CHRONIC OBSTRUCTIVE LUNG DISEASE, REACTIVE AIRWAY DISEASE AND SPONTANEOUS PNEUMOTHORAX
DAVID H. HULL *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 5 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Four respiratory diseases are described in relation to aviation medicine: sarcoidosis, chronic obstructive lung disease, reactive airway disease, and spontaneous pneumothorax. Each is discussed in the context of flying safety, operational efficiency, and problems of treatment. Guidelines are offered for decisions on management and disposal of aircrew candidates and of trained aircrew who have a history of one of these diseases or who develop the disease during their flying career. Author

N87-24077# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
HYPERTENSION IN THE AVIATOR
WILLIAM B. KRUYER *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 3 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Systemic hypertension is one of the most commonly encountered medical problems for both the general medical practitioner and the specialist in aerospace medicine. Its frequent occurrence, its contribution to the risk of cardiovascular events, and problems with early detection and compliance with therapy all make hypertension a health problem of significant concern. It is clear from the literature that therapy for moderate and severe hypertension significantly reduces morbidity and mortality. However much study and debate has occurred regarding the benefit of mild hypertension. The appropriateness of therapy for mild hypertension is discussed based on a review of several major studies from the world literature. Detrimental effects of thiazide diuretics have been reported, prompting interest in the use of smaller doses of thiazide diuretics as well as interest in the use of other agents as first line therapeutic choices. Current USAF policies regarding the treatment of hypertension in aviation are discussed as well as considerations that must be addressed in the study of new medications for use in the aviator population. Author

N87-24078# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Clinical Sciences Div.
CORONARY RISK FACTORS IN AEROSPACE MEDICINE
JAMES R. HICKMAN, JR. *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 8 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Coronary risk factors may be used in the aeromedical setting to identify aviators who are at high risk for the development of coronary artery disease and are, therefore, at a higher risk for sudden incapacitation. Coronary risks may be used to identify those aviators who need additional testing in an attempt to discover asymptomatic coronary disease. Coronary risk factor analysis should also be applied to the entire aviator population in order to identify those aviators who need routine or intensive risk factor modification. Certain lipid patterns, especially familial hyperlipidemia patterns, may be used to identify younger trainees who do not represent a good long-term training investment because of high risk of subsequent development of coronary artery disease.
Author

N87-24079# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
CARDIOPULMONARY SCREENING FOR HIGH-PERFORMANCE FLYING: SELECTION AND RETENTION ISSUES
G. W. GRAY *In* AGARD Short Course on Cardiopulmonary Aspects of Aerospace Medicine 4 p (SEE N87-24070 17-52) Mar. 1987
(AGARD-R-758) Avail: NTIS HC A07/MF A01

Detection methods used in the cardiopulmonary screening of aircrew are discussed with reference to candidate selection standards and retention of older experienced pilots. Aircrew candidate screening emphasizes the diagnosis of mostly asymptomatic diseases and disorders. It is designed to identify structural cardiac abnormalities and cardiac arrhythmias that may be a problem in the high +G(z) environment. Screening should also be directed toward pulmonary disorders which may compromise human effectiveness in rapid onset high G (ROHG) and high sustained G (HSG) fighter operations. In experienced aircrew, screening emphasis shifts to the detection of abnormalities which develop with age, particularly, coronary heart disease and small airways disease. Current issues including tobacco smoking, the effects of repetative HSG on the heart and lungs, minimal coronary heart disease, and coronary angioplasty are also discussed.
M.G.

N87-25709# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
BIOCHEMICAL ENHANCEMENT OF PERFORMANCE
Mar. 1987 132 p In ENGLISH and FRENCH Symposium held in Lisbon, Portugal, 30 Sep. - 2 Oct. 1986
(AGARD-CP-415; ISBN-92-835-0414-3; AD-A185128) Avail: NTIS HC A07/MF A01

In modern weapons systems, the operator is in an environment of high information flux. His ability to receive, process, and act on the information is finite and therefore full system effectiveness may never be achieved because of operator limitations. Major advances are being made in areas dealing with regulation of neuronal responsiveness. This offers a number of opportunities for exploring ways in which the biochemistry of neurons may be altered, reversibly, to increase responsiveness to neurotransmitters and/or other agents. Human performance may be enhanced through these alterations. The agents which initiate the change in neuron responsiveness may be supplied through nutrition, pharmaceuticals, or biochemicals. The use of pharmaceutical to promote sleep, increase vigilance, and to alter regulatory centers is considered. Neurotransmitter precursors were supplied via nutritional supplements. For individual titles, see N87-25710 through N87-25722.

N87-25710# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
ENHANCEMENT OF PERFORMANCE: OPERATIONAL CONSIDERATIONS
A. N. NICHOLSON *In* AGARD Biochemical Enhancement of Performance 6 p (SEE N87-25709 19-52) Mar. 1987
(AGARD-CP-415) Avail: NTIS HC A07/MF A01

Maintaining the effectiveness of aircrew during intensive and sustained operations requires knowledge from many disciplines. The first is that of understanding how the performance of individuals is modified by unusual patterns of work and rest, and how deterioration in performance can be limited by the use of short periods of sleep. The second is a detailed understanding of drugs and how they can be used either to preserve sleep or to maintain viligance. The initial approach, if this is possible, must be to optimize the work pattern, but the pattern of rest can always be optimized. The most effective approach at present is likely to be the use of short periods of sleep, probably before rather than during duty periods, and to ensure restful sleep between operations by the use of hypnotics. At present the role of hypnotics is much less certain. Caffeine is used widely and is clearly effective. Drugs which modify monoaminergic transmission require a much greater understanding, both their pharmacological effects on the central nervous system and the effects on performance, both advantageous and adverse, before they can be considered for use in operations.
Author

N87-25711# Massachusetts Inst. of Tech., Cambridge. Dept. of Brain and Cognitive Sciences.
USE OF TYROSINE AND OTHER NUTRIENTS TO ENHANCE AND SUSTAIN PERFORMANCE
RICHARD J. WURTMAN *In* AGARD Biochemical Enhancement of Performance 4 p (SEE N87-25709 19-52) Mar. 1987
(AGARD-CP-415) Avail: NTIS HC A07/MF A01

Administration of supplemental tyrosine can increase the release of the catecholamines dopamine, norepinephrine, and epinephrine from physiologically-active neurons, and can thereby modify behaviors and other neuronal functions that are mediated by these neurotransmitters. The tyrosine acts by increasing the substrate saturation of the enzyme tyrosine hydroxylase; when a given neuron is firing frequently this enzyme becomes phosphorylated and, consequently, tyrosine-dependent. The amount of tyrosine that enters the brain varies with the plasma tyrosine ratio, i.e., the ratio of the plasma tyrosine concentration to the summed concentrations of other large neutral amino acids that compete with tyrosine for transport across the blood-brain barrier. Hence, the administration of pure tyrosine is much more effective than eating proteins, which contain tyrosine: the proteins contain and deliver to the blood stream considerably larger amounts of the other large neutral amino acids. Tyrosine administration protects rats from the neurochemical and behavioral effects of stress; its ability to enhance performance of stressed humans is under exploration.
Author

N87-25712# Army Research Inst. of Environmental Medicine, Natick, MA.
DEVELOPMENT OF A PARADIGM TO ASSESS NUTRITIVE AND BIOCHEMICAL SUBSTANCES IN HUMANS: A PRELIMINARY REPORT ON THE EFFECTS OF TYROSINE UPON ALTITUDE- AND COLD-INDUCED STRESS RESPONSES
L. E. BANDERET, H. R. LIEBERMAN (Massachusetts Inst. of Tech., Cambridge.), R. P. FRANCESCONI, B. L. SHUKITT, R. F. GOLDMAN, D. D. SCHNAKENBERG, T. M. RAUCH, P. B. ROCK, and G. F. MEADORS, III *In* AGARD Biochemical Enhancement of Performance 12 p (SEE N87-25709 19-52) Mar. 1987
(AGARD-CP-415) Avail: NTIS HC A07/MF A01

Tyrosine is the precursor for the catecholamine neurotransmitters dopamine and norepinephrine. Recent experiments have shown the behavior of animals given tyrosine is less impaired after stressful treatments than that of animals given placebo. Whether tyrosine administration would reduce adverse behavioral and physiological effects in humans was investigated by two combined environmental stressors, hypoxia and cold. Twenty-seven young male military volunteers were tested in a double-blind crossover design. The subjects were tested once with a placebo and once with tyrosine at a control condition and at two levels of multiple environmental stressors. Performance tests evaluated simple and choice reaction time to visual stimuli,

viligance, and processing of symbolic, numerical, verbal, and spatial materials. Blood samples were analyzed for plasma tyrosine and cortisol concentrations. Performance, symptoms, and mood were adversely affected by both levels of high altitude and cold. Tyrosine administration appeared to minimize the adverse consequences of these stressors. Tyrosine enhanced performance and reduced subjective symptoms. Mood states were also improved. Tyrosine had more beneficial effects at progressively more stressful altitude and cold conditions. Author

N87-25713# Basel Univ. (Switzerland). Dept. of Surgery Research Div.

MULTIVARIATE AND PSYCHO-PHYSIOLOGICAL FUNCTIONS OF DSIP

GUIDO A. SCHOENENBERGER, A. ERNST, and D. SCHNEIDER-HELMERT *In* AGARD Biochemical Enhancement of Performance 11 p (SEE N87-25709 19-52) Mar. 1987

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

From 1969 to 1977 the Delta-Sleep-Inducing-Peptide (DSIP) was isolated, characterized, and synthesized. Beside humoral sleep induction, DSIP acts upon the circadian rhythmicity of the locomotor activity and transmitter concentrations in the brain as well as on that of plasma proteins and cortisol levels in rats. The DSIP influences the prolactine levels and the circadian activity of N-Acetyl Transferase. The DSIP-like immunoreactive material showed a circadian rhythmicity in breast milk during normal lactation. The DSIP plasma concentrations also exhibit a rhythmic 24 h pattern, the amplitude of which apparently depends on the magnitude of body-exercise. The DSIP in humans was found also to exert a bell shaped dose response curve exhibiting an activating effect during awake states in situations conductive to sleep. Clinically and statistically significant effects upon sleep architecture were seen from 1 h through 20 h after injection; adverse effects were never observed. Single dose treatments of insomnia showed significant normalization effects of DSIP in all sleep parameters as did repeated administrations in chronic insomniacs. Daytime performance was found to improve after DSIP injections which at a higher dose exerted a beneficiary effect in organic insomniacs. In summary DSIP is suggested not only to be a sleep promoting and maintaining peptide but a supramodulatory active psychophysiological programming substance. Author

N87-25714# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France). Div. de Neurophysiologie Appliquee.

INTRODUCTION OF A NEW STIMULANT: CRL 40476 [PRESENTATION D'UN NOUVEAU STIMULANT: LE CRL 40476]

C. L. MILHAUD and D. P. LAGARDE *In* AGARD Biochemical Enhancement of Performance 7 p (SEE N87-25709 19-52) Mar. 1987 In FRENCH

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

The use of stimulants constitutes one of the possible approaches to maintaining vigilance during sustained, long-duration operations. The efficiency and safety of the stimulant CRL 40476 was evaluated using the macaque rhesus. Measurements of nocturnal activity, as well as the interpretation of electroencephalographic records provide evidence of a powerful anti-sleep effect without the disturbance of the sleep pattern. The safety studies showed an absence of side effects on vegetative and behavioral functions, particularly those typical of amphetamines, for the dosages utilized to maintain wakefulness. Operational experimentation will be able to provide a preliminary determination of effective doses and administration frequencies for healthy humans. M.G.

N87-25716# Centre d'Essais en Vol, Bretigny-sur-Orge (France). Lab. de medecine Aerospatiale.

THE EVALUATION OF VIGILANCE IN STUDIES OF AERONAUTIC PHARMACOLOGY [L'EVALUATION DE LA VIGILANCE DANS LES ETUDES DE PHARMACOLLGIE EN AERONAUTIQUE]

J. L. POIRIER and H. VIEILLEFOND *In* AGARD Biochemical Enhancement of Performance 8 p (SEE N87-25709 19-52) Mar. 1987 In FRENCH

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

The design and results of various tests addressing two aspects of vigilance, psychomotor response and memorization, are described. The tests included short-term memorization tasks, visual compensatory pursuit/tracking along two axes coupled with a secondary task measuring the response time of the subject to a visual cue, and visual pursuit tasks in a dynamic simulated-flight environment. The effects of four drugs were assessed: the psychotrope Medifoxamine 50, the antihistamine Astemizole, the psychostimulant Debrumyl, and the vasodilator RU 24722. M.G.

N87-25717# Centre d'Essais en Vol, Bretigny-sur-Orge (France). Lab. de Medecine Aerospatiale.

THE EFFECT OF ACETYL-DL-LEUCINE ON THE VESTIBULO-OCCULAR REFLEX IN HUMANS [EFFET DE L'ACETYL-DL-LEUCINE SUR LA PERFORMANCE DU REFLEXE VESTIBULO-OCCULAIRE CHEZ L'HOMME]

A. LEGER, D. LEJEUNE, and H. VIEILLEFOND *In* AGARD Biochemical Enhancement of Performance 8 p (SEE N87-25709 19-52) Mar. 1987 In FRENCH

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

The effect of the antivertiginous agent acetyl-dl-leucine on the vestibulo-ocular reflex was tested. Twelve volunteers were administered the drug or a placebo via intravenous injection and subjected to vestibular stimulation. Electro-occulography was used to record horizontal nystagmus during and after rotations. The results demonstrate that acetyl-dl-leucine, administered at therapeutic doses, did not alter the quantitative characteristics of the vestibulo-ocular reflex. M.G.

N87-25718# Harvard Medical School, Boston, MA. Dept. of Physiology and Biophysics.

HOMEOSTATIC, ENTRAINMENT AND PACEMAKER EFFECTS OF DRUGS THAT REGULATE THE TIMING OF SLEEP AND WAKEFULNESS

MARTIN C. MOORE-EDE and THOMAS A. HOUPT *In* AGARD Biochemical Enhancement of Performance 9 p (SEE N87-25709 19-52) Mar. 1987

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

The timing of wakefulness and sleep in humans and other diurnal primates is influenced not only by the duration of prior wakefulness or prior sleep, but also by the phase of the circadian timing system. In continuous, round-the-clock operations, or with transportation between time zones, conflicts frequently occur between these determinants of arousal state. The predictive circadian component favors wakefulness and sleep at phases consistent with the recent history of environmental and internal time cues. On the other hand, the reactive homeostatic component is principally determined by the length of prior wakefulness on the particular day in question. Investigations of pharmacological agents which influence the timing of sleep and wakefulness indicate they may exert their effects directly on the neuronal/humoral mechanisms responsible for the generation of sleep, or by altering the phase of the circadian system. The circadian effects may either be achieved by influencing the interaction between environmental light-dark cycles and circadian pacemakers. Examples of drugs which appear to have predominantly homeostatic effects, pacemaker effects, or entrainment effects are discussed. An appropriate strategy for the management of alert wakefulness at any hour of day and night must use the appropriate pharmacological tools to manage circadian and homeostatic components of wakefulness and sleep. Author

N87-25719# Secretariat General de la Defense Nationale, Paris (France).

SIDE EFFECTS OF HYPNOTIC BENZODIAZEPINES ON THE VIGILANCE AND EFFICIENCY OF PERSONNEL AFTER AWAKENING [EFFETS RESIDUELS DES BENZODIAZEPINES HYPNOTIQUES SUR LA VIGILANCE ET L'EFFICIENCE DES PERSONNELS AU REVEIL]

L. CROCQ and M. A. CROCQ *In* AGARD, Biochemical Enhancement of Performance 13 p (SEE N87-25709 19-52) Mar. 1987 In FRENCH

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

In order to detect and evaluate the side effects of hypnotic benzodiazepines on the vigilance and efficiency of personnel after awakening, a double blind study was performed with three hypnotic benzodiazephines which satisfy military operational requirements. At four day intervals sixteen subjects were administered one of five substances in uncertain order (placebo, Loprazolam 1 mg, Triazolam 0.25 mg, Triazolam 0.50 mg, and Flunitrazepam 1 mg). On awakening, psychometric tests were performed which

determined the subjective state, attention, psychomotor efficiency, short- and long-term memory, mathematical reasoning, performance with complex tasks, and performance with information overload. The results showed the existence of a psychometric deterioration, manifested in the final test scores, with higher intellectual functions (reasoning, complex tasks, and information overload) being more greatly affected than gross aptitudes (attention and memory). However, differences in noticable deterioration were evident between subject groups and individuals and between the various drugs. M.G.

N87-25720# Naval Health Research Center, San Diego, CA. Behavioral Psychopharmacology Dept.

SEDATING AND NONSEDATING SLEEPING AIDS IN AIR OPERATION

CHERYL L. SPINWEBER *In* AGARD Biochemical Enhancement of Performance 12 p (SEE N87-25709 19-52) Mar. 1987 Sponsored by the Department of the Navy

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

Both sedating and nonsedating sleeping aids may be appropriate for use in specific operational environments to promote sleep and permit efficient utilization of rest periods. Sedating agents, such as the benzodiazeprine triazolam, produce an impairment window which is a period of time postadministration when performance and responsivity during sleep are impaired. Nonsedating agents, such as the amino acid l-tryptophan, enhance sleep but do not alter performance of responsivity at any time postadministration. In a field trial of the use of l-tryptophan in the U.S. Marines airlifted from California to Okinawa, l-tryptophan increased total sleep time the first night after arrival. This sleep enhancement was associated with significantly faster reaction times the next day, sparing of short-term memory from jet-lag effects, and more rapid recovery of reaction time over the first three days after arrival. Which type of agent to use in support of an air operation will be determined by the nature of the environments in which rest periods will occur and the duration of scheduled sleep times. Author

N87-25721# School of Aerospace Medicine, Brooks AFB, TX. Aerospace Medical Div.

FB-111A AIRCREW USE OF TEMAZEPAM DURING SURGE OPERATIONS

WILLIAM F. STORM and ROBERT C. PARKE *In* AGARD Biochemical Enhancement of Performance 12 p (SEE N87-25709 19-52) Mar. 1987

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

The objectives of this field study were to evaluate the performance capabilities and sleep patterns of USAF FB-111A aircrews using temazepam as a sleep aid during premission crew rest. Seven 2-man aircrews participated in two data collection periods. During each period, a crew flew a pair of extended duration nighttime missions, one each on consecutive nights. The mission on the first night was an actual FB-11A training mission. The mission the subsequent night was flown in a high-fidelity simulator. Crews were administered 30 mg temazepam for the daytime crew rest interval between one pair of actual and simulated missions and a placebo for the crew rest between the other pair of missions. Sleep during daytime crew rest was of longer duration and better quality with temazepam than with the placebo. Twelve hours after drug ingestion, aircrew performance of the simulator missions and selected laboratory tests was similar to that with the placebo. Author

N87-25722# Service de Sante pour l'Armee de l'Air, Paris (France). Dept. de Psychiatrie et Hygiene Mentale Aerospatiales.

PHOBIC MANIFESTATIONS AMONG EXPERIENCED PILOTS [LES MANIFESTATIONS PHOBIQUES CHEZ LES PILOTES CONFIRMES]

J. R. GALLE-TESSONNEAU *In* AGARD Biochemical Enhancement of Performance 5 p (SEE N87-25709 19-52) Mar. 1987 In FRENCH

(AGARD-CP-415) Avail: NTIS HC A07/MF A01

Fear-of-flight phobic responses are not uncommon among experienced pilots. The associated clinical expressions are numerous and varied: psychological, somatic, or behavioral. Early therapeutic intervention of acute reaction states is often favorable. The prognosis is most uncertain in organized pathological conditions and evolving chronic modes. M.G.

N87-27391# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France) Technical Information Panel.

AGARD GUIDE TO AEROSPACE AND DEFENCE TECHNICAL REPORT SERIES IN NATO COUNTRIES

May 1987 348 p

(AGARD-R-743; ISBN-92-835-1549-8; AD-A182802) Avail: NTIS HC A15/MF A01

A guide is presented to technical reports series relating to aerospace and defence research and development currently published by governments, contractors, research laboratories or universities in NATO member countries. The guide lists reports series from Belgium, France, the Federal Republic of Germany, the Netherlands, Norway, the United Kingdom, the United States and international organizations. Information given includes a technical report series code, a title (where available), name and address of the organization producing the series, availability (where known), type of organization and other helpful information provided by the producers. Two indexes are provided: an overall one by number; and one by number within country Author

N87-30065# Britannia Airways Ltd., Luton (England).

IN-FLIGHT ASSESSMENT OF WORKLOAD USING PILOT RATINGS AND HEART RATE

ALAN H. ROSCOE *In* Advisory Group for Aerospace Research The Practical Assessment of Pilot Workload p 78-82 (SEE N87-30054 24-54) Jun. 1987

(AGARD-AG-282) Avail: NTIS HC A07/MF A01

At present the most used and probably the most reliable methods for assessing pilot workload in flight are based on some form of subjective reporting by experienced test pilots. Subjective opinions are susceptible to bias and preconceived ideas and so may occasionally result in false estimates of workload. For more than 15 years subjective reporting at RAE Bedford has been augmented by recording their heart rates. At first pilots described workload in a relatively unstructured manner but the need for some form of rating scale was soon apparent. After much trial and error, a 10 point rating scale using the concept of spare capacity was developed. The overall design is based on the Handling Qualities Rating Scale of Cooper and Harper. During the past 8 years a number of flight trials have used pilot ratings and heart rate responses to assess workload. The rationale for using heart rate in assessing pilot workload is based on the concept of neurological arousal. The technique is described and examples of its use are given. Also listed and briefly discussed are limitations and pitfalls of the technique. Author

N88-11366# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

SLEEP AND WAKEFULNESS: HANDBOOK FOR FLIGHT MEDICAL OFFICERS, SECOND EDITION

A. N. NICHOLSON and BARBARA M. STONE (Royal Air Force Inst. of Aviation Medicine, Farnborough, England) Jul. 1987 75 p

(AGARD-AG-270(E); AD-A186763) Avail: NTIS HC A04/MF A01

The first edition of this handbook was published in 1982, and since then the understanding of sleep and wakefulness has advanced considerably. This new handbook emphasizes the management of aircrew and the problems they experience in coping with irregularity of rest and activity. Author

N88-12923# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

HUMAN RESPIRATORY RESPONSES DURING HIGH PERFORMANCE FLIGHT

R. M. HARDING (Institute of Aviation Medicine, Farnborough, England) Nov. 1987 93 p

(AGARD-AG-312; ISBN-92-835-1561-7; AD-A191601) Avail: NTIS HC A05/MF A01

The respiratory responses of experienced pilots were studied during flight in a high performance jet aircraft. Over 38 hours of physiological monitoring was carried out involving over 47,000 breaths. The importance and relevance of information about these respiratory responses is reviewed, with particular emphasis on the difficulties of in-flight recording and the history of such experimentation in four specific areas of respiratory physiology:

respiratory frequency and flow, added external resistance, hyperventilation, and the metabolic cost of flying. Author

N88-27684# New York Univ., New York. Dept. of Psychology.
STUDIES OF THE INTACT HUMAN BRAIN: IMPLICATIONS FOR PERFORMANCE
LLOYD KAUFMAN *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 17 p (SEE N88-27683 21-51) Feb. 1988 (AGARD-CP-432) Avail: NTIS HC A18/MF A01

The development and testing of multi-channel neuromagnetometers are discussed in relationship to providing information needed concerning brain activity. Also discussed is the relationship between the number of sensing channels and the background noise. A brief account of some of the analytical methods applied to neuromagnetic data is provided. B.G.

N88-27685# New York Medical Coll., NY. Div. of Biological Psychiatry.
CEEG DYNAMIC BRAIN MAPPING: A NEW METHOD TO EVALUATE BRAIN FUNCTION IN DIFFERENT PSYCHOLOGICAL AND DRUG CONDITIONS
TURAN M. ITIL, KURT Z. ITIL, EMIN ERALP, A. AKMAN (HZI Research Center, Tarrytown, N.Y.), and A. MANCO *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 16 p (SEE N88-27683 21-51) Feb. 1988 (AGARD-CP-432) Avail: NTIS HC A18/MF A01

The electroencephalogram (EEG), discovered more than half a century ago, is still the only non-invasive, simple and objective method to continuously and repetitively study brain function, and has recently gained new significance since quantification by microprocessors was developed. Quantification of single-lead EEG proved to be of significant value in psychotropic drug development. Discoveries of the psychotropic properties of drugs and the determination of bioavailability of CNS-active compounds validated this method. It was demonstrated that the brain's bioelectrical activity, even recorded in only one area of the brain, can represent brain function and is closely associated with human behavior. A newly-developed brain function monitoring system using multi-lead, broad frequency spectrum Computer-analyzed Electroencephalogram (CEEG) with Dynamic Brain Mapping seems to be a very promising methodology to study human behavior and to monitor its changes due to external and internal factors. Author

N88-27686# EEG Systems Lab., San Francisco, CA.
FOURTH GENERATION NEUROCOGNITIVE PATTERN ANALYSIS SYSTEM
A. S. GEVINS, N. H. MORGAN, S. L. BRESSLER, D. S. GREER, B. COSTALES, K. SMITH, and R. FAUCETTE *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 13 p (SEE N88-27683 21-51) Feb. 1988 Original contains color illustrations
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The generic term neurocognitive pattern (NCP) analysis is used to refer to procedures being developed to extract spatiotemporal neurocognitive patterns from the unrelated neuroelectric noise of the brain. Recordings with up to 64 scalp channels during highly controlled tasks are now routine in the laboratory, as is the extended signal processing sequence required to extract minute neurocognitive singals from gigabyte sets of single-trial data. More robust measures of the degree of functional interdependency between electrodes were developed and applied to several prior neuropsychological models of the rapidly shifting cortical network accompanying expectancy, stimulus registration and feature extraction response preparation and execution, and updating to feedback about response accuracy. These results suggest that it is possible to characterize functional interdependencies of event-related processing between local neural areas by measuring the wave congruence and lag time of appropriately preprocessed low-frequency brain waves. Determining the distributed functional network of specialized areas of the brain producing the observed patterns is a formidable problem which is being attacked on a number of fronts. Author

N88-27687# New York Univ. Medical Center. Brain Research Labs.
NORMATIVE DEVELOPMENTAL EQUATIONS FOR THE EEG AND THEIR SENSITIVITY TO NEUROLOGICAL AND PSYCHIATRIC DISORDERS
E. R. JOHN and L. S. PRICHEP *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 7 p (SEE N88-27683 21-51) Feb. 1988 Prepared in cooperation with Kline (Nathan S.) Inst. for Psychiatric Research, Orangeburg, N.Y. Original contains color illustrations
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Although the electroencephalogram (EEG) is altered by many brain dysfunctions, its clinical utility is severely limited by reliance upon visual pattern recognition and subjective interpretation. The goal was to not only replace subjective judgments by objective quantification, but to extend the utility of electrophysiological examinations beyond their traditional role in the detection of neurological disorders to the assessment of cognitive impairments and the evaluation of psychiatric patients. The initial studies were focussed on the problem of learning disabilities in children. As the techniques evolves, they were applied successfully to the assessment of pediatric neurological patients, to adult patients with mild head injury, cerebrovascular disease including transient ischemic attacks, alcoholism, cognitve impairment due to senile dementia, affective disorders, and psychoses. The method which was developed for these purposes, called neurometrics, is based upon the computerized extraction of a wide variety of objective indices of brain function as reflected in electrophysiological activity, the multivariate statistical evaluation of these quantitive measures, and the display of diagnostically significant findings in color coded topographic maps easily interpretable by the clinician without extensive specialized training. Author

N88-27688# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THE APPLICATION OF NON-STATIONARY DATA ANALYSIS TECHNIQUES IN THE IDENTIFICATION OF CHANGES IN THE ELECTROENCEPHALOGRAM ASSOCIATED WITH THE ONSET OF DROWSINESS
NICOLA A. WRIGHT, R. G. BORLAND, and AMANDA MCGOWN *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 5 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The electrical activity of the brain was analyzed using techniques to detect the occurrence of non-stationarities associated with transitional states between alert wakefulness and sleep. Eight minutes of resting eyes closed data were used in the analysis. A visual inspection was performed to classify the record into epochs of varying lengths according to the different states of arousal. Three states were defined: alert wakefulness, drowsy sleep, and a transitional state. Nonstationary data analysis techniques were used to identify these changes automatically. The techniques used were autoregressive modeling, in which the prediction error was used as a criterion to detect change, and evolutionary power spectrum analysis, where a spectral ratio was defined to detect differences between short epochs of the signal. In addition, the autocorrelation function was calculated for a limited number of lags, and changes in the function with reference to previous epochs used to identify the onset of change. These techniques were compared with methods of analysis based on a pre-defined epoch length, to determine the most efficient method of detecting changes associated with the transition between alertness and drowsiness. A discriminant function was calculated for each of the three visually classified states to define a classification rule, which was then used to allocate the segments produced by each of the automatic analysis techniques to one of the three states of alertness. Finally, the performance of each technique was assessed in terms of its ability to correctly classify segments of data. Author

N88-27689# National Hospital, Oslo (Norway). Lab. for Clinical Neurophysiology.

A STATISTICAL PROCEDURE FOR THE EVALUATION OF PRESENCE/NON-PRESENCE OF STIMULUS-RELATED EEG ACTIVITY

NILS IRGENS BACHEN *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 9 p (SEE N88-27683 21-51) Feb. 1988 (AGARD-CP-432) Avail: NTIS HC A18/MF A01

Averaging of a sufficient number of stimulus-related sample functions is a commonly applied method for the demonstration of evoked activity in the electroencephalogram (EEG). However, problems may arise in the visual evaluation of averaged waveforms when the signal-to-noise ratio is low, such as for instance in certain cerebral disease conditions, or when the intensity of the stimuli is low. In such situations the question of presence or not of evoked activity may be of material importance. Even experienced observers will find it difficult to give a reliable answer if their judgment has to depend only on visual assessment of the averaged waveforms obtained. A statistical test for the presence of evoked activity may be a guide to the correct decision in such cases. A statistical procedure based on phase value measurements of Fourier component in the post stimulus sample functions is presented. The distribution of these phase values is uniform in the interval 0 to 360 degree when the EEG sample functions contain no evoked activity. On the other hand, an aggregation of phase values in a certain angular region and hence a nonuniform distribution is to be expected if evoked activity is present. A statistical procedure testing a null hypothesis assumption of uniformity may thus be applied in the evaluation of presence/nonpresence of stimulus-related activity in the critical situations. A test of the Kolmogorov-Smirnov type, Kuiper's V(sub n) test, was applied with satisfactory results. Author

N88-27690# Dalhousie Univ., Halifax (Nova Scotia). Dept. of Ophthalmology.

DISSECTING THE VISUAL AND AUDITORY PATHWAYS BY MEANS OF THE TWO-INPUT TECHNIQUE

D. REGAN and M. P. REGAN *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 9 p (SEE N88-27683 21-51) Feb. 1988 Sponsored by the National Sciences and Engineering Research Council, Canada, MRC, Canada and AFOSR, Washington, D.C.
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

An evoked potential for identifying the nonlinear characteristics of specialized sensory neural mechanisms in the human brain is described. For example, subjects viewed a grating pattern modulated at F(sub 1) Hz superimposed on a second grating modulated at F(sub 2) Hz. The VEP consisted of about 20 discrete frequency components, each of less than 0.004 Hz bandwidth. Most would be destroyed by conventional averaging, but could be measured by zoom-FTT technique that gives 25,000 resolvable bins over DC-100 Hz. A mathematical treatment was developed such that the pattern of behavior among these VEP components fingerprints the nonlinear processing. Orientation tuning bandwidths (20 deg) and the spatial frequency tuning of a phase-independent visual mechanism; strong interactions between response to orthogonal orientations; and a possible EP means of investigating the auditory hair cell transducer characteristic are reported. Author

N88-27691# Consiglio Nazionale delle Ricerche, Rome (Italy). Istituto de Elettronica dello Stato Solido.

SQUID INSTRUMENTATION FOR NEUROMAGNETIC STUDY OF COMPLEX BRAIN ACTIVITY

GIAN LUCA ROMANI *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 7 p (SEE N88-27683 21-51) Feb. 1988 (AGARD-CP-432) Avail: NTIS HC A18/MF A01

The impressive results obtained during the last few years by applying the neuromagnetic method to the investigation of brain physiology and pathology have given an extraordinary impulse to the development of large multi-sensor systems, which should permit, in a relatively near future, to simultaneously detect the distribution of the magnetic field over a large area of the scalp and to achieve a real time functional localization of active cerebral sources. An outline of the main instrumental problems in the choice of an optimal sensor configuration (for large mutlichannel systems) is presented, with particular emphasis on the capability featured by different kinds of superconducting gradiometers to identify complex cerebral sources, and on the need for more sophisticated model sources. Author

N88-27692# Consiglio Nazionale delle Ricerche, Rome (Italy). Istituto di Elettronica dello Stato Solido.

ELECTRIC AND MAGNETIC BRAIN ACTIVITY RELATED TO COGNITIVE PERFORMANCE

ROBERT M. CHAPMAN, IVO MODENA, LIVIO MARICI, VITTORIO PIZZELLA, GIAN LUCA ROMANI, CARLO SALUSTRI, JOHN W. MCCRARY, and SUSAN GARNSEY (Rochester Univ., N. Y.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 8 p (SEE N88-27683 21-51) Feb. 1988
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(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Cognitive performance and brain activity; memory storage component in evoked potentials; connotative meaning; and syntactic differences in words and linguistic processing were examined. B.G.

N88-27693# Muenster Univ. (Germany, F.R.). Inst. of Experimental Audiology.

NEUROMAGNETIC EVIDENCE OF PLACE MECHANISMS FOR FREQUENCY AND INTENSITY CODING IN THE HUMAN AUDITORY CORTEX

M. HOKE, C. PANTEW, K. LEHNERTZ, and B. LUETKENHOENER *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 12 p (SEE N88-27683 21-51) Feb. 1988 Sponsored by Deutsche Forschungsgemeinschaft, West Germany and Heinrich-Hertz-Stiftung, West Germany
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The influence of two decisive parameters of the acoustic stimulus (frequency and intensity) on the auditory evoked magnetic field in response to tone-burst stimulation was investigated in four normal-hearing subjects. The influence was quantified in terms of changes of the parameters of an equivalent current dipole (spatial coordinates, direction, and strength). The frequency dependence was investigated by varying the carrier frequency of the tone-burst between 250 and 4000 Hz in octave steps with the intensity kept constant at 60 dB HL, while the intensity dependence was investigated by varying the intensity of a 1000 Hz tone-burst between 30 and 80 dB HL in 10 dB steps. The parameters of an equivanlent current dipole (ECD) were determined such that a maximum correspondence between observed and calculated field distribution (semi-infinite volume model) was obtained. The main results are as follows: the location of the ECD changes significantly as a function of test frequency and intensity. Especially the depth increases with the logarithm of test frequency which proves that also in humans the tonotopic organization of the cochlea is maintained in the auditory cortex. The decrease in depth of the ECD with increasing stimulus intensity supports the hypothesis that place mechanisms also play a role for intensity coding. Author

N88-27694# Simon Fraser Univ., Burnaby (British Columbia). Brain Behaviour Lab.

THE INTERACTION OF THALAMO-CORTICAL SYSTEMS IN THE 40 HZ FOLLOWING RESPONSE

H. WEINBERG, D. CHEYNE, P. BRICKETT, R. GORDON, and R. HARROP *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 6 p (SEE N88-27683 21-51) Feb. 1988
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The study reported is an extension of the initial auditory experiments to include the study of 40 Hz vibration of glaborous skin receptors and examination of the interaction of simultaneous (in phase) auditory and tactile simulation. The data presented suggest that different systems are active in response to 40 Hz tactile vibration and auditory stimulation, although the EEG response at the vertex remains quite similar. B.G.

N88-27695# Simon Fraser Univ., Burnaby (British Columbia). Brain Behaviour Lab.

A STUDY OF SOURCES IN THE HUMAN BRAIN ASSOCIATED WITH STEREOPSIS

H. WEINBERG, P. BRICKETT, A. ROBERTSON, D. CRISP, D. CHEYNE, and R. HARROP *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 6 p (SEE N88-27683 21-51) Feb. 1988 Sponsored by the Defence and Civil Inst. of Environmental Medicine, Canada

(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The purpose of the initial stage of the research was to confirm with myoelectrography (MEG) the evidence for multiple stages of processing binocular information, establish what these stages are, and estimate location of generators. Initial experiments are designed to compare the magnetic fields evoked by dynamic random-dot stereograms (DRDSs) and dynamic RDCs in the same subject to see if the DRDC evoked field is similar to the early component of the response to the DRDS. The continuation of these experiments is concerned with the later component of the evoked field and the nature and location of the estimated sources. Author

N88-27696*# Illinois Univ., Champaign. Dept. of Psychology.

EVENT-RELATED BRAIN POTENTIALS AS INDICES OF MENTAL WORKLOAD AND ATTENTIONAL ALLOCATION

ARTHUR F. KRAMER, EMANUEL DONCHIN, and CHRISTOPHER D. WICKENS *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 15 p (SEE N88-27683 21-51) Feb. 1988 Sponsored by NASA, Ames Research Center, Moffett Field, Calif.

(Contract F49620-79-C-0233)

(AGARD-CP-432) Avail: NTIS HC A18/MF A01 CSCL 06P

Over the past decade considerable strides were made in explicating the antecedant conditions necessary for the elicitation, and the modulation of the amplitude and latency, of a number of components of the event-related brain potential (ERP). The focus of this report is on P300. The degree to which the psychophysiological measures contribute to issues in two real-world domains (communication devices for the motor impaired and the assessment of mental workload of aircraft pilots) are examined. Author

N88-27697# York Univ., Downsview (Ontario). Dept. of Physical Education.

THE EFFECTS OF HYPOXIA ON P300 AND REACTION TIME

B. FOWLER, B. KELSO, J. P. LANDOLT, and G. PORLIER (Defence and Civil Inst. of Environmental Medicine, Downsview, Ontario) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 7 p (SEE N88-27683 21-51) Feb. 1988

(Contract DCIEM-W7711-6-9019)

(AGARD-CP-432; DCIEM-87-RR-12) Avail: NTIS HC A18/MF A01

This experiment investigated the effects of three levels of arterial oxyhemoglobin saturation (SaO2 of 75, 70, and 65 percent) on reaction time (RT) and P300 latency and amplitude. Ten subjects responded to visually presented male or female names in an oddball paradigm with accuracy controlled at a high level. Hypoxia increased both RT and P300 latency in a dose-related manner and these variables were strongly correlated. Hypoxia did not influence P300 amplitude. The increase in P300 latency is interpreted as further evidence that hypoxia allows stimulus evaluation processes and that, under the right circumstances, P300 could be used to index the effects of hypoxia on performance. Author

N88-27699# Washington Univ., Saint Louis, MO. Behavior Research Lab.

COGNITIVE TASK DEMANDS AS REFLECTED IN PHYSIOLOGICAL MEASURES

JOHN A. STERN and LANCE O. BAUER (Oklahoma Univ., Oklahoma City.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 11 p (SEE N88-27683 21-51) Feb. 1988

(Contract F49620-83-C-0059)

(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Three experiments are described in which cognitive demands were manipulated. The task was a modified Sternberg paradigm comprised of three task stimuli: the cue, providing information about the memory set, the memory set itself, and a test stimulus, a member of the memory set on half the trials. Among variables investigated were set size and nature of the stimulus material. Physiological measures included EEG event-related potentials (ERP) to the three stimuli (task-RSPs), ERPs to probe stimuli (probe-ERPs), and flashes irrelevant to performance. Three measures derived from the eye blink and one heart rate measure were used. Results demonstrated ERP changes related to task difficulty. Some involved the ERP to the memory stimulus and some, the prove ERP. Heart rate changes, some related to expectancy, others to task demands, were also obtained. Blink probability, duration and timing, all reflected stimulus expectancy and difficulty. These results suggest that work load, as well as attention, can be evaluated using physiological measures. Author

N88-27702# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).

PSYCHOPHYSIOLOGICAL MEASURES OF DROWSINESS AS ESTIMATORS OF MENTAL FATIGUE AND PERFORMANCE DEGRADATION DURING SLEEP DEPRIVATION

R. A. PIGEAU, R. J. HESLEGRAVE, and R. G. ANGUS *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 16 p (SEE N88-27683 21-51) Feb. 1988

(AGARD-CP-432) Avail: NTIS HC A18/MF A01

A methodology developed to measure drowsiness electrophysiologically as an index of chronic fatigue experienced during periods of sleep loss is described. Nine volunteers performed a continuous cognitive workload schedule with 15 minute breaks occurring every 2 hours throughout a 64 hour sleep deprivation experiment. To measure fatigue a 4 minute eyes closed relaxation period was embedded once every hour within a battery of cognitive tasks. The subjects were instructed to relax with their eyes closed but remain awake and alert. The EEG signals collected during these periods were both visually scored and computer quantified. Two raters visually scored the signals for: time of first stage 1 sleep onset, number of stage 1 sleep onsets, shortest and longest time in stage 1, and total amount of state 1 sleep (or deepest). Period analysis was performed on the digitized data and a drowsiness scale was developed by subtracting the amount of theta and delta from alpha while controlling for individual differences by dividing the results by alpha minus theta minus delta activity present in the baseline. The results indicate that for individual subjects drowsiness onset latencies, performance, subjective scales, and the drowsiness index are all intercorrelated. It is suggested that these EEG techniques, as well as the methodology of embedding eyes close relaxation periods, yield sensitive measures for detecting differential levels of drowsiness during sleep deprivation. Author

N88-27703# EEG Systems Lab., San Francisco, CA.
NEUROPHYSIOLOGICAL PATTERNS OF OPERATIONAL FATIGUE: PRELIMINARY RESULTS
A. S. GEVINS, B. A. CUTILLO, R. M. FOWLER-WHITE, J. ILLES, S. L. BRESSLER, and J. C. MILLER (Test Group, 6520th, Edwards AFB, Calif.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 9 p (SEE N88-27683 21-51) Feb. 1988 Sponsored by AFOSR, Washington, D.C., School of Aerospace Medicine, Brooks, AFB, Tex., National Inst. of Neurological and Communicative Diseases and Strokes, Washington, D.C. and NSF, Washington, D.C. Original contains color illustrations
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Impaired behavior consequent to prolonged mental work is commonly attributed to the effects of fatigue on higher cognitive functions rather than to changes in rote perceptuomotor or motor functions. A deeper understanding of these effects awaits better knowledge of the underlying neurophysiological mechanisms. Here a modes contribution is made toward this end with a study of event-related, spatiotemporal neuroelectric patterns of five U.S. Air Force test pilots performing a high-load visuomotor monitoring task while alert, becoming fatigued, and fully fatigued. The preliminary results suggest that although neural systems responsible for primary visual stimulus processing remain relatively unaffected, cortical associative areas implicated in task-specific response inhibition are affected even during early stages of fatigue. With further research, it may be possible to design on-line devices for predicting transient cognitive lapses and performance decrements resulting from operational fatigue. Author

N88-27705# Burden Neurological Inst., Bristol (England).
EVENT-RELATED AND STEADY POTENTIAL CHANGES IN THE BRAIN RELATED TO WORKLOAD DURING TRACKING
W. C. MCCALLUM, R. COOPER, and P. V. POCOCK *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 10 p (SEE N88-27683 21-51) Feb. 1988 Sponsored by British Aerospace, United Kingdom and the Ministry of Defence, United Kingdom
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

In two experiments event-related potentials (ERPs) and slow potential changes were recorded from normal subjects performing a visual tracking in which the level of difficulty was systematically varied. In the second experiment a secondary discrimination task was added to increase the level of operator load and to probe the allocation of cerebral processing resources. The most notable feature to emerge was a protracted slow potential shift, associated with the primary task. The amplitude of this shift proved to be sensitive to the difficulty manipulations such that increased difficulty resulted in increased negativity. However, a memory task introduced in the early part of each trial tended progressively to decrease the amplitude of the shift as the memory demand increased. The ERPs to the individual points of decision and response during the course of a trial were also found to be sensitive to the level of task loading. The introduction of the secondary task resulted in a possible further increase in the negative shift to tracking, but in reductions in the amplitude of late cognition components of the secondary task ERPs compared with their levels when this task was presented on its own. Author

N88-27706# EEG Systems Lab., San Francisco, CA.
NEUROPHYSIOLOGICAL PRECURSORS OF ACCURATE VISUOMOTOR PERFORMANCE
A. S. GEVINS, B. A. CUTILLO, S. L. BRESSLER, N. H. MORGAN, R. M. FOWLER-WHITE, D. S. GREER, J. ILLES, J. C. DOYLE, R. S. TANNEHILL, and G. M. ZEITLIN *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 11 p (SEE N88-27683 21-51) Feb. 1988 Sponsored by AFOSR, Washington, D.C., School of Aerospace Medicine, Brooks, AFB, Tex., NSF, Washington, D.C., National Inst. of Neurological Diseases and Strokes, Washington, D.C. and ONR, Washington, D.C. Original contains color illustrations
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Using advanced, signal processing techniques, the rapidly changing, spatial mass neuroelectric patterns associated with preparation and execution of precise right- and left-hand finger pressures in response to visual numeric stimuli in seven healthy right-handed adult male subjects were measured. Previously unseen pre-stimulus differences between patterns associated with subsequently accurate and inaccurate performance were revealed. A spatially specific, multi-component neural preparatory set, composed of invariant left frontal and midline precentral components and hand-specific central and posterior parietal components, appear to be essential for accurate performance of certain types of difficult visuomotor tasks. When this preparatory set is weakened, or inappropriate, subsequent performance is likely to be inaccurate. Author

N88-27708# Naval Biodynamics Lab., New Orleans, LA. Impact Sciences Dept.
EVOKED POTENTIAL ANALYSIS OF IMPACT ACCELERATION EXPERIMENTS
DAVID L. MATSON and MARC S. WEISS *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 13 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The use of somatosensory evoked potentials (SEPs) as an assessment tool for transient injury in rhesus macaques undergoing impact acceleration in the -Gx direction is examined. Adult male rhesus macaques, seated on a sled and restrained (except for the head and neck), were accelerated at peak sled accelerations ranging from 95.5 to 1039.6 m/sec squared. The sled was decelerated by friction forces ranging from 0.7 to 3.0 m/sec squared. Somatosensory stimuli were delivered prior to, during, and after impact. Amplified SEP activity was telemetered and recorded on magnetic tape. The raw SEP data were digitized and analyzed off-line. Results for cortical SEPs are consistent with and extend previous analyses, suggesting a threshold for transitory changes in cervical SEP latencies in macaques at peak -Gx sled accelerations below 550 m/sec squared. This threshold is below the threshold for single impact -Gx neuropathological injury in macaques (800 m/sec squared), and suggests a role for cortical SEPs in establishing injury critieria for humans. Author

N88-27709# School of Aerospace Medicine, Brooks AFB, TX.
EEG INDICES OF G-INDUCED LOSS OF CONSCIOUSNESS (G-LOC)
NITA L. LEWIS, JENNIFER B. MCGOVERN, JAMES C. MILLER, DOUGLAS R. EDDY, and ESTRELLA M. FORSTER (Rothe Development, San Antonio, Tex.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 12 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

To investigate the utility of the electroencephalogram (EEG) as an indicator of state of consciousness, human brain activity was recorded during exposure to rapid onset (6 G/sec) centrifugation (+7G). Eight healthy volunteers were given at least two sessions of sustained acceleration on the USAFSAM human centrifuge. The sessions were conducted without G-suits and subjects were instructed to relax and not attempt anti-G straining maneuvers. Six subjects each experienced two episodes of G-induced loss of consciousness (G-LOC) while one subject lost consciousness once and experienced visual blackout once. One subject remained conscious but experienced visual grayout in both sessions. The EEG signals were recorded with EEG Grass gold-cup electrodes which were held in place by using gauze and collodion. Data were digitized at 256 samples per second and transferred to a DEC PDP-11/55 computer for analysis. Results demonstrated a shift from beta to delta activity with pronounced absence of beta activity during unconsciousness. These results are in keeping with findings in the anesthesia and aerospace medicine literature. The EEG can be useful in detecting unconsciousness during acceleration. Author

N88-27710# Naval Air Development Center, Warminster, PA.
DETECTION OF ACCELERATION (+GZ) INDUCED BLACKOUT BY MATCHED-FILTERING OF VISUAL EVOKED POTENTIALS
JOHN G. NELSON, JOSEPH P. CAMMAROTA, and LEONID HREBIEN *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 13 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

In air-combat-maneuvering and on human centrifuges, moderate levels of positive acceleration (+Gz), coupled with moderate rates of onset, produce visual symptoms which are ordinarily progressive: decreasing visual sensitivity, dimming of visual field, peripheral light-loss, and central light-loss of consciousness, subjective visual symptoms are the most commonly used tolerance end point in acceleration research. In order to provide an objective indication of the integrity of the visual system, a method for real-time monitoring of the steady-state visual evoked potential (VEP) was developed. Using the Fast Fourier Transform (FFT), a method for maximizing the signal-to-noise ratios was developed: a digital, frequency domain, non-white-noise matched filter, with evaluation only at the expected response peak. Experiments on the U.S. Naval Development Center's Human Centrifuge demonstrated that the response does progressively decrease, disappearing at black-out. Improved computer facilities have permitted evaluation of alternative methods of processing, and the effectiveness of such processing. Data from a static experiment using four stimulus repetition rates and two electrode positions showed that windowing of the time record prior to FFT does not necessarily improve detection. Author

N88-27712# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
MOTION EVOKED VESTIBULAR POTENTIALS
G. WILSON, R. LUCIANI, and D. RATINO (Air Force Human Resources Lab., Williams AFB, Ariz.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 5 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Motion evoked potentials (MER) were collected from subjects while they were rotated from side to side in a seated position. The MERs were biphasic with major component mean latencies of 278 and 388 msec. It is concluded that the MERs are of brain origin and not due to artifacts from the recording environment. The latencies of the waveform components of the MER suggests that the MER results from the onset of the rotation stimulus. Differences between the MERs reported and those of other published reports may be due to the added involvement of the saccule/utricle apparatus and the more rapid onset of the stimulus. Author

N88-27713# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
THE EFFECT OF MILD HYPOXIA ON THE VESTIBULAR EVOKED RESPONSE
W. D. FRASER, N. BLACK, D. E. EASTMAN, and J. P. LANDOLT *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 10 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The effect of hypoxia on the long-term vestibular evoked response was examined in eight sitting subjects on a small target light that rotated with the subject. Evoked responses were recorded during 10 minutes of rotational stimulation after breathing each gas mixture for a minimum of 25 minutes. For intermittent clockwise (CW) rotation in the horizontal plane, a reproducible negative potential developed at electrode sites located between the vertex and the linked ears during air breathing conditions. It peaked close to the point of maximum velocity of the sinusoidal stimulus. The results indicate that the cortical processing of vestibular sensations may be affected even under very mildly phyoxic conditions. Animal studies have indicated that the levels of hypoxia used in this study can significantly alter neurotransmitter metabolism in brain tissue. Modification in neurotransmitter synthesis and concentration by the hypoxic conditions may explain the susceptibility of cortical processing of sensory information to very mild hypoxia. *Compensatory changes in cerebral blood flow and neurotransmitter* synthesis may be responsible for the reduced effect under the *more severe hypoxic conditions.* Author

N88-27714# Hordt Research, Development and Therapy, Rodgau (Germany, F.R.).
MEASUREMENT AND CLASSIFICATION OF THE MODE OF ACTION OF ANTIDEPRESSANT DRUGS
ALBRECHT FRAUENDORF, DAVID JOHNSON, and LOTHAR DEMISCH (Johann-Wolfgang-Goethe-Univ., Frankfurt am Main, West Germany) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 9 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

In a comparison of the chronic effects on the central nervous system of five new generation antidepresssant, a dose-response study was performed with 5 to 7 healthy subjects per substance. Following standard medical screening, intraindividual comparisons after one week at each of the three dosages. Two MAO-inhibitors, a NA-reuptake inhibitor, a serotonine-reuptake inhibitor, and an alpha 1/alpha 2 adrenergic receptor, and serotonine S sub 2 (receptor-antagonist). The visual evoked potentials were recorded *from electrode position O sub z between* O sub 1 and O sub 2. The brightness, contract, and color channels of the visual system were stimulated using on-off, checkerboard, and color changes respectively. After digitizing, the evoked potentials were subjected to Fourier filtering and analyzed in the standard EEG frequency ranges delta, theta, alpha, and beta. This improved stability and *precision of measurement without phase shifts. The latency* changes of all components were measured and used to form attenuation and activation coefficients in each range. With the help of factor analysis, an activity profile of the effects of each of these drugs in the CNS was plotted in three-dimensions. Both activation and attenuation coefficients were used to classify the effects of the antidepressants at the cortical level. Author

N88-27715# Johann-Wolfgang-Goethe-Univ., Frankfurt am Main (Germany, F.R.).
MEASUREMENT OF ELECTRICAL ACTIVITY IN THE CNS WITH CORTICAL EVOKED POTENTIALS AND EEG: EFFICACY PROFILES OF DRUGS USING FACTOR ANALYSIS
DAVID JOHNSON, ALBRECHT FRAUENDORF (Hordt Research, *Development and Therapy, Rodgau, West Germany*), *and* KURT OFFENLOCH *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 8 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

In a series of experiments with 20 healthy, subjects per substance, the influences of a new nootropic drug and three cardiovascular agents on the CNS were measured and placebo controlled. The EEG and visual cortical evoked potentials were recorded from electrode position O sub z between O sub 1 and O sub 2 according to the 10 to 20 system. Three channels of the visual system were selectively stimulated (contrast, brightness, and color using checkerboard, flash, and color change). Acute and chronic studies were reported. Each VEP was filtered into the standard EEG-frequency range. Latency changes of the EP were evaluated in each range and analyzed with the Fourier technique. The cardiovascular substances caused a significant latency increase of beta-components with apparent latencies of 80 to 100 ms. This attenuation was shown in the contrast and even stronger in the color channel of the visual system. For the nootropic substance, a significant latency decrease was found for three components of the visual evoked potential in the theta-range. Their latencies are from 170 to 360 ms. The results of the EEG analysis are compared to the EP results. Generalized changes for groups of substances and highly specific profiles of activity for individual substances may be measured using this set of stimulus and analysis techniques. Activation and attenuation of activity for one and the same substances also were measured indicating multiple modes of actions. This may reflect cognitive processes and sensomotor activity. Author

N88-27716# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France). Div. de Neurophysiologie Appliquee.
AN APPROACH TO STUDYING THE EFFECTS OF PSYCHOSTIMULANTS ON CEREBRAL ELECTRICAL ACTIVITY IN THE NON-HUMAN PRIMATE [UNE APPROCHE DES EFFETS DE PSYCHOSTIMULANTS SUR L'ACTIVITE ELECTRIQUE CEREBRALE CHEZ LE PRIMATE NON HUMAIN]
D. LAGARDE and C. MILHAUD *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 11 p (SEE N88-27683 21-51) Feb. 1988 In FRENCH
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The effects of three psychostimulant substances on brain electrical activity in the rhesus monkey were studied. The prime objective of these experiments was to obtain a data base of EEG properties and the changes caused by well-known psychostimulants at different dosages, and compare them to the EEG modifications induced by experimental psychotropic drugs. The power spectral density was used to analyze EEG data into different frequency bands for caffeine, d-amphetamine sulfate, and the experimental drug CRL 40476. In general, the results showed that caffeine caused a significant increase in delta activity, some decrease in the theta and alpha bands, and variable decreases in the beta band. Amphetamine produced an increase in delta and alpha activities, relative stability with signs towards an increase in theta activity, and a clear decrease in beta activity. The CRL 40476 caused important increases in delta activity, no changes in theta and alpha activity, and some decrease in the level of beta activity. Author

N88-27717# Italian Air Force Aerospace Medical Center, Rome. Neuropsychophysiology Group.
SPONTANEOUS CEREBRAL ELECTRICAL ACTIVITY DURING PROLONGED HYPOGLYCEMIA: A QUANTITATIVE STUDY IN HUMANS
SILVIO PORCU, ROBERTO BERTI, and ALBERTO LALA *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 12 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The importance of neuroglycopenia secondary to hypoglycemia as a possible cause or contributing factor in aircraft accidents was stressed. The study was designed to investigate the neurophysiological correlations of neuroglycopenia. The generation of spontaneous cerebral electrical activity in healthy young adults is quantified in a computer-assisted study, with subjects placed under fixed hypoglycemic conditions. Author

N88-27718# Dalhousie Univ., Halifax (Nova Scotia). Dept. of Ophthalmology.
RELATION BETWEEN VEP AND VISUAL FUNCTION IN LESIONS OF THE OPTIC NERVE AND VISUAL PATHWAY
D. REGAN and D. NEIMS *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 8 p (SEE N88-27683 21-51) Feb. 1988 Sponsored in part by Medical Research Council of Canada, Multiple Sclerosis Society of Canada, Baker Trust of Canada and NIH, Bethesda, Md.
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Several authors have claimed that visual evoked potential (VEP) abnormality is not closely related to sensory visual loss in patients with multiple sclerosis. However, all of the studies assessed sensory visual loss entirely in terms of Snellen visual acuity. Recent findings indicate the possibility that this lack of correlation between VEPs and sensory data might be due, at least in part, to the inability of Snellen's test to detect the full range of visual losses associated with visual pathway dysfunction. Before discussing abnormalities of pattern VEPs in patients with demyelinating diseases, the reasons why the Snellen acuity provides only an incomplete test of visual function loss are explained. Author

N88-27720# Royal Air Force, Wroughton (England). Neurology Dept.
DETECTION OF LATENT EPILEPSY IN AIRCREW CANDIDATES
R. T. G. MERRY *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 3 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Epilepsy is a common medical disorder, with a prevalence of 0.5 to 0.8 percent, and is the commonest cause of accidents due to medical incapacity in drivers. Although imperfect, the electroencephalogram (EEG) is useful in the detection of a latent predisposition to epilepsy, and is recommended as an obligatory part of the initial medical examination of candidates for military aircrew. Author

N88-27721# Oficinas Gerais de Material Aeronautico, Alverca (Portugal).
THE AUDITORY EVOKED RESPONSE IN MILITARY PILOTS
NUNO A. A. CASTELOBRANCO, JOSE H. MARVAO, M. SALOME CASTELOBRANCO, and ANTONIO J. ENTRUDO (Portugal Air Force Hospital.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 8 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

This study relates to the effect of G forces, through an aerobatic flight profile without G suit protection, upon twenty military pilots with varying flight experience. The auditory evoked response during rest showed significant differences in wave 5 and in the 1 to 5 interval. Immediately following the flight, differences were observed in wave 3. These results suggest the importance which this electrophysiological method may have on measuring accumulated fatigue. Immediate fatigue implies complex mathematical problems presently under study. Simultaneously, hemorrheologic, hormonal and biochemical studies were conducted for a better understanding of the physiological effects of fatigue. Though it is recognized that the test population is relatively small (20 pilots), an expanded study is underway in order to compile more conclusive data. Author

N89-12171# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
MOTION CUES IN FLIGHT SIMULATION AND SIMULATOR INDUCED SICKNESS
Jun. 1988 196 p In ENGLISH and FRENCH Symposium held in Brussels, Belgium, 29 Sep. - 1 Oct. 1987
(AGARD-CP-433; ISBN-92-835-0466-6; AD-A202492) Avail: NTIS HC A09/MF A01

These proceedings include seventeen papers, ensuing discussions of the papers, and a Round Table Discussion from the Symposium sponsored by the AGARD Aerospace Medical Panel held in Brussels, Belgium. The frequency of reports of undesirable effects associated with simulator training has increased as simulator usage has increased to offset the higher costs and risks of conducting training in the complex modern aircraft. Review of current and anticipated future trends in simulator design features suggests that additional problems will arise if research on the etiology of simulator-induced motion sickness and other unwanted simulator effects is insufficient to counteract problems before they arise. The objective of this symposium was to examine simulator-induced effects, their operational implications, and their etiology in order to develop ideas for reducing undesired effects. For individual titles, see N89-12172 through N89-12188.

N89-12172# Essex Corp., Orlando, FL.
ETIOLOGICAL SIGNIFICANCE OF EQUIPMENT FEATURES AND PILOT HISTORY IN SIMULATOR SICKNESS
R. S. KENNEDY, K. S. BERBAUM, G. O. ALLGOOD, N. E. LANE, M. G. LILIENTHAL (Naval Training Systems Center, Orlando, Fla.), and D. R. BALTZLEY *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 22 p (SEE N89-12171 03-52) Jun. 1988
(AGARD-CP-433) Avail: NTIS HC A09/MF A01

The U.S. Navy has conducted a survey in 10 flight trainers where motion experience questionnaires and performance tests were administered to pilots before and after 1200 separate exposures. From these measures on pilots, several findings

emerged: (1) specific histories of motion sickness were predictive of simulator sickness symptomatology; (2) postural equilibrium was degraded after hops in some simulators; (2) self-reports of motion sickness symptomatology revealed three major symptom clusters; gastrointestinal, visual, and vestibular; (3) certain pilot experiences in simulators and aircraft were related to severity of symptoms experienced; (4) simulator sickness incidences varied from 10 to 60 percent; (4) substantial perceptual adaptation occurs over a series of hops; (6) in two moving-base flight trainers motion sickness incidence appeared to be related to the amount of acceleration (energy) experienced in frequency ranges around 0.2 Hz. The findings are discussed in the context of sensory conflict theory and recommendations are made for simulator design criteria. Suggestions are made as to how to relate simulator and equipment configuration to the separate symptom clusters as an aid to the diagnosis of specific problems within particular simulators. It is believed that this holds promise in diagnosing simulator equipment problems (e.g, alignment, inertial motion profile, cue asynchrony) since different symptom clusters may be related to different equipment features. Author

N89-12173# National Aerospace Lab., Amsterdam (Netherlands).

TECHNOLOGY INVOLVED IN THE SIMULATION OF MOTION CUES: THE CURRENT TREND

H. A. MOOIJ *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 15 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

The subject of motion cue generation is a topic that requires serious attention from all involved in the design, development and manufacture of flight simulators. The enhanced realism in the depiction of terrain, sky, and other aircraft available in current visual systems has been associated with an increasing number of instances of simulator sickness. This form of sickness is the constellation of symptoms which may be experienced by pilots as a result of flying a simulator. As one of the introductory papers of the AGARD Aerospace Medical Symposium on Motion cues in flight simulation and simulator induced sickness this paper presents observations concerning the current trend in visual and motion systems. After an introduction of basic cuing methodology in flight simulation, the overview concentrates on developments in image generation, image display, platform motion cue generation and motion hardware mechanisms. The paper concludes with some observations concerning the importance of maintenance and calibration of flight simulator installations. Author

N89-12174# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).

AETIOLOGICAL FACTORS IN SIMULATOR SICKNESS

A. J. BENSON *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 8 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

The clinical features of simulator sickness are similar to the malaise induced by other motion stimuli. The essential etiology of the condition is considered to be the same as in other types of motion sickness, namely, the mismatch between the motion information provided by the body's sense organs and the brain's internal model of expected motion cues. The mismatch can be between concomitant inputs provided by the angular and linear acceleration transducers of the vestibular apparatus, or between visual and vestibular inputs. More significantly, in a fixed base simulator it is the absence of expected inertial cues when the ambient visual system is stimulated by the external world, visual display that engenders neural mismatch. Even when the simulator has a motion base, quantitive and temporal disparities between visual and inertial cues commonly occur and can contribute, along with visual distortions and other anomalies, to the induction of the motion sickness syndrome. Author

N89-12175# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France). Centre d'Essais en Vol.

HORIZONTAL STUDY OF THE INCIDENCE OF SIMULATOR INDUCED SICKNESS AMONG FRENCH AIR FORCE PILOTS [ETUDE HORIZONTALE DE L'INCIDENCE DU MAL DES SIMULATEURS DANS LES FORCES AERIENNES FRANCAISES]

A. LEGER, P. SANDOR, and R. P. DELAHAYE (Service de Sante pour l'Armee de l'Air, Paris, France) *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 7 p (SEE N89-12171 03-52) Jun. 1988 In FRENCH; ENGLISH summary

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

Reports of simulator sickness obtained from pilots in the Air Force of France are summarized. Of 164 pilots responding, 153 responses were judged suitable for general descriptive analysis, and 132 were retained for detailed analysis. In contrast to other studies in which on-site investigators evaluated effects induced by specific simulators, questionnaires were used to obtain information on the past simulator experience of pilots (and motion sickness in general) from different units of the French Air Force. Thus, the results are based on questionnaires answered anonymously relating to past experience in different simulators over a number of years. Sixty-seven percent of those responding had experienced simulator-induced sickness to some degree, but the majority of effects elicited were moderate and decreased rapidly after several sessions. Aftereffects were absent in 51 percent, insignificant in 34.8 percent, moderate in 9.8 percent, and severe in 3.8 percent of the responding subjects. In contrast with an earlier study, statistically significant relationship between simulator sickness and motion sickness in general (indicated by scores from a motion sickness questionnaire) was not found. Author

N89-12176# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).

SIMULATOR INDUCED SICKNESS AMONG HERCULES AIRCREW

L. E. MAGEE, L. KANTOR, and D. M. C. SWEENEY *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 8 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

The purposes of this study were to investigate the incidence, severity and time-course of simulator sickness among pilots and flight engineers training on a C-130H (Hercules) flight simulator, and to assess the influence of flight experience on susceptibility. Evidence of simulator sickness was collected by questionnaire, tests of balance, and observation. The questionnaires were completed at the conclusion of a four-hour training session and 20 hours later. The balance tests were performed immediately prior to and immediately following the training session. Overt signs of pallor, sweating, drowsiness and visual nystagmus were also recorded at these times. Thirty-five of the 42 aircrew (i.e., 83 percent) tested reported characteristic symptoms of simulator sickness. The most prevalent were eyestrain, mental and physical fatigue, and after-sensations of motion. Some effects persisted following simulator training for many hours although most were not severe. Few had delayed onset. Although eleven subjects (26 percent) reported loss of balance at the end of the training session, performance on the balance tests improved; this suggests a practice effect which masks ataxia. With the exception of occasional nystagmus, no overt signs of simulator sickness were evident. The relationships between aircraft experience, both general and type-specific, and diagnostic scores based on symptoms were examined. There was no evidence to indicate that experience influenced susceptibility to simulator sickness. Author

N89-12177# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).

SIMULATOR SICKNESS IN THE ROYAL AIR FORCE: A SURVEY

J. W. CHAPPELOW *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 11 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

A questionnaire survey was undertaken of pilots with experience of two air combat simulators. Two hundred and seventy one respondents completed questionnaires, some up to two years retrospectively and others immediately after a simulator session. There were, thus, four separate studies. The questionnaires sought

information on the incidence of disequilibrium and other symptoms experienced in the simulator and after leaving it. The proportion of those suffering at least one symptom in the simulator varied between 50 percent and more than 90 percent across studies (53.5 percent overall). However, not all the symptoms reported were unequivocally ascribable to disequilibrium. The proportion of each sample reporting delayed symptoms was between 10 percent and 50 percent (13 percent overall). The effect on the respondents' motivation to use the simulator was negligible. Author

N89-12178# Army Aeromedical Research Lab., Fort Rucker, AL.

SIMULATOR SICKNESS IN US ARMY AND NAVY FIXED- AND ROTARY-WING FLIGHT SIMULATORS

DANIEL W. GOWER, JR., MICHAEL G. LILIENTHAL, ROBERT S. KENNEDY, and JENNIFER E. FOWLKES (Essex Corp., Orlando, Fla.) *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 20 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

As technology has been developed to provide improved visual and motion systems in operational flight trainers and weapons tactics trainers, there have been increasing reports of the occurrence of simulator sickness. Simulator sickness here refers to one or more symptoms which can occur while in a simulator, immediately after exposure, or at some later time. Flight instructors have complained these symptoms interfere with simulator usage. More critical is the potential for in-flight problems due to prolonged physiological effects. As a result, flight activities after simulator flight have been limited in some commands. The U.S. Army Aeromedical Research Laboratory at Fort Rucker, Alabama, and the Naval Training Systems Center at Orlando, Florida, conducted field surveys to document the extent of the simulator sickness problems at operational fixed and rotary-wing simulator sites. Data are pooled from 10 different Navy flight simulators and the Army's AH-64 flight simulator. The total number of surveys is about 1500, with the number of subjects in each simulator type ranging from 18 to 280. The simulator sickness incidence rates and the relative frequency of specific symptoms are presented and correlational factors such as flight experience, simulator experience, and flight mode also are presented. Difficulties in assessing the duration of simulator sickness effects are noted, and attempts made to present the symptom duration for the Army's AH-64 combat mission simulator (CMS). Unique to this CMS is its use of the helmet display unit (HDU) in conjunction with the other visuals in the simulator. Author

N89-12179*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

THE USE OF VESTIBULAR MODELS FOR DESIGN AND EVALUATION OF FLIGHT SIMULATOR MOTION

STEVEN R. BUSSOLARI, LAURENCE R. YOUNG (Massachusetts Inst. of Tech., Cambridge.), and ALFRED T. LEE *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 11 p (SEE N89-12171 03-52) Jun. 1988

(Contract NAG2-12)

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

Quantitative models for the dynamics of the human vestibular system are applied to the design and evaluation of flight simulator platform motion. An optimal simulator motion control algorithm is generated to minimize the vector difference between perceived spatial orientation estimated in flight and in simulation. The motion controller has been implemented on the Vertical Motion Simulator at NASA Ames Research Center and evaluated experimentally through measurement of pilot performance and subjective rating during VTOL aircraft simulation. In general, pilot performance in a longitudinal tracking task (formation flight) did not appear to be sensitive to variations in platform motion condition as long as motion was present. However, pilot assessment of motion fidelity by means of a rating scale designed for this purpose, were sensitive to motion controller design. Platform motion generated with the optimal motion controller was found to be generally equivalent to that generated by conventional linear crossfeed washout. The vestibular models are used to evaluate the motion fidelity of transport category aircraft (Boeing 727) simulation in a pilot performance and simulator acceptability study at the Man-Vehicle Systems Research Facility at NASA Ames Research Center. Eighteen airline pilots, currently flying B-727, were given a series of flight scenarios in the simulator under various conditions of simulator motion. The scenarios were chosen to reflect the flight maneuvers that these pilots might expect to be given during a routine pilot proficiency check. Pilot performance and subjective rating of simulator fidelity was relatively insensitive to the motion condition, despite large differences in the amplitude of motion provided. This lack of sensitivity may be explained by means of the vestibular models, which predict little difference in the modeled motion sensations of the pilots when different motion conditions are imposed. Author

N89-12180# German Army Hospital, Ulm (Germany, F.R.). Abt. Neurologie and Psychiatrie.

MOTION CUES IN EVERY DAY LIFE

J. KRIEBEL, A. KORNHUBER, and M. LANG (Ulm Univ., West Germany) *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 8 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

Motion cues are perceived via different sensory modalities. Convergence of teleceptive and proprioceptive sensory information is a prerequisite of task-related senseful motor reaction. Research with event-related brain potentials (ERP) delivers important functional and topographical information of these complex interactions. From ERP data the function of the frontomesial supplementary motor area (SMA) could be analyzed. Their important role in timing sequential tasks and connecting the sensory and motor system is demonstrated. Sensory dysfunctions might irritate the onset and sequence of task related motor reactions. Vestibular evoked cerebral potentials are chosen to demonstrate the restrictions of the interpretion of the ERP results. From steady state evoked and transient evoked potentials further knowledge can be expected. Author

N89-12181# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Industrial Engineering and Operations Research.

MANIFESTATION OF VISUAL/VESTIBULAR DISRUPTION IN SIMULATORS: SEVERITY AND EMPIRICAL MEASUREMENT OF SYMPTOMATOLOGY

JOHN G. CASALI and LAWRENCE H. FRANK (Pacific Missile Test Center, Point Mugu, Calif.) *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 18 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

Reported incidence rated of vehicular simulator induced sickness in operators is highly variable both within and between devices. Recent literature reviews show that documented incidence rates range from 0 to nearly 90 percent in flight devices and even higher in some driving devices. However, the severity of the simulator sickness problem is not adequately gauged by a simple count of those operators experiencing one or more physiologic symptoms. Instead, a battery of metrics is useful in identifying and properly assessing an induced state of simulator sickness. This is of particular importance with the recent thrust in empirical research toward determination of the effects of simulator design parameters, such as control loop delays, on operator sickness and performance. This paper reviews the symptomatology experienced by operators of flight and driving simulators. Drawing upon this review, dependent measures are recommended for use in simulator-sickness research, including self-report forms, specific physiologic indices, postural equilibrium tests, performance tests, and susceptibility prediction instruments. A tabular documentation of published research studies concerning simulator sickness is also provided. Author

N89-12182# Pacific Missile Test Center, Point Mugu, CA.

MODELLING OPERATOR CONTROL PERFORMANCE AND WELL-BEING AS A FUNCTION OF SIMULATOR VISUAL AND MOTION SYSTEM TRANSPORT DELAYS

LAWRENCE H. FRANK and JOHN G. CASALI (Virginia Polytechnic Inst. and State Univ., Blacksburg.) *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 7 p (SEE N89-12171 03-52) Jun. 1988

(AGARD-CP-433) Avail: NTIS HC A09/MF A01

The role of visual-motion coupling delays and cueing order on operator performance and uneasiness was assessed in driving simulators by means of a response surface methodology central-composite design. The most salient finding of the study was that visual delay appears to be more disruptive to an

individual's control performance and well-being than is motion delay. Empirical multiple regression models were derived to predict 10 reliable measures of simulator operator driving performance and comfort. Principal components analysis on these 10 models decomposed the dependent measures into two significant models which were labeled vestibular disruption and degraded performance. Examination of the empirical models revealed that, for asynchronous delay conditions, better performance and well-being were achieved when the visual system led the motion system. A secondary analysis of the role of subject gender and perceptual style on susceptibility to simulator sickness revealed that neither of these independent variables was a significant source of variance. Author

N89-12183# Centre de Medecine Aerospatiale, Brussels (Belgium).
AN INVESTIGATION OF SIMULATOR SICKNESS AND AN ELECTRONYSTAGMOGRAPHIC STUDY [ENQUETE SUR LE MAL DES SIMULATEURS DE VOL COUPLEE A UNE ETUDE NYSTAGMORGRAPHIQUE]
G. DEHEYN, P. DEGRAFF, and P. VANDENBOSCH *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 5 p (SEE N89-12171 03-52) Jun. 1988 In FRENCH; ENGLISH summary
(AGARD-CP-433) Avail: NTIS HC A09/MF A01

Simulator sickness, which is related to travel sickenss, is a product of high technology, safety requirements and budgetary limitations. This new pathology affects experienced pilots and is the result of conflicting sensations, experienced in an unfamiliar environment. We conducted a survey of a Belgian Air Force fighter squadron in order to evaluate the frequency of simulator sickness and the symptoms experienced. Ten percent of the pilots questioned regularly experienced simulator sickness and twenty-five percent felt it occasionally in varying degrees. We also attempted to objectify the problems of vertigo and disorientation by means of an electronystagmographic study of 12 pilots during their training on a flight simulator. We were surprised by the poor ocular response during the simulated flight. Nystagmic movements appeared rarely and then only fleetingly, mainly at the end of a turn. They were all low amplitude. We were not able to establish a correlation between the objective vestibular responses and the subjective feelings of simulator sickness. Author

N89-12184*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
HEAD-MOUNTED SPATIAL INSTRUMENTS: SYNTHETIC REALITY OR IMPOSSIBLE DREAM
STEPHEN R. ELLIS, ARTHUR GRUNWALD, and MORDEKHAI VELGER *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 8 p (SEE N89-12171 03-52) Jun. 1988
(AGARD-CP-433) Avail: NTIS HC A09/MF A01

A spatial instrument is defined as a display device which has been either geometrically or symbolically enhanced to better enable a user to accomplish a particular task. Research conducted over the past several years on 3-D spatial instruments has shown that perspective displays, even when viewed from the correct viewpoint, are subject to systematic viewer biases. These biases interfere with correct spatial judgements of the presented pictorial information. It is also found that deliberate, appropriate geometric distortion of the perspective projection of an image can improve user performance. These two findings raise intriguing questions concerning the design of head-mounted spatial instruments. The design of such instruments may not only require the introduction of compensatory distortions to remove the neutrally occurring biases but also may significantly benefit from the introduction of artificial distortions which enhance performance. These image manipulations, however, can cause a loss of visual-vestibular coordination and induce motion sickness. Additionally, adaptation to these manipulations is apt to be impaired by computational delays in the image display. Consequently, the design of head-mounted spatial instruments will require an understanding of the tolerable limits of visual-vestibular discord. Author

N89-12185# York Univ. (Ontario). Human Performance Lab.
INFLUENCE OF VECTION AXIS AND BODY POSTURE ON VISUALLY-INDUCED SELF-ROTATION AND TILT
I. P. HOWARD, B. CHEUNG, and J. LANDOLT (Defence and Civil Inst. of Environmental Medicine, Downsview, Ontario) *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 8 p (SEE N89-12171 03-52) Jun. 1988
(AGARD-CP-433) Avail: NTIS HC A09/MF A01

Yaw vection is induced by a scene rotating about spinal axis (z axis), pitch vection by a scene rotating about an axis in the mid-frontal plane (y axis) and roll vection by a scene rotating about an axis parallel to the line of sight (x axis). Each of these axes can be vertical or horizontal, making six conditions in all, of which only four have been studied previously. We studied vection and illusory body tilt under all six conditions, with a full rotating field, reduced somesthetic cues and in a situation in which body rotation could occur. Yaw vection around a vertical axis was strongest. Forward pitch vection was stronger than backward pitch vection. Contrary to previous reports, for most subjects backward illusory tilt was much stronger than forward illusory tilt. Two subjects experienced 360 deg body rotation in the horizontal-pitch condition. The direction of pitch axis asymmetry was found to be consistent and not related to the asymmetry of vertical optokinetic nystagmus. Author

N89-12186# York Univ. (Ontario). Human Performance Lab.
VECTION AND THE SPATIAL DISPOSITION OF COMPETING MOVING DISPLAYS
I. P. HOWARD, M. OHMI, W. SIMPSON, and J. P. LANDOLT (Defence and Civil Inst. of Environmental Medicine, Downsview, Ontario) *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 8 p (SEE N89-12171 03-52) Jun. 1988
(Contract DCIEM-97711-4-7936/8SE84-00110)
(AGARD-CP-433) Avail: NTIS HC A09/MF A01

In Experiment 1 we investigated the relative effectiveness of two superimposed displays in generating circular vection as a function of: (1) the separation in depth between them, (2) their perceived relative ditances, and (3) which display was in the plane of focus. Circular vection was found to be governed by the display that was perceived to be more distant, even when it was actually nearer. Vection was not affected by whether the near or far display was in the plane of focus, nor by which display was fixated or pursued by the eyes. In Experiment 2 we asked whether the generally held belief that vection is induced most effectively by the peripheral stimuli is due to an artifactual effect of perceived distance. The experiment assessed the separate contributions of foreground-background and central-peripheral placement of competing displays. It was found that both factors contribute in an interactive way to the experience of vection. In Experiment 3 we investigated how linear forward vection induced by a looming visual display is affected by the near-far relationships of competing displays. Author

N89-12187# University Hospital, Leuven (Belgium). Dept. of Otoneurology and Equilibriometry.
CUES FOR TRAINING VERTIGO, PROVIDING SUGGESTIONS FOR THE MANAGEMENT OF SIMULATOR SICKNESS
MARCEL E. NORRE *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 4 p (SEE N89-12171 03-52) Jun. 1988
(AGARD-CP-433) Avail: NTIS HC A09/MF A01

Clinical experience with exercise treatment for vertigo has confirmed the extreme adaptibility of the balance system. Vestibular Habituation Training (VHT) for provoked (positioning) vertigo provides some interesting cues in the scope of the theme of this meeting, related to simulator sickness. The disabling sensation, called motion sickness, means only a disturbance similar to vertigo. In both, the sensory observation of the environment by the three sensors results in a sensory mismatch. In vertigo it is one of the

sensors that works in a wrong way and in motion sickness it is an unusual presentation of the environment structure that causes the mismatch. *Provoked vertigo as well as motion sickness is* linked to actual working of the system. In both situations the system has to work up changing relationships: in the provoked vertigo the changing situation has no contradiction in se related to a normal working schedule of the system, whereas it has in motion *sickness. In* both cases it must be possible to re-organize the effect of the changed sensory input by central adaptation. Clinical experience confirmed it; repeated exposure to the mismatch is the very stimulus and has a positive effect in provoked vertigo. Persons with motion sickness can be habituated in the same way as we observe it for our patients with provoked vertigo: i.e., progressively by exposure and specifically, related to the stimulus pattern of the exposure. Author

N89-12188*# National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX.
PREADAPTATION TO THE STIMULUS REARRANGEMENT OF WEIGHTLESSNESS: PRELIMINARY STUDIES AND CONCEPTS FOR TRAINER DESIGNS
D. E. PARKER and M. F. RESCHKE *In* AGARD, Motion Cues in Flight Simulation and Simulator Induced Sickness 9 p (SEE N89-12171 03-52) Jun. 1988 Prepared in cooperation with *Miami Univ., Oxford,* Ohio
(AGARD-CP-433) Avail: NTIS HC A09/MF A01

An effort to develop preflight adaptation training (PAT) apparatus and procedures to adapt astronauts to the stimulus rearrangement of weightless spaceflight is being pursued. Based on the otolith tilt-translation reinterpretation model of sensory adaptation to weightlessness, two prototype preflight adaptation trainers (PAT) have been developed. These trainers couple pitch *movement of the subject with translation of the visual surround.* Subjects were exposed to this stimulus rearrangement for periods of 30 m. The hypothesis is that exposure to the rearrangement would attenuate vertical eye movements was supported by two experiments using the Miami University Seesaw (MUS) PAT prototype. The Dynamic Environment Simulator (DES) prototype failed to support this hypothesis; this result is attributed to a peculiarity of the DES apparatus. A final experiment demonstrated *that changes in vertical eye movements were not a consequence* of fixation on an external target during exposure to a control condition. Together these experiments support the view that preflight adaptation training can alter eye movements in a manner consistent with adaptation to weightlessness. Following these initial studies, concepts for development of operational preflight trainers were proposed. The trainers are intended to: demonstrate the stimulus rearrangement of weightlessness; allow astronauts to train in altered sensory environment; *modify sensory motor reflexes;* and reduce/eliminate space motion sickness symptoms. Author

N89-17399# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel
SLEEP AND WAKEFULNESS: HANDBOOK FOR FLIGHT MEDICAL OFFICERS, 2ND EDITION
A. N. NICHOLSON and BARBARA M. STONE (Royal Aircraft *Establishment, Farnborough, England.) 1987 92 p*
(AGARD-AG-270(F)) Avail: NTIS HC A05/MF A01

The first e, tion of this handbook was published in 1982, and since then the understanding of sleep and wakefulness has advanced considerably. This new handbook emphasizes the *mangagement* of aircrew and the problems they experience in coping with irregularity of rest and activity. Author

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BEHAVIORAL SCIENCES

Includes psychological factors; individual and group behavior; crew training and evaluation; and psychiatric research.

N87-29505# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).
STUDY OF ANTICIPATION MECHANISMS IN THE AERONAUTICAL ENVIRONMENT [ETUDE DES MECANISMES D'ANTICIPATION EN AERONAUTIQUE]
R. AMALBERTI, CL. VALOT, and J.-P. MENU *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 14 p (SEE N87-29503 24-06) Feb. 1987 In FRENCH
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Pilot behavior during anticipation activities is discussed. These types of activities make use of the ability to mentally represent *the result of changes produced in a given situation, allowing for* related events and real action potentials. Anticipation activities may take place at various levels including initial mission planning and necessitated in-flight changes thereto, during the use of standard procedures to accomplish various flight maneuvers and other highly routine acts, and during the acquisition and transfer of information to and from the hardware system using its displays and controls. Both behavioral observation and interview techniques *with experienced and inexperienced pilots were used to reveal* the rules by which these anticipation activities are carried out and how they differ as a function of the specific knowledge of the pilot at a given point in time and the available time to consider alternate responses. M.G.

N87-29506# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.) Helicopter and Military Aircraft Group
THE TASK TAXONOMY METHOD: A BASIS FOR AN EXPERT SYSTEM ON HUMAN RELIABILITY
R. SEIFERT and K. BRAUSER *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 8 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

A survey of human error (HE), its definition, nature of HE and the categorization of HE's, causes and prevention measures is described. Then a HE rating scale is introduced, which allows the assignment of HE probability (HEP) values measured into 10 reliability classes (RC). Based on HEP values measured for a number of human performances, a Task Taxonomy Method is developed. This method allows the assignment of a relative weight *to all task factors and to all performance shaping factors involved* in the task performance. The task taxonomy method is a tool to predict the HEP and RC of tasks allocated to man. Such a predictive tool is used for analysis, definition and design of man machine systems. Rules of an Expert System are described which facilitates the application and use of the task taxonomy method. Author

N87-30060# McDonnell-Douglas Corp., Long Beach, CA.
MENTAL WORKLOAD MEASUREMENT IN OPERATIONAL AIRCRAFT SYSTEMS: TWO PROMISING APPROACHES
MICHAEL BIFERNO *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 44-51 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

When evaluating aircraft systems, the most useful mental workload (MWL) measures are those which can be employed inflight or full mission simulations. This *requires measures to be* noninterfering, relatively unobtrusive, and provide estimates of operationally relevant MWL while maintaining high levels of validity and reliability. In the context of automated systems, the strategy was to define MWL as language based mental activity and to *develop subjective ratings* (opinion scale) in the short term and event related brain potential (ERP) measures in the long term. Subjective ratings are being employed to estimate the required degree of attention to perform information processing, mental operations, and actions. This organization aids in the identification of undesirable MWL levels associated with system displays, logic, and controls. In addition to providing a quantitative workload rating,

this technique elicits verbal explanations if high MWL levels are reported. Author

N88-27698# Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek Soesterberg (Netherlands). Human Performance Group.
USING ERPS TO STUDY HUMAN INFORMATION PROCESSING
A. W. K. GAILLARD. *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 6 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The event-related brain potential (ERP) technique may provide an inobtrusive measure of the processing of psychological information during task performance. Some investigators regard ERPs even as a direct manifestation of the ongoing psychological processes. Before such a strong claim can be made several methodological problems have still to be solved. The definition and identification of the various components in the ERP, the separation of exogenous and endogenous components, and the different ways in which inferences can be made about psychological processes on the basis of ERP components, is the low comparability of ERP measures across paradigms are discussed. Author

N88-27701# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
THE EFFECT OF ENDOGENOUS ALPHA ON HEMISPHERIC ASYMMETRIES AND THE RELATIONSHIP OF FRONTAL THETA TO SUSTAINED ATTENTION
R. PIGEAU, R. HOFFMANN, S. PURCELL, and A. MOFFITT (Carleton Univ., Ottawa, Ontario.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 16 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Data are represented which suggest that the degree of hemispheric alpha asymmetry is related to resting eyes closed endogeneous alpha activity. Also, it is demonstrated that frontal theta activity varies with the difficulty level of an additional tasks. Both results share a common emphasis on electrophysiological individual difference. The electroencephalogram (EEG) recordings from 54 right-handed subjects performing 5 cognitive tasks were collected and quantified using period analysis. The subjects were rank ordered on the basis of their hemispherically averaged alpha activity during an eyes closed baseline condition. A similar procedure was performed for frontal theta to distinguish theta generators. Utilizing a L-R/L+R asymmetry index the results indicate that high and middle alpha generators displayed the hypothesized and asymmetry relationship whereas the low alpha generators did not. This implies that low alpha generating subjects may negatively affect EEG laterality studies. Results from the addition task indicate that hemispherically averaged theta activity varies curvelineanly as a function of increaseing task difficulty. Subjects displaying higher performance scores on the additional task also demonstrate higher frontal theta values, suggesting theta is associated with sustained focused attention of higher order cognitive processes. Author

N88-27707# Naval Aerospace Medical Research Lab., Pensacola, FL.
THE NEUROELECTRIC SELECTION OF NAVAL AVIATION PERSONNEL: AN EVALUATION
R. R. STANNY, D. L. REEVES, M. R. BLACKBURN, and G. R. BANTA (Naval Medical Research and Development Command, Bethesda, Md.) *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 8 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The value of using event-related potentials to predict success in naval aviation is examined. The background of the project, some methodological considerations, and the approach to the problem are discussed. Some early results have become available and are encouraging. Author

N88-27711# Veterans Administration Hospital, Sepulveda, CA. Neuropsychology Research Dept.
ELECTROENCEPHALOGRAPHIC CORRELATES OF PILOT PERFORMANCE: SIMULATION AND IN-FLIGHT STUDIES
M. B. STERMAN, G. J. SCHUMMER, T. W. DUSHENKO, and J. C. SMITH. *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 16 p (SEE N88-27683 21-51) Feb. 1988
(Contract AF-AFOSR-0231-83; AF-AFOSR-0335-82)
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Both laboratory and in-flight studies were performed in order to evaluate the utility and feasibility of EEG monitoring as a means of identifying central nervous system correlates of performance and G-force effects during military flight operations. Four studies were conducted, two with controlled laboratory simulation, and two in actural flight during military training missions. Data analysis focused on EEG power-spectral density characteristics and their temporal modulation, specifically in sensorimotor and visual cortical areas. Several consistent findings emerged. During competent performance, a highly unique discrepancy appeared between the left and right hemispheres in central 8 to 15 Hz activity. This pattern disappeared as performance degraded. The temporal modulation of this activity also reflected these changes. During high G-force situations, power at frequencies below 8 Hz was progressively and non-specifically enhanced. Continued competent performance, however, was still reflected by the pattern described. These findings are discussed in terms of their neurophysiological implications. Author

N88-27719# Hellenic Air Force General Hospital, Athens (Greece). Neurological Clinic.
CORRELATION BETWEEN EEG ABNORMAL ACTIVITY AND AIRCRAFT ACCIDENTS: A LONG TERM OBSERVATION
A. STAVROPOULOS. *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 5 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

During 1975 to 1976, 64 student pilots of the Hellenic Air Force Air Academy were studied with electroencephalographic protocol including activation procedures. In 13 of them, abnormal encephalographic activity was observed. During their 10-year flying career as fighter pilots, six pilots with abnormal EEGs were involved in 10 aircraft accidents due to pilot error, while only 3 pilots of the 51 with normal EEGs were involved in 4 accidents due to pilot errors. Author

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MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

Includes human engineering; biotechnology; and space suits and protective clothing.

N87-13934# Rheinische Braunkohlenwerke A.G., Cologne (Germany, F.R.). Hauptabteilung Arbeitsmedizin.
RELATIONSHIPS BETWEEN WHOLE-BODY VIBRATION AND DISORDERS OF THE BACKBONE DIAGNOSED ON OPERATORS OF EARTH-MOVING MACHINERY
G. ZERLETT. *In* AGARD Backache and Back Discomfort 5 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

A study was based on interviewing 352 operators of earth-moving machinery who had been exposed to whole-body vibration for at least 3 years. A further examination dealt with the evaluation of available X-rays showing different parts of the spines of 251 machinery operators who had been exposed to vibration for at least 10 years. The discomfort most often mentioned was impairment of health and well-being during and after the working shift (mentioned by 75% and 59% respectively). Apart from that, the percentage of subjects complaining about spinal discomforts was much higher for the exposed group than for the non-exposed group (70% and 54% respectively). The epidemiologic study resulted in an objective confirmation of the spinal discomforts

indicated, 2/3 of which had been related by the operators to the lumbar spine. Of all disorders diagnosed for the operators, the lumbar syndrome accounted for the greatest share by far 81%. In three cases, diagnosis for the operators was avulsion fracture of the spinous processus of a vertebral body in the cervical column. The frequency distribution resulting from the radiographic examination of 251 earth-moving machinery operators with at least a 10 years exposure to whole-body vibration showed that morphological changes in the lumbar spine occur earlier and much more frequently than in the case of non-exposed persons.

Author

N87-13935# Institut National de Recherche et de Securite pour la Prevention des Accidents du Travail et des Maladies Professionnelles, Vandoeuvre (France).

THE WORKPLACE VIBRATION ENVIRONMENT OF OFF-ROAD MACHINES

P. BOULANGER, P. DONATI, J. P. GALMICHE, and L. ROURE *In* AGARD Backache and Back Discomfort 11 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Measurements made with manufacturers and users enabled I.N.R.S. to evaluate the vibration exposure at the workplace of about 70 different off-road machines presently used in France and the efficiency of machine suspension seats. Measurements were obtained from accelerometers mounted triaxially, placed on the seat pan and on the floor beneath the seat. More than 150 runs were performed to consider a range of typical operating conditions of vehicles studied. According to the standard AFNOR NF E 90-401 the vibration exposures measured on running vehicles fitted with pneumatic tires (dumpers and off-road trucks, tractor scrappers, off-road fork lift trucks, etc...) were greater than those recorded in excavators and back-hoe loaders while digging trenches. The drivers were exposed mainly to vertical vibration unless the vehicles were used for excavating or scraping. In addition, the results show how poor the isolation provided by the seat vertical suspension systems is, especially for those vehicles fitted with pneumatic tires. This proves the necesssity to apply seat test code as defined by the French standard AFNOR E 58-074 for off-road machines. The measurements made on the floor beneath the seat generally validate the pertinence of input vibration spectral classes recommended by this standard to test seats in the laboratory although some modifications are suggested. Particularly, it is proposed to include the dumpers and off-road trucks and to define two new classes to take into account horizontal vibrations when necessary.

Author

N87-13936# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).

BACK PAIN AND DISCOMFORT RESULTING FROM EXPOSURE TO VIBRATION IN TRACKED ARMOURED VEHICLES

D. BEEVIS and S. E. FORSHAW *In* AGARD Backache and Back Discomfort 7 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

The interrelationship of vehicle ride, operator exposure and back pain was studied using a pool of drivers from the Combat Arms School (CAS), who were required to drive long hours in M113 armored personnel carriers. Among the 28 CAS M113 drivers with back problems, ten had recurrent lower back pain to the extent that time was missed from work. Of the ten, one required surgery during the period of the investigation, and another six, who were free from congenital abnormalities of the spine, were found by X-ray examination to have changes such as degenerative disc disease. A three-aspects approach was taken for the investigation. The first aspect was to review the medical history of the pool drivers for the three years prior to the investigation, and to compare them with those of two other groups of drivers. One group, (RCR drivers), drove the same vehicle but for fewer average hours per week. The other group (Centurion drivers), drove a slower, heavier vehicle for a similar number of hours per week. The second aspect of the study was to review the exposure history of the three groups of drivers. This was done using a modified version of the questionnaire developed by Fitzgerald and Crotty. The third aspect of the study involved the recording and analysis of the ride characteristics of the M113 and the Centurion. Accelerations were measured in three orthogonal axes at the driver's buttocks, as each vehicle was driven at representative speeds over various types of road and terrain. A one-third octave-band analysis of the data was then compared with the exposure limit (EL), the fatigue decreased proficiency boundary (FDP), and the reduced comfort boundary (RC) of ISO 2631. Specific results and data analysis are outlined and it is concluded that the high incidence of back pain observed in the pool driver group was the result of poor posture and exposure to intense levels of vibration and shock for periods exceeding the exposure limits recommended by ISO 2631, and that the incidence of back pain among RCR and Centurion drivers was related to poor driving posture.

M.G.

N87-13939# Army Aeromedical Research Lab., Fort Rucker, AL.

BACK DISCOMFORT IN US ARMY HELICOPTER AIRCREW MEMBERS

D. F. SHANAHAN, G. R. MASTROIANNI, and T. E. READING *In* AGARD Backache and Back Discomfort 10 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

The relationship of back discomfort to military helicopter flight operations was studied in this questionnaire survey of 802 U.S. Army helicopter pilots. Of the surveyed population, 584 (72.8%) pilots reported experiencing back discomfort while flying over the last two years. The discomfort generally was described as a dull ache confined to the lower back, with a mean onset time of 88 minutes into a mission. The relationship of reporting the pain to physical characteristics, past medical history, physical activity, and aviation experience is discussed. For over half of the respondents (50.1%), the pain was transient (less than 24 hours duration), resolving rapidly after discontinuing a provoking flight. Nevertheless, there was a significant number of aviators who reported persistent symptoms lasting over 48 hours (14.5%). Possible etiologies of the pain for both groups, as well as potential methods of prevention are discussed.

Author

N87-13945# Loughborough Univ. of Technology (England). Dept. of Human Sciences.

VEHICLE VIBRATION AND BACK PAIN

J. SANDOVER *In* AGARD Backache and Back Discomfort 9 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Although it is often suggested that chronic low back pain in professional drivers is related to vibration or posture, we have only a limited theoretical framework to work with. Well organised, prospective epidemiological studies may demonstrate that chronic low back pain in drivers or pilots is related to high levels of vibration or poor posture. However, they will get us little further without the theoretical base. In this paper, it is assumed that chronic back pain is dependent primarily on disc degeneration and that disc degeneration, in turn, arises from fatigue-induced damage to the vertebral end-plates or to the tissues of the annulus. It will be shown that in either case, time to failure is related to an exponential function of stress such that instantaneous stress maxima are more important then long term (e.g., r.m.s.) stress values. We usually assume the some frequency weighting function is needed to predict, from vehicle vibration, the spinal stress that may lead to malfunction. This function may be based on equal discomfort contours, biomechanics data or a simple model. It is shown that basic assumptions on the effects and on frequency weighting can markedly affect the evaluation of particular vibration environments.

Author

N87-13946# Technische Univ., Munich (Germany, F.R.)

IN-VIVO EXPERIMENTS ON THE RESPONSE OF THE HUMAN SPINE TO SINUSOIDAL G SUB Z VIBRATION

F. W. HAGENA, C. J. WIRTH, J. PIEHLER, W. PLITZ, G. O. HOFMANN, and T. ZWINGERS *In* AGARD Backache and Back Discomfort 12 p (SEE N87-13932 05-52) Jun. 1986

(AGARD-CP-378) Avail: NTIS HC A12/MF A01

The transmissibility of the human spine to vertical G(z)-vibration was up to now investigated mainly by measurements on the body-surface and the head. As it is known that vibration transmission between skin-soft tissue-bone is not linear, we thought it necessary to inert percutaneous K-wires into the spinous process for direct measurements. In 11 healthy subjects at various defined heights of the spine including the head the amplitude ratio was measured to the sacrum and in comparison to the shake table. The tests were performed in standing and sitting position on a

shake table with vibration control system. The natural frequency of the spine was confirmed by additional in-vitro tests on isolated lumbar spine segments under special conditions. The human spine acts as a vibration system with three defined areas of resonance. The spinal column causes an adsorption up to the head. Rigid body segments as well as fusional to spinal segments lead to increased strain in neighbouring segments. This was proved by in vivo as well as in vitro investigation. A new set-up for in vitro tests was developed. Author

N87-13947# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
***IN VIVO* MEASUREMENTS OF VIBRATION TRANSMISSION IN THE HUMAN SPINE Abstract Only**
G. B. J. ANDERSSON, M. M. PANJABI, L. JORNEUS, and E. HULT *In its* Backache and Back Discomfort 2 p (SEE N87-13932 05-52) Jun. 1986 Sponsored in part by Swedish Work Environment Fund
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Although conclusive evidence does not exist, there are many epidemiological surveys suggesting an increase risk of low back pain in persons exposed to vibrations. Theoretical calculations indicate that spinal motion segment components can be stressed by whole body vibration exposure to the degree that fatigue failure can occur. Further, it is also known that vibration can interfere with disc nutrition. Several studies have been published in which the response of the trunk as a whole to vibration was measured. These measurements were usually made with a single uniaxial accelerometer placed on the head of the subject or at some place on the surface of the trunk. The output accelerations have then been related to the input, i.e., vibration transfer functions have been calculated. In this paper, in vivo experiments are discussed in which vibration was measured in the three principal directions in the sagittal plane with accelerometers attached directly to lumbar vertebrae in human volunteers. Author

N87-13953# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario). Biosciences Div.
POSTURAL FATIGUE AND THE BACKACHE OF HELICOPTER PILOTS
T. J. BOWDEN *In* AGARD Backache and Back Discomfort 10 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378; DCIEM-85-R-30) Avail: NTIS HC A12/MF A01

A review of the literature on the back pain of helicopter pilots suggests that postural fatigue, rather than specific injury to the spine, may be the cause of much of the reported pain. Postural fatigue is defined here as fatigue in specific muscles whose continuous activity is required to maintain a working posture. Descriptions of the back pain of helicopter pilots are compared with those of the phenomenon of postural fatigue. It is significant that there is a strong association between the pilot's back pain and actual flight duty. Biomechanical aspects of the pilot's environment and of tasks within the cockpit are assessed as potential causes of postural fatigue. Both posture and vibration within the cockpit may be possible causes, since both conditions may impose continuous activity on muscles of the lower back. Postural fatigue is a temporary problem, but the causes of postural fatigue, such as sedentary work in awkward postures, are considered by many authors to be related to increased incidence of chronic back pain, back disease and related disability. Repeated exposure to postural fatigue may increase the likelihood of mechanical back injury by reducing the effectiveness of the protection given to the spine by its supporting muscles during tasks involving bending and lifting. Electromyography has been used to index postural fatigue in the laboratory, as well as in the civilian work environment. By objectively defining muscle activity and fatigue, electromyographic methods may allow the objective assessment of different ergonomic proposals to relieve the back pain in helicopter pilots. Author

N87-13954# Vermont Univ., Burlington. Dept. of Orthopaedics and Rehabilitation.
MUSCLE FATIGUE IN STATIC AND VIBRATIONAL SEATING ENVIRONMENTS
M. H. POPE, D. G. WILDER, and D. D. DONNERMEYER *In* AGARD Backache and Back Discomfort 10 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

In order to perform an objective assessment of muscle fatigue in a UH-1-H cockpit seating environment, instrumentation was developed to sense and use as an outcome measure the shift in the center frequency of the electromyographic (EMG) spectrum of the dorsal lumbar musculature. Subjective assessment of fatigue was accomplished by means of a visual analog scale indicating discomfort as a function of duration of exposure to the seated environment. Twenty subjects (10 male and 10 female) were exposed to the same seating environment (in terms of both static posture and vibration exposure) as that experienced by the UH-1-H helicopter pilot. The vibration environment of a UH-1-H helicopter was recorded and reproduced using a servohydraulic vibration simulator. Each exposure lasted two hours. Marginally significant fatigue, as measured by the center frequency shift method, occurred only as a result of the sustained static posture. In contrast, all exposures to this seating environment, in both static and vibration modes, produced significant subjective discomfort in both buttocks and lower back. Thus, the predominant cause of back discomfort and fatigue in this instance appears to be the UH-1-H specific seated posture rather than the UH-1-H specific vibrational environment. Author

N87-13955# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
LOWER BACK PAIN IN HELICOPTER PILOTS: ETIOPATHOLOGICAL FACTORS [LOMBALGIES DES PILOTES D'HELICOPTERES FACTEURS ETIOPATHOGENIQUES]
J. L. POIRIER, D. LEJEUNE, P. J. METGES, and H. VIEILLEFOND *In* AGARD Backache and Back Discomfort 7 p (SEE N87-13932 05-52) Jun. 1986 In FRENCH
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

Back pain is presently one of the occupation related hazards of concern to the helicopter pilot. The physiopathogenesis is tied to two factors: posture and vibration. From the postural point of view, our aim was to determine the specific positional characteristics of the spine of a subject seated at the pilot station. Beginning from data obtained with radiography, we have defined rules for the conception and realization of helicopter seats. As concerns mechanical vibration, we conducted a comparative study of the vibration transmissibility for various helicopter seats and seat cushions. It is now possible to contribute improvements to pilot comfort in the postural domain from the point of view of vibration protection. M.G.

N87-13956# Tor Vergata Univ., Rome (Italy). Dept. of Electronic Engineering.
VIBRATION MEASUREMENTS ON HELICOPTER AIRCREW: A NEW APPROACH
M. A. D. PETTERNELLA, R. BERTI (Aerospace Medicine Center, Rome (Italy).), A. LALA, and R. ANTONINI *In* AGARD Backache and Back Discomfort 12 p (SEE N87-13932 05-52) Jun. 1986
(AGARD-CP-378) Avail: NTIS HC A12/MF A01

A method is proposed for obtaining the time-dependent pattern of vibrations transmitted to the seated pilot, by means of a map showing the direction and magnitude of all measured vectors. The pattern easily allows the observer to distinguish between rotational and translational motion. Because the direction of translational motion (or the axis of rotational motion) is not the same in different flight conditions, a suitable reorientation of the frame of reference is required in order to compare the various situations. In this way it is also possible to observe changes of the spin axis or of the direction line, in case of rotational or translation motion respectively. Some results obtained from measurements on board a helicopter at two sites (seat and backrest) are presented. Three orthogonal acceleration vectors are examined. Patterns corresponding to different flight conditions are shown, before and after frame reorientation. The paper closes with a frequency analysis of some of the measurements, comparing amplitudes and phases of the spectral components at the same frequencies, before and after frame reorientation. Author

N87-18987# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

IMPROVED GUIDANCE AND CONTROL AUTOMATION AT THE MAN-MACHINE INTERFACE

WALTER M. HOLLISTER, ed. Dec. 1986 123 p
(AGARD-AR-228; ISBN-92-835-1537-4; AD-A177651) Avail: NTIS HC A06/MF A01

Modern control and display technology has already reduced significantly the workload associated with piloting all forms of airborne vehicles. However, increased demands on the pilot make it desirable to establish how automation may further reduce both the cognitive and desision-making workload of the pilot. There is evidence that under high workload, in poor visibility, or for maximum combat capability, the pilot could perform better with control inputs more directly related to the outputs over which he needs control. There are also basic questions as to what information the pilot really needs, what control and management functions can be automated, and what functions must the pilot retain to perform his task satisfactorily in relation to different mission aspects. The AGARD GCP/WG.07 members were asked to identify the most promising options for improved automation at the man-machine interface of flight vehicles and present their findings. Author

N87-23644# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Ergonomics and Cockpit System.

COMPUTER SIMULATION STUDIES ON HUMAN CONTROL RELIABILITY IN MANUAL AIRCRAFT CONTROL: THE ORIGIN OF PIO

K. BRAUSER and R. SEIFERT *In* AGARD Flight Simulation 19 p (SEE N87-23633 17-09) Sep. 1986
(AGARD-CP-408) Avail: NTIS HC A16/MF A01

Pilot induced oscillations usually are defined as a sensitive indication of bad handling qualities. In the view of human performance reliability, PIO's are related to input errors with respect to the control characteristics of the controlled system. It is a general rule that man will make errors while performing arbitrary tasks under the influence of possible performance shaping factors (PSF's). A recently developed Task Taxonomy Method is used as a tool for the assessment of Human Error Probabilities (HEP) depending quantitatively on the effects of performance shaping factors (PSF) like task dimensions and characteristics, operator characteristics, system characteristics and environment factors. Using this Task Taxonomy procedure, HEP values for the manual aircraft control task have been calculated. HEP values are drastically increased (0.5 to 0.9) by the influence of bad handling qualities, while good handling qualities may only reduce the HEP value to 0.1, because other PSF's may remain still active. Therefore PIO incidents remain possible, even in aircraft with good handling qualities. This has been demonstrated by means of SAINT computer simulations using appropriate HEP values. Author

N87-25769# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

IMPACT OF FUTURE DEVELOPMENTS IN ELECTRONIC TECHNOLOGY ON COCKPIT ENGINEERING

R. EGGLESTON, ed. (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.) Jun. 1987 29 p
(AGARD-R-757; ISBN-92-835-1551-X; AD-A183571) Avail: NTIS HC A03/MF A01

Presented are the results of the Cockpit Engineering subpanel of an AGARD workshop on The Potential Impact of Future Developments in Electronic Technology on the Future Conduct of Air Warfare held at the SHAPE Technical Center in The Hague, Netherlands, from 21 to 25 October 1985. The report considers the issue of how advances in electronics technology are expected to impact cockpit engineering for future airborne weapon systems, surveys the cockpit engineering problem, and provides a limited treatment of the considerations and developments believed to be needed to ensure that the potential offered by new electronic technologies is realized in future weapon systems. Author

N87-29504# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.

AUTOMATION AT THE MAN-MACHINE INTERFACE

WALTER M. HOLLISTER *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 10 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

There is a recognized need for automation. However, detailed analysis shows that the term automation is too broad for making specific research recommendations. The specific characteristics vary in kind and degree as a function of the piloting tasks. In some cases, the task should be left entirely to the pilot. In many cases, computer aiding is the best choice. A method for allocating functions between automated systems and the pilot is presented using the theory of divided attention. It describes a structured approach for reducing the control dwell fraction with improved flying qualities. There is a need for fundamental research into the understanding of how the human pilot operates as part of the aircraft and weapons control system. Author

N87-29507# Washington Univ., Saint Louis, MO.

CLOSING THE MAN-MACHINE LOOP: ON THE USE OF PHYSIOLOGICAL MEASURES TO AFFECT COMPUTER-CONTROLLED DEVICES

J. A. STERN, G. F. WILSON, and M. THEISSEN (General Dynamics Corp., Fort Worth, Tex.) *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 5 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Results suggest that physiological information: heart rate, eye blink, etc., as well as information about operator performance and system characteristics, could be used to alert the operator, change displays, or permit the hardware to take over certain functions. Utilization of physiological data from the operator must be used with certain cautions in mind. For example, physical exertion causes changes in heart rate. The system would have to be provided with information concerning physical exertion, so that the heart rate data could be appropriately interpreted in a larger context. This is true of the information concerning aircraft performance as well, where the pattern of inputs from various sensors is analyzed in order to make a decision about an action to be taken. Author

N87-29508*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

THE EFFECTS OF DISPLAY-CONTROL I/O, COMPATIBILITY, AND INTEGRALITY ON DUAL-TASK PERFORMANCE AND SUBJECTIVE WORKLOAD

PAMELA S. TSANG (Illinois Univ., Savoy.), SANDRA G. HART, and MICHAEL A. VIDULICH *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 9 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01 CSCL 05H

The utility of speech technology was evaluated in terms of three dual task principles: resource competition between the time shared tasks, stimulus central processing response compatibility, and task integrality. Empirical support for these principles was reviewed. Two studies investigating the interactive effects of the three principles were described. Objective performance and subjective workload ratings for both single and dual tasks were examined. It was found that the single task measures were not necessarily good predictors for the dual task measures. It was shown that all three principles played an important role in determining an optimal task configuration. This was reflected in both the performance measures and the subjective measures. Therefore, consideration of all three principles is required to insure proper use of speech technology in a complex environment Author

N87-29509# Royal Air Force, London (England).

A STUDY OF PILOT FLIGHT INFORMATION CROSSMONITORING PERFORMANCE

V. P. SCHMIT *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 12 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

A experiment is discussed which investigated the ability of the pilot to crossmonitor between Head Up display and Head Down instruments. In a situation with high error rates, no subsidiary tasks

and with explicit exclusion of troubleshooting (i.e., a best case), results show a low error detection rate, long detection times and significant flying performance decrements while crossmonitoring. Error detection performance is correlated not with the amount of time spent crossmonitoring, but with the frequency at which the pilot chooses to crossmonitor. Extrapolation from the results suggests that, at least for the conditions of this experiment, crossmonitoring should occur every 22 to 23 sec to ensure acceptable error detection. The evidence points clearly to the need to remove the crossmonitoring task from the pilot and make it an automated function for future aircraft. Author

N87-29510# *Centre d'Etudes et de Recherches de Medecine* Aerospatiale, Paris (France).
SOPHISTICATED INTEGRAL CONTROL METHODS FOR USE IN FLIGHT [LES MOYENS DE COMMANDE INTEGRES SOPHISTIQUES SERONT-ILS CONCUS POUR ETRE UTILISABLES EN VOL]
J.-P. MENU, G. SANTUCCI, and R. AMALBERTI *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 6 p (SEE N87-29503 24-06) Feb. 1987 In FRENCH
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

The changing nature of display and control requirements for modern aircraft and the various means by which information is transferred to and from the pilot are reviewed. Some of the known factors affecting human performance are discussed including: (1) desaturation and contrast loss in electronically generated information during high illumination inflight conditions; (2) the effects of high acceleration on both foveal and peripheral presentations of information; (3) manual control designs which obscure some settings when engaged; and (4) the improper labelling of display and control devices. The potential use of voice interactive control devices, especially in overcoming problems inherent in multitask situations, is also discussed. Finally, the relative merits of dedicated and multifunctional displays and controls are examined along with the theoretical causes of increased higher cognitive workloads required by multifunction devices. M.G.

N87-29516# Centre d'Etudes et de Recherches de Medecine Aerospatiale Paris (France) Lab. Central de Biologie Aerospatiale.
ORGANIZATION OF DISPLAYS IN THE VISUAL SPACE OF THE COMBAT AIRCRAFT PILOT [ORGANISATION DES VISUALISATIONS DANS L'ESPACE VISUEL DU PILOTE D'AVION DE COMBAT]
J.-P. MENU and R. AMALBERTI *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 12 p(SEE N87-29503 24-06) Feb. 1987 In FRENCH
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

The psychophysiological problems associated with the specific organization of cockpit displays were examined through laboratory studies and pilot surveys. The response time associated with the transition between head-up and head-down displays was measured under various conditions. It was found that reduced transition times could be obtained through the use of intermediate display concepts. Illumination level and visual adaptation were identified as important factors in the optimal integration of displays. M.G.

N87-30054# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
THE PRACTICAL ASSESSMENT OF PILOT WORKLOAD
ALAN H. ROSCOE, ed. (Britannia Airways Ltd., Luton, England) Jun. 1987 141 p
(AGARD-AG-282; ISBN-92-835-1546-3; AD-A184834) Avail: NTIS HC A07/MF A01

Whether one is attempting to reduce workload in the cockpit of a combat aircraft to improve mission effectiveness, or to optimise workload levels on the flight deck of a civil airliner to improve safety, it is important to be able to assess workload in practical terms. In the case of the civil transport aircraft the findings of the President's Task Force on Crew Complement have underlined the need to assess workload in flight reliably in order to satisfy certification requirements for new aircraft. The main purpose of this report is to provide guidance for the assessment of pilot workload in practical situations. The various techniques available for assessing pilot workload are introduced and briefly reviewed. Some techniques that have been successful inflight are presented along with techniques for assessing workload for the purpose of aircraft certification. For individual titles, see N87-30055 through N87-30069.

N87-30055# Ergometrics Technology, Inc., Dayton, OH.
IN-FLIGHT WORKLOAD ASSESSMENT USING EMBEDDED SECONDARY RADIO COMMUNICATIONS TASKS
CLARK A. SHINGLEDECKER *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 11-14 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

The embedded secondary task methodology was developed to improve the practical utility of dual task measures for inflight workload assessment, while retaining many of the scientific advantages associated with traditional laboratory secondary tasks. The concept of the embedded secondary task is based on the hypothesis that instrumentation limitations, task intrusion, and poor operator acceptance can be minimized by designing secondary tasks which are fully integrated with system hardware and with the crewmember's conception of the mission environment. By their nature, such tasks are realistic components of crewstation activity, yet their performance can be manipulated and measured independently of the primary activities of interest. While several classes of aircrew activity are potential candidates for isolation and use as embedded tasks, radio communication tasks are particularly suitable for this purpose. Such tasks closely resemble the nonadaptive discrete secondary tasks used in numerous workload studies and have many properties of good measurement tasks. Measurement techniques are described and examples of use are given along with limitations. Author

N87-30056# Douglas Aircraft Co., Inc., Long Beach, CA.
USE OF TASK TIMELINE ANALYSIS TO ASSESS CREW WORKLOAD
G. STONE, R. K. GULICK, and R. F. GABRIEL *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 15-31 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

As systems have become more sophisticated, the role of humans in operating and maintaining them has grown more complex. There has been a steadily growing recognition that human characteristics, particularly limitations and abilities, must be considered in some depth in system design if design objectives are to be met. The size and role of the crew represent critical decisions. Mission performance has a direct relationship to the ability of the crew to carry out all of the required functions. The use of workload measures to assess the viability of a selected crew complement as well as other crew interfaces was considered. Several techniques are listed which are used to assess workload including task/timeline analysis measures. It appears to be the most easily implemented and could meet most of the established criteria. A model was developed to utilize this workload measure in the design, verification of design improvements, and certification of recent aircraft. This approach is presented and discussed in detail. E.R.

N87-30057# Boeing Co., Seattle, WA.
PILOT SUBJECTIVE EVALUATION OF WORKLOAD DURING A FLIGHT TEST CERTIFICATION PROGRAMME
FRANK T. RUGGIERO and DELMAR M. FADDEN *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 32-36 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

To date there is no agreed upon definition of mental workload and therefore there is no agreement on how it should be measured. Three aspects of mental workload are agreed upon: it is a multidimensional construct, a clear distinction must be maintained between imposed mental load (task load) and the mental load as experienced (subjective load), and the use of subjective ratings should be central to any investigation of workload. The Pilot Subjective Evaluation (PSE) process developed in conjunction with the FAA is outlined which supplements the analytical, simulator, and flight test crew workload evaluation techniques used to demonstrate compliance with the minimum crew size requirement regulations. Author

N87-30058# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. for Flight Guidance.
THE USE OF SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE IN A COMPLEX FLIGHT TASK
F. V. SCHICK and R. L. HANN (Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.) *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 37-41 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

Techniques for measuring mental workload can be divided into three basic categories: physiological, behavioral, and subjective. One particular technique belonging to the subjective group of methods, which always use some form of operator self-report (e.g., rating scales or questionnaires) is discussed. In order to deal with the undesirable properties of subjective methods, a procedure known as the Subjective Workload Assessment Technique (SWAT) was developed. In SWAT, subjective workload is defined as being composed of three dimensions: time load, mental effort load, and psychological stress load. This method is introduced and discussed. E.R.

N87-30059# Illinois Univ., Urbana-Champaign. Dept. of Psychology.
WORKLOAD METHODOLOGY
EMANUEL DONCHIN and CHRISTOPHER D. WICKENS *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 42-43 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

The goal of the proposed technique is to employ two converging methodologies to track the workload changes during the ILS approach to landing. The two methodologies, based upon the Event Related Brain Potential (ERP) and the Sternberg Memory Search task, provides information that is both sensitive, detecting variations in resource demand when they occur, and diagnostic, localizing these changes within the multidimensional space underlying human processing resources. Each of these techniqes are briefly described. The ERP is a transient series of voltage oscillations in the brain that can be recorded from the scalp in response to the occurrence of a discrete event. The Sternberg Memory Search requires the pilot to identify whether or not a displayed character is one of a set of characters that is held in short term memory. Author

N87-30061# Ergometrics Technology, Inc., Dayton, OH.
CORTICAL EVOKED RESPONSE AND EYEBLINK MEASURES IN THE WORKLOAD EVALUATION OF ALTERNATIVE LANDING SYSTEM DISPLAYS
R. D. ODONNELL and GLENN WILSON *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 52-55 (SEE N87-30054 24-54) Jun. 1987 Prepared in cooperation with Aerospace Research Labs., Wright-Patterson AFB, Ohio
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

Based on the results of a number of studies, it was decided to construct a battery of physiological tests, each of which had shown some promise in laboratory studies of being sensitive to various aspects of workload. This Neuropsychological Workload Test Battery (NWTB) is undergoing validation testing in several simulator environments. Two of the most promising measures from this battery are the transient cortical evoked response and several analyses of eyeblink behavior. It is becoming clear that these techniques can contribute complementary types of information on the amount of workload being experienced by the operator, and could form the basis of a measurement system which would tap both global and specific aspects. Rationales are given for these techniques along with a description and examples of their use. E.R.

N87-30062*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
IN-FLIGHT ASSESSMENT OF WORKLOAD USING INSTRUMENT SCAN
J. R. TOLE (Digital Analysis Corp., Reston, Va.) and R. L. HARRIS, SR. *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 56-59 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

During instrument flight, the pilot obtains information concerning aircraft state by cross checking or scanning the flight instruments. The exact method of scanning the instrument panel varies from pilot to pilot but there are some basic features common to a good scan pattern. The method discussed may be considered a candidate for workload studies with piloting tasks which will invoke a regular visual scan (spatial/temporal pattern of eye movements) during instrument flight. It is important to point out that instrument scan by itself is not a complete indicator of workload nor is task attention necessarily associated with where the pilot happens to be looking at a particular instant. However, whenever instrument scan is required in a piloting task, analysis of scanning behavior may yield important direct or indirect information concerning workload. Author

N87-30063# British Aerospace Dynamics Group, Hatfield (England). Test Pilots Office.
FLIGHT TEST EVALUATION OF CREW WORKLOAD. PART 1: AIRCRAFT CERTIFICATION FOR A MINIMUM CREW OF TWO PILOTS
W. A. WAINWRIGHT *In* Advisory Group for Aerospace Research The Practical Assessment of Pilot Workload p 60-68 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

The method developed to certificate the BAe 146 for operation by a minimum crew of two pilots to regulations is described. The method is based primarily on subjective assessment of workload but employs objective data to support that assessment. All the data were collected from one flying phase and no flight or ground simulator assessments were performed, neither were the results correlated with any previous evaluation. The flight test evaluation used a variety of assessment methods, including practical demonstration, qualitative and quantative subjective evaluation, subjective comparison with similar aircraft types, and objective physiological evaluation. All confirmed that the crew workload on the BAe 146 was compatible with operation by a minimum crew of 2 pilots. This method is briefly discussed. Author

N87-30064# Royal Air Force Strike Command, High Wycombe (England).
MEASUREMENT OF AIRCREW WORKLOAD DURING LOW-LEVEL FLIGHT. PART 1: A COMPARISON BETWEEN IN-FLIGHT AND POST FLIGHT ASSESSMENT METHODS
I. GAVIN LIDDERDALE *In* Advisory Group for Aerospace Research The Practical Assessment of Pilot Workload p 69-77 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

The results of a comparative study of the use of inflight and postflight methods of subjective workload assessments in a modern military combat aircraft are presented. The assessments were made during a demanding low level flight task which was undertaken to assess workload and define crew cooperation procedures for pilot and navigators during terrain following flight. The inflight workload assessments were made using a modified version of the Cooper-Harper scale which is referred to as the Bedford Scale. Postflight ratings were made using a method of pairwise comparisons based on a method reported by Saaty. Other measures, including physiological recordings and voice tapes were also taken during the trials to provide additional data. From the results of the trials, it was found that both methods of subjective workload assessment produced similar results and a rank order analysis gave high correlations. A hypothetical Recce/Attack task for fast jet aircraft was chosen to illustrate the application of the workload measurement techniques described. The technique relies on the use of subjective ratings scales and physiological measures supported by voice recordings and flight data recordings. Author

N87-30066# Cranfield Inst. of Tech., Bedford (England). Applied Psychology Unit.
THE ASSESSMENT OF WORKLOAD IN HELICOPTERS
HELEN C. MUIR and ROBERT ELWELL *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 83-89 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

In aviation an assessment of workload is often used as one component in a program of research. The objective of the research may vary from an assessment of the activities of the crew to an evaluation of either cockpit modifications or operational changes. Thus workload assessments will form one of a series of stages in the research. A model is presented in which the stages of the investigation which will proceed and follow the workload assessment are described. An application of this approach to the assessment of workload in helicopters is used to illustrate the practical implications of the model. Author

N87-30067# Airbus Industrie, Blagnac (France).
ASSESSING WORKLOAD FOR MINIMUM CREW CERTIFICATION. PART 1: STATIC WORKLOAD ANALYSIS AND PERFORMANCE ANALYSIS
J. J. SPEYER, A. FORT, J. P. FOUILLOT, and R. D. BLOMBERG *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 90-115 (SEE N87-30054 24-54) Jun. 1987 Prepared in cooperation with Centre de Recherches de Medecine Aeronautique, Paris (France) and Dunlap and Associates, Inc., Norwalk, Conn.
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

The critical importance of man machine interaction has been recognized in the field of aircraft handling qualities. The recognition that man machine interaction is part of a complex information transfer process between pilots, the aircraft and ground facilities is relatively new. Classical are the systematic methods for assessing aircraft handling qualities, which inspired the approach to workload assessment presented. Also classical topics in flight test are the determination of static and dynamic stability, the former indicating the tendency of an aircraft to return to its equilibrium position, the latter indicating the way an aircraft returns to its equilibrium position. Analogous to the complementarity of these evaluations, the Static Taskload and the Dynamic Workload Methods were developed. Both methods address particular workload functions and factors. *These methods are briefly described and discussed.* Author

N87-30068*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
MEASUREMENT OF PILOT WORKLOAD
SANDRA G. HART *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 116-122 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

A multistage process for evaluating the workload of a five-minute segment of flight including approach and landing for a typical transport aircraft was described. The goal of the analysis was to compare the workload of the two pilots. Four types of measurement techniques were suggested: Analytic (a preliminary task and time line analysis identified task requirements and target performance levels); Performance (flight path control, communications, and interval production); Physiological (heart rate and heart rate variability); and Subjective ratings (a multidimensional technique developed at NASA Ames). Author

N87-30069# National Aerospace Lab., Amsterdam (Netherlands).
INVESTIGATION OF WORKLOAD MEASURING TECHNIQUES: A THEORETICAL AND PRACTICAL FRAMEWORK
RENE C. VANDEGRAAFF *In* Advisory Group for Aerospace Research and the Practical Assessment of Pilot Workload p 123-130 (SEE N87-30054 24-54) Jun. 1987
(AGARD-AG-282) Avail: NTIS HC A07/MF A01

A number of considerations involved in the setting up of an investigation dealing with the problem of being able to draw conclusions from a variety of experimental measures in a complex task situation are discussed. Several implications are pointed out, such as the problem of dealing with contradictory outcomes, the designating of artefacts, and the problem of formulating final conclusions with the (a priori) availability of a superior method for evaluating other methods. An experimental program is outlined which is based on (normal) approach conditions for civil fixed wing aircraft. The task conditions in this experiment are selected to serve as an operationally based framework for comparing different workload evaluation methods, for evaluating the effects of specific task conditions and for investigating the strategies needed for drawing final conclusions from a variety of outcomes. Author

N88-11668# Royal Netherlands Air Force, The Hague.
DEVELOPMENT, TESTING AND EVALUATION OF A NIGHT VISION GOGGLE COMPATIBLE BO-105 FOR NIGHT LOW LEVEL OPERATION
R. H. FRIEDERICY *In* AGARD, Rotorcraft Design for Operations 8 p (SEE N88-11649 03-05) Jun. 1987
(AGARD-CP-423) Avail: NTIS HC A14/MF A01

With the recommended equipment package, it was demonstrated that a BO-105 helicopter could be operated by experienced helicopter pilots at low level at night over fairly unfamiliar terrain under adverse weather conditions. The helmet mounted night vision goggles (NVG) gave a night low level capability. The third generation image intensifying tube (IIT) added an extra darkness and reduced visibility margin. The blue NVG cockpit lighting made easy monitoring of flight and engine performance instruments possible and allowed the use of navigation equipment. This greatly improved confidence and reduced workload. Author

N88-19559# British Aerospace Public Ltd. Co., Lancashire (England). Military Aircraft Div.
COMPUTER AIDED TACTICS FOR AIR COMBAT
N. MITCHELL *In* AGARD, Advances in Air-Launched Weapon Guidance and Control 11 p (SEE N88-19553 12-15) Dec. 1987
(AGARD-CP-431) Avail: NTIS HC A06/MF A01

In order to achieve maximum operational effectiveness with an acceptable crew workload, the new generation of NATO fighter aircraft will contain a significant degree of automation and computer support for the crew. One key area of support is computer aided tactics, which help the crewman to assess the complex air battle situation, select appropriate targets, and plan the best method of attack. A microcomputer tactical aid called MITAC is described. By computing a range of possible aircraft and missile flight paths and processing the results through a sequence of tactical flight rules, MITAC can offer the crewman useful advice on recommended attacks and their consequences. *It provides good insight into the* sort of facility that could be available in the next generation of fighter cockpits. Author

N88-20186# McDonnell-Douglas Helicopter Co., Mesa, AZ. Engineering and Training Simulation.
REDUCING ROTARY WING AIRCRAFT DEVELOPMENT TIME/COST THROUGH THE USE OF SIMULATION
S. RAMACHANDRAN, W. E. RICHESON, and D. C. BORGMAN *In* AGARD, Flight Vehicle Development Time and Cost Reduction 8 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Advances in simulation technology have made man-in-the-loop simulation highly capable, desirable and affordable for rotorcraft design and development. Since the use of simulation as a design tool is relatively new to the helicopter industry, the U.S. Army/McDonnell Douglas Helicopter Company AH-64A (Apache) is used as an example to evaluate the potential cost and time savings realizable through the use of simulation. It is shown that a modern full mission engineering simulator when used effectively could provide cost savings of several millions of dollars, and could reduce helicopter development and flight test by at least a year or two. The means to exploit the full potential of simulation during rotorcraft design, development, and test are also discussed. Author

N88-27700# Royal Army Medical Coll., London (England).
CAN CNV AMPLITUDE PREDICT ABILITY TO ACCOMPLISH A DEMANDING TASK?
PETER ABRAHAM *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 2 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

Increased Contingent Negative Variation (CNV) was related to attention, effort, and quick response to stimuli, while decreased

CNV amplitude was related to distraction, delayed reaction times, and disorder of mental or emotional functioning. These observations suggest that CNV amplitude measured in the laboratory might be a useful predictor of an individual's ability to accomplish a demanding sensorimotor task under operational conditions. One such task is the operation of a surface-to-air missile known as Blowpipe. Firing this weapon requires rapid responses to that information, under stressful conditions. It also requires auditory stimuli emanating from the weapon. Thus firing operation is not unlike a CNV-generating situation. The Blowpipe training program afforded an opportunity to test the usefulness of CNV measurement for predicting operational performance as assessed during the firing of real missiles on a testing range. It was hypothesized that low laboratory CNV amplitude would predict unsuccessful Blowpipe firing and vice versa. The CNV amplitude was measured in 75 soldiers engaged in training as missile operators. Sixty-nine subjects completed the qualifying course and fired real missiles. Those who showed poor firing performance had CNV amplitudes at the extremes of the range. Selection strategies are discussed.
Author

N88-27704# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
FIGHTER PILOT PERFORMANCE DURING AIRBORNE AND SIMULATOR MISSIONS: PHYSIOLOGICAL COMPARISONS
JUNE J. SKELLY, BRADLEY PURVIS, and GLENN WILSON *In* AGARD, Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine 16 p (SEE N88-27683 21-51) Feb. 1988
(AGARD-CP-432) Avail: NTIS HC A18/MF A01

The growing importance of simulators for training, research, and certification focuses attention on how little is known about whether the behavioral outcomes obtained in a simulator really represent the operational situation. The research addresses this issue, and proposes that use of physiological measures to examine the correspondence between pilot responses during actual missions and comparable simulated missions. Physiological measures of electrical brain activity, heart rate, and eye movements were taken while pilots flow tactical training missions in both the A-7 aircraft and simulator. These measures did discriminate between: flight position (wing vs lead); actual and simulated flight; type of mission event (e.g., takeoff, maneuvers, weapons delivery), and individual pilots.
Author

N88-27749# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
ENGINEERING DATA COMPENDIUM. HUMAN PERCEPTION AND PERFORMANCE. USER'S GUIDE
KENNETH R. BOFF, ed. and JANET E. LINCOLN, ed. (Dayton Univ., OH) 1988 142 p Prepared in cooperation with NASA, Washington, ASD, Wright-Patterson AFB, OH, Human Engineering Labs., Aberdeen Proving Ground, MD, Human Systems Div., Brooks AFB, TX, Army Research Inst. for the Behavioral and Social Sciences, Alexandria, VA, Naval Training Systems Center, Orlando, FL, Air Force Human Resources Lab., Wright-Patterson AFB, OH, and AGARD, Neuilly-Sur-Seine, France
(LC-87-19560) Avail: NTIS HC A07/MF A01 CSCL 05H

The concept underlying the Engineering Data Compendium was the product of a research and development program (Integrated Perceptual Information for Designers project) aimed at facilitating the application of basic research findings in human performance to the design and military crew systems. The principal objective was to develop a workable strategy for: (1) identifying and distilling information of potential value to system design from the existing research literature, and (2) presenting this technical information in a way that would aid its accessibility, interpretability, and applicability by systems designers. The present four volumes of the Engineering Data Compendium represent the first implementation of this strategy. This is the first volume, the User's Guide, containing a description of the program and instructions for its use.
F.M.R.

N88-28630# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
ENGINEERING DATA COMPENDIUM. HUMAN PERCEPTION AND PERFORMANCE, VOLUME 1
KENNETH R. BOFF, ed. and JANET E. LINCOLN, ed. (Dayton Univ., OH) 1988 923 p Prepared in cooperation with NASA, Washington, ASD, Wright-Patterson AFB, OH, Human Engineering Labs., Aberdeen Proving Ground, MD, Human Systems Div., Brooks AFB, TX, Army Research Inst. for the Behavioral and Social Sciences, Alexandria, VA, Naval Training Systems Center, Orlando, FL, Air Force Human Resources Lab., Wright-Patterson AFB, OH, and AGARD, Neuilly-Sur-Seine, France
(LC-87-19560) Avail: NTIS HC A99/MF E03 CSCL 05H

The concept underlying the Engineering Data Compendium was the product an R and D program (Integrated Perceptual Information for Designers project) aimed at facilitating the application of basic research findings in human performance to the design of military crew systems. The principal objective was to develop a workable strategy for: (1) identifying and distilling information of potential value to system design from existing research literature, and (2) presenting this technical information in a way that would aid its accessibility, interpretability, and applicability by system designers. The present four volumes of the Engineering Data Compendium represent the first implementation of this strategy. This is Volume 1, containg sections on Visual Acquisition of Information, Auditory Acquisition of Information, and Acquisition of Information by Other Senses.
F.M.R.

N88-28631# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
ENGINEERING DATA COMPENDIUM. HUMAN PERCEPTION AND PERFORMANCE, VOLUME 2
KENNETH R. BOFF, ed. and JANET E. LINCOLN, ed. (Dayton Univ., OH) 1988 977 p Prepared in cooperation with NASA, Washington, ASD, Wright-Patterson AFB, OH, Human Engineering Labs., Aberdeen Proving Ground, MD, Human Systems Div., Brooks AFB, TX, Army Research Inst. for the Behavioral and Social Sciences, Alexandria, VA, Naval Training Systems Center, Orlando, FL, Air Force Human Resources Lab., Wright-Patterson AFB, OH, and AGARD, Neuilly-Sur-Seine, France
(LC-87-19560) Avail: NTIS HC A99/MF E04 CSCL 05H

The concept underlying the Engineering Data Compendium was the product of a Research and Development program (Integrated Perceptual Information for Designers project) aimed at facilitating the application of basic research findings in human performance to the design of military crew systems. The principal objective was to develop a workable strategy for: (1) identifying and distilling information of potential value to system design from existing research literature, and (2) presenting this technical information in a way that would aid its accessibility, interpretability, and applicability by system designers. The present volumes of the Engineering Data Compendium represent the first implementation of this strategy. This is Volume 2, which contains sections on Information Storage and Retrieval, Spatial Awareness, Perceptual Organization, and Attention and Allocation of Resources.
F.M.R.

N88-28632# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
ENGINEERING DATA COMPENDIUM. HUMAN PERCEPTION AND PERFORMANCE, VOLUME 3
KENNETH R. BOFF, ed. and JANET E. LINCOLN, ed. (Dayton Univ., OH) 1988 860 p Prepared in cooperation with NASA, Washington, ASD, Wright-Patterson AFB, OH, Human Engineering Labs., Aberdeen Proving Ground, MD, Human Systems Div., Brooks AFB, TX, Army Research Inst. for the Behavioral and Social Sciences, Alexandria, VA, Naval Training Systems Center, Orlando, FL, Air Force Human Resources Lab., Wright-Patterson AFB, OH, and AGARD, Neuilly-Sur-Seine, France
(LC-87-19560) Avail: NTIS HC A99/MF E03 CSCL 05H

The concept underlying the Engineering Data Compendium was the product of a research and development program (Integrated Perceptual Information for Designers project) aimed at facilitating the application of basic research findings in human performance to the design of military crew systems. The principal objective was to develop a workable strategy for: (1) identifying and distilling information of potential value to system design from existing research literature, and (2) presenting this technical information in a way that would aid its accessibility, interpretability, and

applicability by system designers. The present four volumes of the Engineering Data Compendium represent the first implementation of this strategy. This is Volume 3, containing sections on Human Language Processing, Operator Motion Control, Effects of Environmental Stressors, Display Interfaces, and Control Interfaces (Real/Virtual). F.M.R.

N88-29291# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

VISUAL EFFECTS IN THE HIGH PERFORMANCE AIRCRAFT COCKPIT

Apr. 1988 149 p Lectures held in Brussels, Belgium, 28-29 Apr. 1988, in Copenhagen, Denmark, 2-3 May 1988, in Ankara, Turkey, 5-6 May 1988, and in Athens, Greece, 9-10 May 1988 (AGARD-LS-156; ISBN-92-835-0456-9; AD-A199306) Avail: NTIS HC A07/MF A01

Vision is the key sensory mode by which a pilot receives the vast majority of the information required to successfully fly the aircraft and accomplish his mission. Visual information is received both directly (viewing through the windscreen, heads-up display and visor) and indirectly (viewing instruments, graphics displays and imaging displays) in a continuous stream. The ability of the pilot to perceive, assimulate and act on this vast amount of visual information greatly depends on the quality of the presentation of this information. There are many factors that can reduce the effective visual capability of the pilot. Many of these factors are presented and their effect on vision and visual performance are discussed. For individual titles, see N88-29292 through N88-29299.

N88-29292# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).

VISION AND VISUAL PROTECTION IN FAST JET AIRCRAFT

D. H. BRENNAN *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 13 p (SEE N88-29291 23-54) Apr. 1988 (AGARD-LS-156) Avail: NTIS HC A07/MF A01

Aircrew flying fast jets such as the F-16 require high visual standards in order to be able to react quickly to tactical and emergency situations within their environment. The basic visual physiology of importance in flight is discussed together with the visual standards and associated test methods that are necessary for optimum performance. The hazards of solar radiation are reviewed together with suggestions for the optical and spectral quality of visors and corrective eyewear. Author

N88-29293# Royal Danish Air Force, Vojens.

VISUAL RELATED ACCIDENTS/INCIDENTS

L. SIMONSEN *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 8 p (SEE N88-29291 23-54) Apr. 1988 (AGARD-LS-156) Avail: NTIS HC A07/MF A01

Man has evolved as a creature intended to walk on two feet on the surface of the earth, but has acquired the skill to construct machines which enables him to fly. The process has required this basic man to learn, by training, some necessary skills for adapting his sensory systems. This sensory adaptation is rather fragile and will under situations of stress break down and cause accidents or incidents. Based on accidents/incidents, the different break down modes of man's visual sensory system in the high performance aircraft cockpit are discussed. Author

N88-29294# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.

VISION THROUGH AIRCRAFT TRANSPARENCIES

H. LEE TASK *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 14 p (SEE N88-29291 23-54) Apr. 1988 (AGARD-LS-156) Avail: NTIS HC A07/MF A01

The primary purpose is to discuss in detail the optical and visual effects of aircraft transparencies including windscreens, canopies, head-up display (HUD) combiners, and visors. The majority of the paper will treat aircraft windscreens and canopies with primary emphasis on high performance aircraft. Author

N88-29295# Societe pour l'Equipment des Vehicules, Gosselies (Belgium). Service des Essais en Vol.

GENERAL OPERATIONAL AND TRAINING VISUAL CONCERNS

D. AGNEESSENS *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 17 p (SEE N88-29291 23-54) Apr. 1988 Prepared in cooperation with Societe Anonyme Belge de Constructions Aeronautiques, Brussels, Belgium (AGARD-LS-156) Avail: NTIS HC A07/MF A01

After having stated all the requirements for man-machine interface in modern cockpits, taking into account all the operational requirements, and also the physiological and environmental constraints, the emphasis is put on visual displays, more precisely on the heads-up display (HUD). How they are realized, the information which is presented to the pilot and the physiological problems encountered are discussed such as: effects of G and vertigo. For the latter, the most often cited causes of vertigo are studied. New systems are also cited such as Helmet Mounted Display (HMD) or Night Vision Goggles (NVG). Both are still under development. The need for simulators and the physiological problems associated with their use are addressed. Author

N88-29296# Royal Netherlands Air Force, Zeist.

MAINTENANCE OF VISION-RELATED COMPONENTS

J. M. HARTS *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 11 p (SEE N88-29291 23-54) Apr. 1988 (AGARD-LS-156) Avail: NTIS HC A07/MF A01

Visual obtained information is of the highest importance for the pilot to fulfill his mission or in some cases to survive. Though the pilot is offered more and more information by audio-means, for example aircraft-warnings, the eyes of the pilot are his most important source of information. Through maintenance of vision-related components it can be assured that needed information can reach the pilot undamaged. Within the Royal Netherlands Airforce this maintenance encloses mainly cleaning, checking, and replacement of the vision-related component. As part of checking and replacement of the Head-Up Display boresighting is essential to assure a proper mounting, needed for accurate weapon-delivery. Author

N88-29297# Acrospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.

NIGHT LIGHTING AND NIGHT VISION GOGGLE COMPATIBILITY

ALAN R. PINKUS *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 16 p (SEE N88-29291 23-54) Apr. 1988 (AGARD-LS-156) Avail: NTIS HC A07/MF A01

Proper lighting of aircraft instruments, panels, controls, indicators, and displays is essential in high performance aircraft. The lighting must be useable over a large range of ambient conditions; especially during dawn or dusk transitions and at night. It must be uniform, have low glare, and be continuously dimmable to very low luminance levels, so the pilot can become partially dark adapted for good, out-of-the-cockpit vision. Various aspects of cockpit lighting such as intensity levels, contrast, luminance and color uniformity, red versus white versus blue-green general lighting, color coding, and other parameters are discussed. Daytime lighting requirements will be noted throughtout because they are an important part of the overall design of the lighting system. A special area of interest is night vision goggle compatible cockpit lighting. As night missions evolve, night vision goggles (NVGs) are being used with greater frequency. The characteristics and usage of NVGs are overviewed. Methods of achieving night vision goggle compatibility in the cockpit using filtered incandescent lamps, external bezels, floodlighting, light emitting diodes, electroluminescent lamps, microlouver material, and black flight suits are described. Author

N88-29298# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.

DISPLAY SYSTEM IMAGE QUALITY

ALAN R. PINKUS and H. LEE TASK *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 17 p (SEE N88-29291 23-54) Apr. 1988 (AGARD-LS-156) Avail: NTIS HC A07/MF A01

High performance aircraft employ several types of display systems including panel-mounted cathode-ray tube (CRT) displays,

head-up displays (HUDs), and helmet-mounted displays (HMDs). These may be used to produce imagery from onboard sensors or to provide information in a symbolic format. There are a number of parameters that are used to characterize these displays such as resolution, contrast ratio, luminance, number of gray shades, line rate, interlace ratio, bandwidth, and modulation transfer functions. In the case of the HUDs and HMDs, there are other parameters that further describe the display such as distortion, transmittance, field of view, exit pupil diameter, vergence, and field curvature. These systems, the measurement of various parameters, and how they affect the quality of the display system are described. In addition, methods will be presented that combine the display parameters with human visual system characteristics to produce image quality metrics that are related to operator performance. Author

N88-29299# Societe pour l'Equipment des Vehicules, Gosselies (Belgium).
FUTURE VISUAL ENVIRONMENT AND CONCERNS
D. AGNEESSENS *In* AGARD, Visual Effects in the High Performance Aircraft Cockpit 14 p (SEE N88-29291 23-54) Apr. 1988 Prepared in cooperation with Societe Anonyme Belge de Constructions Aeronaugiques, Brussels, Belgium
(AGARD-LS-156) Avail: NTIS HC A07/MF A01

Visual displays play an important role in the cockpit, where the information coming from various sensors is presented to the aircrew, after processing by computers. A classification of the displays is done, considering the needs in modern cockpit architecture, where different systems are possible according to the mission envisaged. For daylight operations, HMD/S or FLIR systems are considered, with their advantages but also their shortcomings and limitations. For night operations, NVG, LLLTV, or FLIR systems are assessed, and the current problems discussed. The protection of the eyes of the aircrew against intense sources of light, such as laser or nuclear flash, is also considered briefly. Author

N88-29736# Systems Technology, Inc., Hawthorne, CA.
PILOT MODELING
DUANE T. MCRUER *In* AGARD, Advances in Flying Qualities 30 p (SEE N88-29735 24-01) May 1988
(AGARD-LS-157) Avail: NTIS HC A09/MF A01

A description is presented of pilot control behavior in general. The essential features of pilot dynamics are emphasized for closed loop control of an aircraft. The crossover model is presented as the simplest and most useful model for the majority of flying qualities analyses. Two models are developed in some detail: a structural isomorphic form which accounts for some human subsystems as well as the total input output behavior; and an algorithmic optimal control model which attempts to mimic the pilot's total response only. Both full and divided attention conditions are treated. Author

N88-29737# Systems Technology, Inc., Hawthorne, CA.
PILOT MODELING APPLICATIONS
IRVING L. ASHKENAS *In* AGARD, Advances in Flying Qualities 38 p (SEE N88-29735 24-01) May 1988
(AGARD-LS-157) Avail: NTIS HC A09/MF A01

The role of pilot opinion and rating in defining flying qualities, and the pilot adapted control behavior that impinges on such ratings are delineated and discussed. This is preparatory to the exemplary application of frequency domain pilot models to the examination and elucidation of a variety of flying qualities situations. This examination starts with single loop situations which progress in complexity; and then shifts to multiple loop cases, which also progress in complexity. This succession is designed to increasingly reveal the basic pilot centered requirements for good flying qualities. Such requirements, which stem from easily achieved pilot adaption and good resulting closed loop responses, are more generally applicable to new unknown situations than are classical requirements on the open loop controlled element dynamic parameters. However, the latter do in fact influence the ease of piloted closure and the resulting closed loop responses so, when properly expressed in terms of characteristics in the projected crossover frequency region, may also achieve a degree of generality. The pilot centered requirements illustrated by the examples are collected and briefly discussed. Author

N88-29741# Pisa Univ. (Italy). Dipartimento di Ingegneria Aerospaziale.
THE OPTIMAL CONTROL PILOT MODEL AND APPLICATIONS
MARIO INNOCENTI *In* AGARD, Advances in Flying Qualities 17 p (SEE N88-29735 24-01) May 1988
(AGARD-LS-157) Avail: NTIS HC A09/MF A01

The modeling of the human pilot behavior plays an important role in the preliminary analysis of aircraft handling qualities. This is especially true when the designer is confronted with nonconventional aircraft dynamics, tasks and/or lack of sufficient handling qualities data base. One modeling technique is reviewed which was developed in the early 1970's and has been widely used since then: the optimal control model of the human pilot. The model has been validated in a number of tasks and used in the analysis as well as the synthesis of manual control loops. The capabilities of the model are evaluated in the pilot rating prediction, in the analysis and in the synthesis of pilot/vehicle control loops from the handling qualities standpoint. Author

N89-18009# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.
THE MAN-MACHINE INTERFACE IN TACTICAL AIRCRAFT DESIGN AND COMBAT AUTOMATION
Jul. 1988 296 p In ENGLISH and FRENCH Symposium held in Stuttgart, Fed. Republic of Germany, 28 Sep. - 1 Oct. 1987
(AGARD-CP-425; ISBN-92-835-0471-2) Avail: NTIS HC A13/MF A01

Twenty-six unclassified papers of the 31 given at the symposium are presented. The papers were presented under the following headings: Combat scenarios and mission segment requirements; Human capabilities and limitations; Technological capabilities and limitations concerning situations awareness; Technological capabilities and limitations of combat automation; Crew station implementation, and System integration. For individual titles, see N89-18010 through N89-18034.

N89-18010# Test Wing (6510th), Edwards AFB, CA.
MISSION PLANNING AND PROPER DESIGN: THE LONG RANGE CONNECTION
GARY W. MATTHES *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 4 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Mission planning in tactical fighter operations is as important today as it was in any tactical operations of the past. The mission planner's task, whether performed by a pilot or a system operator, can be made easier and less susceptible to errors if designers understand the planners task and design to both move the workload to the planning room and minimize planning by proper choice of operational modes and aircraft sensors. There is a special connection between planning requirements and the design of the avionics suite to include its cockpit layout in a tactical fighter. However, this relationship should not be a simple function: i.e., cockpit workload should not decrease at the expense of ever increasing preflight workload. The move should always be to design cockpits and avionics that move as many functions as possible to the preflight planning room thus easing the pilots inflight duties and allowing him to focus on flying the craft and keeping abreast of the tactical situation. One man's opinion is presented of the importance of mission planning, now and in the future. This opinion was formed over 22 years of flying a wide variety of tactical fighters. Author

N89-18011# Defence Medical Services Directorate, London (England).
HUMAN LIMITATIONS IN FLIGHT AND SOME POSSIBLE REMEDIES
D. C. READER *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 8 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The biodynamic effects of high speed flight can produce sudden loss of consciousness without warning whereas most aircrew are used to the prodromal loss of vision. New advances in the anti G systems design can improve G tolerance but training is foreseen as the short term answer to this problem. Amongst the environmental stresses that limit performance are thermal, vibration,

noise and NBC defence. Personal conditioning is of benefit under high thermal stress, active noise reduction can limit the reduction of noise at the ear and NBC defensive ensembles protect againt NBC agents. The design of the man machine interface can both enhance and detract from crew performance in flight. Head up displays, night goggles, helmet mounted displays, computer graphics, digital maps and integrated sensor displays can be viewed as new features which greatly increase mission capability. Finally, cockpit and system automation offers the chance of significant advances in cockpit design as management tasks can be completely relegated to the electronic crew member, leaving the human as the ultimate decision maker involved only when absolutely necessary. Author

N89-18012# School of Aerospace Medicine, Brooks AFB, TX.
THE PILOT IS NOT THE LIMITING FACTOR IN HIGH PERFORMANCE AIRCRAFT
R. R. BURTON and W. C. ALEXANDER *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 10 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The physiologic requirements to validate a +G sub z tolerance model based on arterial pressure (Pa), eye-heart vertical distance (h), and hydrostatic pressure (P sub H) are investigated. Venous return (VR) and intrathoracic pressure (P sub I) are considered the major physiologic parameters involved in supporting this model at levels above 9 G. Venous return was determined to be adequate to support Pa during either relaxed lower level G tolerance or high sustained G. Some concern exists regarding VR during long duration G exposures, because of the delayed compliant nature of veins. P sub I, the physiologic basis for the anti G straining maneuver (AGSM), was found to be a function of inspiratory volume (V sub I); and therefore, as the subject is reclined to reduce h, the reduction in V sub I prevents a maximum AGSM limiting tolerance to 15 G. On the other hand, pilot pronation may not limit V sub I, and higher G tolerance may be possible. Fatigue was recognized as an important dimension of G tolerance and, as such, was examined as a limiting physiologic function at high sustained G. Primarily, because of the functional coupling between G-level and G-duration tolerances, if one is not G tolerance limiting, neither is the other. Author

N89-18013# British Aerospace Public Ltd. Co., Bristol (England).
A MODEL TO PREDICT VISUAL PERFORMANCE AT THE MAN-DISPLAY INTERFACE IN THE COCKPIT
DIANA F. JOHNSON *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 8 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Some of the problems are summarized which are typically encountered when viewing displays in the military cockpit. It is suggested that design and development of display configurations can be made quicker, cheaper, and more effective than present methods by using mathematical models of the man display interface to predict visual performance. The requirements for such models are discussed. A state of the art model which was developed at British Aerospace is reviewed. The model comprises spectral manipulation routines to calculate how the emission spectrum from a display is modified before reaching the eye, together with a psychophysical vision model which provides an objective measure of visibility. The benefits of using such a model are described. Finally, suggestions are made for future work to extend the present models. Author

N89-18014# Air Force Flight Test Center, Edwards AFB, CA.
PILOT WORKLOAD ASSESSMENT: A FLIGHT TEST APPROACH
REGINA M. PAPA and JANICE R. STOLIKER *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 12 p (SEE N89-18009 10-54) Jul. 1988 Previously announced in IAA as A88-38716
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The present methodology for the assessment of the pilot workload effects of integration between a fighter aircraft and a specialized sensor augmentation system, with a view to the question of single seat cockpit effectiveness is described. It also allows the collection of subjective data pertinent to issues of cockpit controls and displays, situational awareness, task complexity, surviability, and safety. Two different subjective workload metrics (supplemented by structured interviews) are used: the subjective workload assessment technique, and a modified Cooper-Harper type scale tailored for this application through the inclusion of a performance factor. E.R.

N89-18015# National Aerospace Lab., Amsterdam (Netherlands).
CONSIDERATIONS CONCERNING THE ASSESSMENT OF PILOT WORKLOAD FOR COMPLEX TASK CONDITIONS
R. C. VANDEGRAAFF *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 15 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Workload research has led to the development of various measures, mostly concerning difference aspects of task workload. A number of ways concerning the problem of being able to draw conclusions from a variety of experimental measures in a complex task situation are discussed. Several implications are pointed out, such as the problem of dealing with contradictory outcomes, the designating of artefacts, and the problem of formulating final conclusions without the availability of a superior method for evaluating other methods. These considerations were examined in detail in an inflight study concerning the assessment of pilot workload under various instrument approach conditions. The findings are compared with the results of a former inflight experiment dealing with pilot workload. A discussion is given of the results consisting of subjective ratings, physiological measures, and task performance measures. A strategy is discussed dealing with the formulation of final conclusions. Author

N89-18016# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
ADVANCES IN WORKLOAD MEASUREMENT FOR COCKPIT DESIGN EVALUATION
MARIS M. VIKMANIS *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 10 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The stressful mission environment for tactical aircraft in the 1990's will require improved integration of pilot and machine to assure successful operations. Research has focused on the development of quantitative pilot performance and workload measures. Improved methods for defining pilot functions, tasks, and performance variables were developed along with test design and data analysis techniques to support cockpit evaluations. Significant advances in the measurement of workload were made using subjective and neurophysiological techniques. Research on measures of pilot situation awareness and decision making, critical toward understanding the pilot interface with automated systems, is underway. The approach has been to establish a solid base of lab research followed by the test and evaluation of measurement techniques in complex flight simulators and then actual flight experiments. Author

N89-18017# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Group.
MODING STRATEGY FOR COCKPIT DATA MANAGEMENT IN MODERN FIGHTER AIRCRAFT
R. SEIFERT and H. NEUJAHR *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 8 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

A method for moding strategy of cockpit data management in fighter aircraft has been extended to include assessment of access time allowed for information elements and control and differentiation of the mission tasks according to demand type (importance, frequency of use). This method developed so far renders the operational requirement for the cockpit moding. The steps of specifying the cockpit moding are as yet not so well defined. That is why the term moding strategy is used instead of method in the title. The method of deriving the operational requirements and the subsequent tasks to be performed within the process of cockpit moding are examined. The design driving mission is not detailed. The criteria applicable to define and breakdown missions in different scenarios are dealt with elsewhere. Author

N89-18018# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Sistemi Avionici ed Equipaggiamenti.
A MAN-MACHINE INTERFACE SOLUTION: THE EAP GLARE SHIELDS
LUIGINO BONETTO and GIANFRANCO TERRANDO *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 9 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Continuous improvements in capabilities of military aircrafts require sophisticated navigation, communication and weapon systems. In the mean time pilots are required to interact with these systems by using data entry facilities or synthetic data displays. Control panels using traditional push buttons with fixed legend cannot be flexible enough to meet these new requirements. An original solution is presented to control the systems through an integrated alphanumeric keyboard facility using custom push botton matrix with programmable LED display legend. Design and development activities were carried out; two pieces of equipment named LEFT and RIGHT GLARE SHIELDS are now operational on the EAP demonstrator. Author

N89-18019# Air Force Avionics Lab., Wright-Patterson AFB, OH.
PANORAMIC COCKPIT CONTROL AND DISPLAY SYSTEM (PCCADS)
N. SCHWARTZ and EUGENE ADAM (McDonnell Aircraft Co., St. Louis, MO.) *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 10 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

A real time, pilot interactive demonstration and test of a large area fighter cockpit display was conducted. The test of this large area, full color display was conducted in a mock-up cockpit at a simulation facility. This display used essentially the entire instrument panel area to present a moving map with symbology and other information overlain and also presented sensor imagery and other information as required. The information presented could be customized for a particular mission phase or other need. A touch sensitive display as well as other advanced control concepts were also demonstrated in conjunction with the large area display. This display and control concept simplifies and automates many of the control and display functions for the pilot of an advanced fighter aircraft. The results of demonstration and testing with ten pilots are presented. Author

N89-18020# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
MULTISENSOR TARGET RECONNAISSANCE
G. BAUER *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 5 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

An example of the concept of a knowledge based sensor fusion system is presented, which combines a radar primary sensor with an IR secondary sensor. The radar's wide range of view is used for Target Recognition over a large area, while the IR sensor's high resolution at a small angle of aperture is employed for target classification. Author

N89-18021# Centre d'Enseignement et de Recherches de Medecine Aeronautique, Paris (France).
PILOTS AS SUPERVISORS AND MANAGERS OF AUTOMATIC SYSTEMS: A RISKY NEW FACTOR IN MAN-MACHINE SYSTEMS RELIABILITY [PILOTES SUPERVISEURS ET GESTIONNAIRES DE SYSTEMES AUTOMATIQUES UN NOUVEAU ROLE BIEN RISQUE POUR LA FIABILITE DU COUPLE HOMME-MACHINE]
R. AMALBERTI *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 8 p (SEE N89-18009 10-54) Jul. 1988 In FRENCH
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The evolution of the man-machine task related to automized airborne systems is discussed. Cognitive functioning in control processes, information acquisition, and modifications of pilot tasks are addressed. Author

N89-18022# Dassault-Breguet Aviation, Saint Cloud (France).
EXPERT SYSTEM MAN-MACHINE INTERFACE FOR A COMBAT AIRCRAFT COCKPIT
JEAN SAULAIS and PIERRE LARROQUE *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 7 p (SEE N89-18009 10-54) Jul. 1988 In FRENCH; ENGLISH summary
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Through developing navigation and attack systems on combat aircraft and by analyzing the new operational concepts, an ever increasing workload is required from the pilot. An important part of the workload lies in getting the management information to the pilot. In case of very low level flying, getting this information becomes especially tight; the pilot cannot divert his attention from outside the cockpit to watch over the vehicle and its systems. For this reason, modern fighter cockpit are already oriented toward using head-up terminals for displaying built-up information. Enhancements were made on displays in order to increase the capacity of collimated data. In addition, synthetic voice warnings are already used and day after day, the pace of speech processing is increasing. Expert systems are being studied for the purpose of operating at two levels, depending both on its importance with respect to the mission and on the workload inferred by the expert system in the different steps of the mission. Author

N89-18023# Centre d'Essais en Vol, Istres (France).
LESSONS LEARNED FROM THE USE OF NEW COMMAND SYSTEMS [ENSEIGNEMENTS TIRES DE LUTILISATION DE NOUVEAUX SYSTEMES DE COMMANDE]
JACQUES ROSAY *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 7 p (SEE N89-18009 10-54) Jul. 1988 In FRENCH
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The general informatization of combat aircraft has allowed the introduction of radically new cabin architectures and command systems. In these new interfaces, the information that is exchanged between the pilot and machine can undergo processing and take on various forms. The range of possibilities for these processing techniques and forms is vitually limitless. Experiences in the use of certain system elements -- screens, control boards, voice command systems, and ergonomically adapted displays are discussed along with various physical and mental human-factors considerations. Author

N89-18024# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Visual Display Systems Branch.
DESIGN CONSIDERATIONS FOR VIRTUAL PANORAMIC DISPLAY (VPD) HELMET SYSTEMS
DEAN F. KOCIAN *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 32 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Some of the fundamental performance and design parameters that should be considered for the successful evolution and integration of a new type of helmet mounted display (HMD) system intended for use in the military aircraft cockpits are described. It is called a virtual panoramic display (VPD). The parameters discussed include field-of-view, exit pupil, image quality, eye relief, collimation, alignment, size, weight, system integration, etc. For the first time the associated helmet system is considered as an integral subsystem that must be designed to support the requirements of the HMD. Trade-offs relating to the intended VPD applications, HMD design and its impact on the associated image source and display electronics are discussed. Design issues and considerations are developed primarily from the viewpoint of the VPD system integrator. Author

N89-18025# British Aerospace Aircraft Group, Preston (England). Military Aircraft Division.
TOWARDS THE NEXT GENERATION FIGHTER COCKPIT: THE EAP EXPERIENCE
KATHARINE M. WYKES and MAURIZIO SPINONI (Aeritalia S.p.A., Turin, Italy) *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 18 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The main design is outlined of the cockpit of the Experimental Aircraft Program (EAP) aircraft. The structured design process that

was followed is described. The main features of the resulting cockpit are outlined, together with some of the rationale behind their design. These include: (1) Display moding: how the format hierarchy is managed, how the formats were constructed and how color has been used on the displays; (2) The hands on throttle and stick concept and how this applies to the EAP; (3) A manual data entry facility capable of controlling ten different subsystems through totally multifunction devices; and (4) An intelligent warning system based on the use of a digitized voice. These facilities have been flying for over a year now and the experience gained during their design and subsequent flight testing is helping to form the basis for the European Fighter Aircraft cockpit design. Author

N89-18026# . British Aerospace Public Ltd. Co., Brough (England).
PILOT INTEGRATION AND THE IMPLICATIONS ON THE DESIGN OF ADVANCED COCKPITS
R. S. KALAWSKY *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 16 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

A totally enclosed cockpit may quickly become the driving factor for the next generation of tactical fighter aircraft and will deny access to the pilot of essential outside world cues. Also, the number of sensory systems carried aboard the aircraft is inceasing, with the threat of unacceptable pilot workload. Pilot and aircraft reaction times may be a decisive factor in any conflict situation in the future, so the pilot must have a greater situation awareness than ever before. The future cockpit designer must have a greater appreciation and awareness of the human factors related issues, and tailor system performance to match human performance limits. The cockpit situation is assessed and how the pilot can be successfully integrated with newly emerging technologies to overcome the problems introduced by a closed cockpit philosophy and increased workload is examined. An insight into one possible cockpit solution is studied. Author

N89-18027# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
PILOT CONTROL DEVICES
W. FUCHS, R. KODWEISS, and M. WEIDEL *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 13 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Advanced cockpit design requires geometry improvements to accommodate greater pilot percentile ranges, to reduce pilot fatigue and discomfort, to increase G-load resistance and to allow a different ejection path. Simulator trials were performed to optimize the installation positions of control devices for different seat angles, the control parameters including gain and force gradients as well as the use of force and displacement signals. The simulator results will be scaled down for inflight use. Adaptive gain shaping and a reduction of control force using higher controller damping were tested. A method for reducing the risk of loss of consciousness and means to increase pilot efficiency is discussed. Author

N89-18028# Technische Hogeschool, Delft (Netherlands). Faculty of Aerospace Engineering.
ACTIVE AND PASSIVE SIDE STICK CONTROLLERS: TRACKING TASK PERFORMANCE AND PILOT CONTROL BEHAVIOUR
R. J. A. W. HOSMAN and J. C. VANDERVAART *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 11 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

A servo controlled side stick featuring hydraulic actuators with hydrostatic bearings was developed. Due to its smooth operation, low noise characteristics and high bandwidth, a great variety of dynamic characteristics can be simulated. This research tool can very conveniently be used as a conventional passive stick to assess the desired side stick dynamics for future fly by wire aircraft. Still more important is that with a servo controlled side stick, stick force and stick displacement can be controlled virtually independent. This feature can be used for experimental research to investigate the perception and feedback of stick force and stick displacement by the pilot's neuromuscular system in the control task. After a short description of the side stick controller hardware, results of a tracking experiment in a moving base flight simulator is presented. Considerable improvement in tracking performance and significant changes of measured pilot control behavior were found for the active when conpared to the passive control stick. Author

N89-18029# National Research Council of Canada, Ottawa (Ontario). Flight Research Lab.
THE USE OF INTEGRATED SIDE-ARM CONTROLLERS IN HELICOPTERS
J. M. MORGAN and S. R. M. SINCLAIR *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 11 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Research conducted with integrated side stick controllers in a variable stability helicopter is reviewed. The investigations involve the use of three different types of controllers. The advantages and disadvantages of integrated controllers are discussed and an informed opinion of their applicability is presented. Finally, data acquired during a succession of piloted experiments, indicating that Level 1 handling qualities are achievable with these types of controllers, are summarized. Author

N89-18030# Boeing Helicopter Co., Philadelphia, PA.
ADVANCED FLIGHT CONTROL SYSTEM FOR NAP-OF-THE-EARTH FLIGHT
STEVEN I. GLUSMAN, CHARLES DABUNDO, and KENNETH H. LANDIS *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 15 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

A digital/optical flight control system was implemented on a UH-60 Black Hawk helicopter to determine flight control system requirements for Nap-of-the-Earth (NOE) flight. Small-displacement side stick controllers with unique force trim positions were an integral part of the control system design. Controller configurations could be readily altered from a fully integrated 4-axis side stick controller to separated controller and configurations including (3 + 1) collective and (2 + 1 + 1). Control laws were implemented with a model following architecture that facilitates variation of control resp' ' characteristics. The Automatic Flight Control System was ' gned to provide level 1 handling qualities and the Primary Flight Control System was implemented to achieve level 2 handling qualities. The interrelational effects of controller configuration and piloting task on handling qualities was investigated. Handling qualities were evaluated using precision hover and low speed tasks typical of NOE flights as well as tasks performed at airspeeds from 80 to 120 knots. Piloted results are presented with recommendations for future systems. Author

N89-18031# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
MATCHING CREW SYSTEM SPECIFICATIONS TO HUMAN PERFORMANCE CAPABILITIES
KENNETH R. BOFF *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 9 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Despite spectacular advances in display systems and data handling technologies, modern crew systems confront their operators with a large volume of codified information which competes for scarce attentional and control resources. Achieving an optimal fit between system capabilities and the perceptual and performance characteristics of the operator requires the presence of at least three elements: (1) Usable data resources, human performance data; (2) An effective interface providing methods and media to support accession and evaluation of these data, and (3) Sophisticated and Motivated users. Designing for active presence of these elements requires understanding of and assumes some ability to influence individual, organizational and regulatory variables that jointly support the design and acquisition processes. Author

N89-18032# Aerospace Medical Research Labs., Wright-Patterson AFB, OH.
INTEGRATED CONTROL AND AVIONICS FOR AIR SUPERIORITY
JAMES A. KOCHER *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 7 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The Integrated Control and Avionics for Air Superiority (ICAAS) Program is a program to develop, design, and demonstrate selected fighter aircraft technologies needed to kill and survive when outnumbered in air combat engagements. Design emphasis is placed upon functional integration of sensors, fire control, flight control, weapons and interface with the pilot to achieve improved close-in combat. Details of the ICAAS concept and design approach are presented. Author

N89-18033# Air Force Flight Test Center, Edwards AFB, CA.
AFTI/F-16 IMPACT OF COCKPIT AUTOMATION ON PILOT ACCEPTANCE
MARK A. STUBBEN *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 10 p (SEE N89-18009 10-54) Jul. 1988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

The Advanced Fighter Technology Integration (AFTI) F-16 Joint Test Force recently completed a developmental flight test program investigating a fully automated weapons delivery system. The F-16 boasted an impressive array of automatic systems that increased the effectiveness of both the pilot and airframe as an overall weapon system. The highly modified F-16 testbed was fitted with a digital flight control system, a conformally mounted infrared sensor/laser ranging pod, integrated fire/flight control computers, a digital color moving map, and a voice recognition system. The AFTI/F-16 integrated these sensors, avionics, and flight control systems into an Automated Maneuvering and Attack System (AMAS), capable of full authority automatic air to surface weapons delivery with profiles down to 200 ft above ground level. Test results of the developmental flight test program are presented and an assessment is provided of the individual AMAS subsystems on the overall workload of the pilot and the pilot acceptance of a fully automated weapons delivery system. Author

N89-18034# Army Aviation Systems Command, Moffett Field, CA. Aeroflightdynamics Directorate.
ADVANCED HELICOPTER COCKPIT AND CONTROL CONFIGURATIONS FOR HELICOPTER COMBAT MISSION TASKS
LORAN A. HAWORTH, ADOLPH ATENCIO, JR., COURTLAND BIVENS, ROBERT SHIVELY, and DANIEL DELGADO *In* AGARD, The Man-Machine Interface in Tactical Aircraft Design and Combat Automation 16 p (SEE N89-18009 10-54) Jul. 1988 Previously announced as N88-14988
(AGARD-CP-425) Avail: NTIS HC A13/MF A01

Two piloted simulations were conducted by the U.S. Army Aeroflightdynamics Directorate to evaluate workload and helicopter-handling qualities requirements for single pilot operation in a combat Nap-of-the-Earth environment. The single pilot advanced cockpit engineering simulation (SPACES) investigations were performed on the NASA Ames Vertical Motion Simulator, using the Advanced Digital Optical Control System control laws and an advanced concepts glass cockpit. The first simulation (SPACES I) compared single pilot to dual crewmember operation for the same flight tasks to determine differences between dual and single ratings, and to discover which control laws enabled adequate and single pilot helicopter operation. The SPACES II simulation concentrated on single pilot operations and use of control laws thought to be viable candidates for single pilot operations workload. Measures detected significant differences between single pilot task segments. Control system configurations were task dependent, demonstrating a need for inflight reconfigurable control system to match the optimal control system with the required task Author

N89-18440# Volkswagen A.G., Wolfsburg (Germany, F.R.) Research and Development Div.
REQUIREMENTS AND CRITERIA FOR THE PASSIVE SAFETY OF AUTOMOBILES
R. WEISSNER *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 6 p (SEE N89-18421 11-03) Dec. 1988
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

Success was achieved in the last 17 years in increasing traffic safety. The number of people killed has dropped dramatically despite a considerable increase in the number of vehicles involved. The passive safety requirements imposed on passenger vehicles and the technical concepts designed to satisfy these requirements, are examined. The interpretation of the functions leads to the definition of the basic demands to be made of an occupant restraint systems. Use can be made, for example, of belt force limiters to reduce the forces acting on the occupant during the restraint process. A belt lock-up or belt pre-tensioners can be used to limit the throw-forward distance. Numerous measures have to be taken to make a restraint system comfortable. Belt height adjustment, for example, provides an individual adaptation of belt position. An important safety feature is the seat plus head restraint. The seat has a considerable influence on the effectiveness of the entire system both in the event of a head-on collision and in the case of a rear end collision. If it is assumed that there is good correlation between the load values measured with dummies and the real risk of injury for a person involved in an accident, the possible benefit of any safety measure can be forecast. The efforts to improve passive safety must also include cyclists, motor cyclists, and pedestrians. It is hoped that the number of people who sustain serious injuries or even lose their lives as a result of a traffic accident will continue to drop in the future. This goal will be attained if all those involved sustain their efforts to increase road traffic safety. Author

N89-18442# Centre d'Essais en Vol, Bretigny-sur-Orge (France) Lab. de Medecine Aerospatiale.
DESIGN AND SIMULATED-CRASH VALIDATION OF A DYNAMIC RESPONSE RECORDER [CONCEPTION D'UN ENREGISTREUR DE GRANDEURS DYNAMIQUES ET VALIDAITON AU COURS D'UN CRASH SIMULE]
J. M. CLERE, D. LEBRUN, J. DOBUA, and J. L. POIRIER *In* AGARD, Energy Absorption of Aircraft Structures as an Aspect of Crashworthiness 7 p (SEE N89-18421 11-03) Dec. 1988 In FRENCH
(AGARD-CP-443) Avail: NTIS HC A15/MF A01

A small lightweight instrument was developed to record the degree of acceleration experienced by an anthropomorphic manikin during an aircraft crash, with application to the study of the aircraft/seat/occupant interaction. Upon impact, the device automatically records data from the nine locations for a period of six seconds. The performance of the present instrument was experimentally validated during the dropping of a DC-10 fuselage from a height of 6 m. M.G.

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COMPUTER OPERATIONS AND HARDWARE

Includes hardware for computer graphics, firmware, and data processing

N87-19920# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
THE APPLICATION OF MICROCOMPUTERS TO AEROSPACE AND DEFENCE SCIENTIFIC AND TECHNICAL INFORMATION WORK
Oct. 1986 119 p Lecture series held in London, England, 16-17 Oct. 1986, in Ankara, Turkey, 20-21 Oct. 1986 and in Rome, Italy, 23-24 Oct. 1986
(AGARD-LS-149; ISBN-92-835-1538-2; AD-A173314) Avail: NTIS HC A06/MF A01

In 1978 the theme of Lecture Series 92 was the opportunity offered in automation of library and information services by cheaper

faster minicomputer equipment, and new database and applications software. Speakers addressed the feasibility of automation; the techniques for the necessary systems studies; and cost effectiveness in units of tens of man years of programming and equipment costing 100,000 or more. There is now a radical change in what an information specialist may reasonably expect, due largely to the development of the low cost, reliable, general purpose microcomputer. The speakers in this lecture series report the growing role of the microcomputer in cataloguing and library housekeeping; in accessing shared information resources through local and wide networks; and in new approaches to information management and retrieval. For individual titles see N87-19921 through N87-19929.

N87-19921# Strathclyde Univ., Glasgow (Scotland). Dept. of Information Science.
APPLICATIONS IN LIBRARY MANAGEMENT, REQUISITIONS, LOANS AND STOCK CONTROL
PAUL F. BURTON *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 5 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

Applications of the microcomputer in library management, requisitions, loans and stock control are discussed. That the microcomputer has provided numerous libraries and information services (LIS) with an opportunity to automate routines which were previously denied to them because of their size and (usually) their lack of funding, has now achieved the status of a cliche. Plummeting costs of hardware coupled with increasing sophistication and power of software (albeit at increased prices) mean that all but the smallest LIS can now contemplate automation of most routines, including that cluster of applications which is referred to as housekeeping. Indeed, it could be said that these smaller LIS are most able to benefit from computer-based automation, since they are being faced with increasing demands upon their services, demands which have to be met with low (and sometimes reducing) staffing levels. Despite this, the take-up rate of microcomputers has not been high, though there are signs that it is increasing steadily. This can be explained in part by the restrictions of funding which these LIS have faced (in common with all others), but it has to be said that there remains a certain lack of awareness among some LIS managers. Growing number of LIS managers are implementing microcomputers for house-keeping applications, including management tasks, acquisitions, circulation control and aspects of stock management. Author

N87-19929# Strathclyde Univ., Glasgow (Scotland). Dept. of Information Science.
PROCUREMENT AND MANAGEMENT OF MICROCOMPUTER-BASED SYSTEMS
PAUL F. BURTON *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 6 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

Microcomputer-based systems appear to offer an inexpensive approach to library and information system automation. However, to be effective, efficient and cost-effective, it is still necessary to apply some well-established principles to the specification and procurement of micro-based systems. The procurement process, some of the difficulties associated with micro systems, and the difficulties of finding suitable software are discussed. Once installed, a micro-computer system can provide a number of management problems, caused, not least, by the inexperience of operators and the direct impact of the systems (as compared with large systems, which are often supported and operated by qualified personnel). Author

N87-24948# Naval Air Development Center, Warminster, PA.
MACHINE ARCHITECTURES FOR ARTIFICIAL INTELLIGENCE COMPUTING
RAYMOND P. KIRSCH and CHRISTOF H. HEITHECKER *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 11 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

Alternatives to the von Neumann architectural model are under study by members of the advanced computer architecture community. Recent developments in multiprocessor technology can be shown to provide performance speed increases in the execution of expert systems. Several of these efforts are followed closely and are assessed. Author

N87-29520# Naval Ocean Systems Center, San Diego, CA.
RAPID PROTOTYPING OF USER-COMPUTER INTERFACES DURING SYSTEM DESIGN
G. A. OSGA *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 10 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Rapid Prototyping is a process of creating a simulation of a user interface to a completed computer system, early in the design process, before the underlying or application software is developed. This process allows the presentation of display formats and system procedures to users early in the design process, allowing for behavioral data collection and numerous iterations in the user computer interface (UCI) design. The development and use of rapid prototyping software in an expert system development project is discussed. The user interface is a high resolution screen with multiple windows, using a mouse as the primary input device. A design procedure for an interface to an expert system is discussed which includes: (1) an Interface Design Tool, (2) an interface design checklist, and (3) the collection of and analysis of behavioral data during interface testing. Author

N88-10797# Centre National de la Recherche Scientifique, Toulouse (France).
COMPUTING SYSTEMS DEPENDABILITY AND FAULT TOLERANCE: BASIC CONCEPTS AND TERMINOLOGY
J. C. LAPRIE *In* AGARD, Fault Tolerant Considerations and Methods for Guidance and Control Systems 15 p (SEE N88-10796 02-08) Jul. 1987
(AGARD-AG-289) Avail: NTIS HC A07/MF A01

Provided is a conceptual framework for expressing the constituents of dependable computing, i.e., the impairments to dependability: faults, errors and failures, the means for dependability: fault avoidance, fault tolerance, fault removal, and fault forecasting; the measures of dependability: reliability and availability. Emphasis is placed on the dependability impairments and on fault tolerance. Informal but precise definitions are given. Author

N89-10833# Electronique Serge Dassault, Saint Cloud (France).
A HIGHLY RELIABLE COMPUTER FOR AIRBORNE APPLICATIONS
MICHEL MUENIER *In* AGARD, Computing Systems Configuration for Highly Integrated Guidance and Control Systems 17 p (SEE N89-10831 02-01) Jun. 1988
(AGARD-LS-158) Avail: NTIS HC A08/MF A01

The reliability features of the CMF (French Military Computer) AIR embedded computer supporting its operational software are described. This computer was designed to meet the requirements of the ACE (European Combat Aircraft)/RAFALE D aircraft. Therefore, it has to be highly dependable to satisfy severe physical requirements (size, weight, power consumption, etc.) and to support real-time software execution (this software being written in high-level languages such as Ada and LTR3, a French Pascal-like real-time language). The general structure of the computer is first presented, emphasis being placed on the technological choices (for example, the use of ASICs: Application Specific Integrated Circuits). The various protective mechanisms provided at the level of the machine (hardware and microcode) are then presented: data access control and code execution control. Finally, a short presentation of the software production environment is given. In conclusion, the compromise made between operational dependability and performance characteristics are summarized. Author

N89-10837# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH. Avionics Lab.
HIGH SPEED PARALLEL PROCESSING NETWORKS FOR ADVANCED ARCHITECTURES
D. REED MORGAN *In* AGARD, Computing Systems Configuration for Highly Integrated Guidance and Control Systems 17 p (SEE N89-10831 02-01) Jun. 1988
(AGARD-LS-158) Avail: NTIS HC A08/MF A01

Many force multiplier improvements in vehicle control, situation awareness and crew decision aiding will be made possible if affordable, flyable supercomputers and associated software can be developed for next-generation military aircraft. New functional architectures will emerge because dramatic improvements in processing speed can be implemented through tightly coupled networks. Unconstrained system architectures can be developed where the system designer will have the capability to fuse together needed logical functions irrespective of previous boundaries. In addition, increased local processing (e.g., smart sensors) will be made possible to improve threat and target classification. Robust use of real-time artificial intelligence at both local, functional and system levels will be achievable, along with improvements in fault tolerance and system diagnostics. Author

N89-11395# *Advisory Group for Aerospace Research and* Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
COMPUTATIONAL FLUID DYNAMICS: ALGORITHMS AND SUPERCOMPUTERS
WOLFGANG GENTZSCH, KEN W. NEVES, and H. YOSHIHARA, ed. (Boeing Military Airplane Development, Seattle, Wash.) Mar. 1988 195 p
(AGARD-AG-311; ISBN-92-835-0448-8; AD-A196777) Avail: NTIS HC A09/MF A01

Cost-effective vectorization of fluid dynamic codes, in particular the Navier/Stokes Code, is covered relative to the supercomputer architecture. Subjects include current supercomputer architecture; minisupercomputers; impact of hardware on computing; software migration issues; benchmarking; guidelines on FORTRAN vectorization at the do-loop level; restructuring of basic linear algebra algorithms; and restructuring guidelines for basic fluid dynamic codes. A glossary of supercomputing terms is given in the Appendix. For individual titles, see N89-11396 through N89-11401.

N89-11396# *Boeing Computer Services Co., Seattle, WA.*
HARDWARE ARCHITECTURE, CHAPTER 2
KEN W. NEVES *In* AGARD, Computational Fluid Dynamics: Algorithms and Super Computers p 11-53 (SEE N89-11395 02-60) Mar. 1988
(AGARD-AG-311) Avail: NTIS HC A09/MF A01

An overview of computer architectures is given. The purpose is not to offer a text book description of the electronics behind computing, but rather an appreciation of the barriers on computer development that have led to the complex design of today's supercomputers. This introductory section will examine: (1) the need for increased computer power as a result of the pressure from new computational processes; (2) the limits and barriers of hardware; (3) a brief history of parallelism; and (4) an overview of parallelism in today's computers. Following this Background section, an indepth look at today's supercomputer architectures and emerging computer products is given. In chapter 3, the impact of new hardware architecture on algorithms will be examined. Like computational fluid dynamics, supercomputing has developed a set of terms, definitions, and ad hoc descriptions of common processes. In this monograph most of these terms will be defined when used. Nevertheless, in an attempt to aid the reader, an informal glossary of supercomputing terms is included in an appendix. Author

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COMPUTER PROGRAMMING AND SOFTWARE

Includes computer programs, routines, and algorithms, and specific applications, e.g., CAD/CAM.

N87-19922# Canadian Forces Coll., Toronto (Ontario).
MICROCOMPUTER-BASED CATALOG CREATION SOFTWARE OPTIONS FOR SMALL LIBRARIES
C. E. MURPHY *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 7 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

The microcomputer-based catalog creation options available to small libraries are discussed. Possible criteria for software evaluation are suggested. Two catalog creation software packages, INMAGIC, a database management system and CARD DATALOG, an off-the-shelf catalog creation program are described in terms of the suggested software evaluation criteria. Microcomputer-based catalog creation software -- software intended to enable libraries to build an in-house database of machine-readable bibliographic records -- can provide small libraries with an affordable means of transcending the information retrieval limitations of the traditional catalog and of automating some of the routine functions associated with the generation of cataloging products. However, microcomputer-based catalog creation can also prove to be an expensive trap for the unwary. Author

N87-19925# Ashford (J. H.) Associates Ltd., Maidenhead (England).
MICROCOMPUTERS IN INFORMATION RESOURCE SHARING. PART 1: DATA AND GRAPHICS SYSTEMS
J. H. ASHFORD *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 9 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

The number of online numeric data sources now exceeds that of the bibliographic and full text systems. Most of the databases are of financial or economic data, but a significant proportion deals with scientific, technical and medical information, and environmental studies are well covered. Examples of North American and European sources are given, and issues of data quality and property rights are discussed. The application of data from a shared source normally involves access in a language specialized to that database, and the subsequent use of flexible software to format and present the retrieved data. This final step may be done on the host system, using programs provided by the data vendor, but is increasingly being transferred to the user's micro computer, using either general purpose software, or micro computer versions of mainframe utilities. The scope of analysis, tabulation and graphical presentation now on offer is considered, and the implications for choice of micro computer systems, and for information staff training and career development are considered. Author

N87-19928# Ashford (J. H.) Associates Ltd., Maidenhead (England).
TRENDS IN SOFTWARE AND SYSTEM DEVELOPMENT
J. H. ASHFORD *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 12 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

The developments in microcomputers now being applied in information work have, in the majority of cases, been adopted from innovations directed at very much larger markets. Present trends are to reduce real costs of both software and equipment, which is helpful in making existing systems cheaper, but not necessarily good for new library oriented developments. The need for fact retrieval is becoming more important, and developments in electronic publishing and document exchange will be important. The integration of text, graphics and images is improving depending partly on new software ideas, and partly on the availability of optical disc storage for large volumes of data. Text retrieval is becoming a feature of some relational database systems, offering an alternative to inverse file approaches, and the use of signature

representations may lead both to simple small scale retrievers, and to methods of identifying duplicate records in archives.
Author

N87-20200# National Aerospace Lab., Amsterdam (Netherlands).
FLEXIBLE GRID GENERATION FOR COMPLEX GEOMETRIES IN TWO SPACE DIMENSIONS BASED ON VARIATIONAL PRINCIPLES
B. OSKAM and G. H. HUIZING *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 14 p (SEE N87-20199 13-02) Nov. 1986 Sponsored by Netherlands Agency for Aerospace Programs
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A method is described that is suitable for the numerical generation of boundary-conforming curvi-linear coordinate systems. The method is based on the decomposition of a multiply connected domain into a number of simply connected zones. In each zone the grid is computed by solving a system of Euler equations that minimizes a functional of the unknown transformation functions. This system of equations and the natural boundary conditions of the minimization problem are discussed. A first illustration of this technique is given for the case of a three-element airfoil. Author

N87-20201# Aircraft Research Association Ltd., Bedford (England).
A DISCUSSION ON A MESH GENERATION TECHNIQUE APPLICABLE TO COMPLEX GEOMETRIES
N. P. WEATHERILL, J. A. SHAW, C. R. FORSEY, and K. E. ROSE *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 12 p (SEE N87-20199 13-02) Nov. 1986 Sponsored by Ministry of Defence and British Aerospace
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A general three-dimensional block structured grid generation technique is described. It was coupled with an Euler algorithm to simulate the flow around complicated aerodynamic configurations. The flow field is subdivided into a set of non-overlapping blocks and grids are generated simultaneously in all of the blocks using an elliptic grid generation method. Appropriate boundary conditions applied on the face of the blocks ensure that grid lines pass smoothly between blocks leaving the grid globally smooth. Details of the surface and field grid generation are given and techniques to control the position of grid points are highlighted. Grid topologies for complicated civil and military configurations are discussed. Examples are given of grids for complicated configurations and some results of flow calculations on block structured grids are shown. Author

N87-20202# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Theoretical Aerodynamic Group.
NUMERICAL GRID GENERATION AROUND COMPLETE AIRCRAFT CONFIGURATIONS
WILLY FRITZ *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 8 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A method for accurately generating boundary conforming, three-dimensional computational grids applicable to realistic aircraft configurations is presented. Configurations with an arbitrarily shaped and positioned wing, a horizontal tail (or canard) and a vertical tail attached to an arbitrarily shaped fuselage can be treated. The grid generation technique divides the computational domain into multiple rectangular blocks whose structure follow the natural lines of the configuration. For each of these contiguous sub-regions the grids are generated separately and then patched together to cover the entire physical region. The grids for the sub-regions are generated by the solution of elliptical partial differential equations (PDE). The method is an automated procedure but with interactive control and optimization possibilities which enable the user to produce coordinate lines with sufficient continuity across the block boundaries. Due to the block structure and the data organization of the method very fine grids (up to several millions of gnd points) for complete aircraft configurations can be generated. Author

N87-20203*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
GEOMETRY DEFINITION AND GRID GENERATION FOR A COMPLETE FIGHTER AIRCRAFT
THOMAS A. EDWARDS *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 12 p (SEE N87-20199 13-02) Nov. 1986 Previously announced as N86-28050
(AGARD-CP-412) Avail: NTIS HC A19/MF A01 CSCL 09B

Recent advances in computing power and numerical solution procedures have enabled computational fluid dynamicists to attempt increasingly difficult problems. In particular efforts are focusing on computations of complex three-dimensional flow fields about realistic aerodynamic bodies. To perform such computations, a very accurate and detailed description of the surface geometry must be provided, and a three-dimensional grid must be generated in the space around the body. The geometry must be supplied in a format compatible with the grid generation requirements, and must be verified to be free of inconsistencies. A procedure for performing the geometry definition of a fighter aircraft that makes use of a commercial computer-aided design/computer-aided manufacturing system is presented. Furthermore, visual representations of the geometry are generated using a computer graphics system for verification of the body definition. Finally, the three-dimensional grids for fighter-like aircraft are generated by means of an efficient new parabolic grid generation method. This method exhibits good control of grid quality. Author

N87-20204# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
AN ASSESSMENT OF THE USE OF LOW-ORDER PANEL METHODS FOR THE CALCULATION OF SUPERSONIC FLOWS
J. S. SMITH and D. S. WOODWARD *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 8 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

Three low-order panel methods developed for the analysis of supersonic flows were used to make calculations for a number of test configurations, with the aim of establishing the range of problems for which this class of computational method yields adequate solutions. The programs investigated were the Woodward USSAERO/C program, the related NLRAERO program, and the British Aerospace Warton supersonic panel program. Results obtained using these programs were evaluated against theoretical and experimental data for a number of test cases covering wing-alone, body-alone and wing-body geometries. It is concluded that low-order panel methods can provide adequate solutions for supersonic flows about wings, bodies and wing-body combinations, provided the assumptions implicit in the linearised potential flow model are not violated. Examples show that the prediction of lift and pitching moment curve slopes for quite complex configurations may be acceptable, but that the detailed pressure distributions are not always predicted satisfactorily. In particular, serious problems are encountered in calculating the flow about wings with rounded supersonic leading edges due to the linearised flow model which is used. Author

N87-29521# British Aerospace Aircraft Group, Preston (England). Advanced Systems Dept.
A GRAPHICAL AID TO IKBS PROGRAM DEVELOPMENT
P. J. KEARNEY and B. HUNT *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 18 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Intelligent Knowledge Based Systems (IKBS) developments fall into 2 categories: real time airborne applications of system automation and tactical decision aid type, and ground based expert systems. The first of these presents major difficulties with regard to Quality Assurance testing of the codes produced, while the second suffers from the inappropriateness of stand alone workstations and classical artificial intelligence (AI) approaches within the industrial aerospace context. British Aerospace is applying its extensive experience in conventional software methodologies to the new demands presented by IKBS, both to the developer and the user. One of the tools under development is known as GRIN (Graphical Representation of an Inference Network) and is described, together with an overview of an approach to AI. GRIN presents an inference network in a dynamic diagrammatic form, which maximizes the user's comprehension of

the knowledge base, and hence eases development and maintenance of an IKBS. It is considered that this tool and the philosophy behind it will reinforce the view that IKBS represents a natural extension of programming technology rather than a radical change. Author

N88-10816# Electronique Serge Dassault, Saint Cloud (France).
HOW TO USE PROLOG FOR EXPERT SYSTEM PROGRAMMING
MICHEL MUENIER, PATRICK TAILLIBERT, and SERGE VAHENNES *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 8 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

A description is given of how PROLOG is used to develop expert systems. It is shown that PROLOG had to be extended towards an object oriented representation. The basic mechanisms that should occur in such a representation to make expert programming easier are discussed. The EMICAT (MI4) environment, constructed on this PROLOG extension so that knowledge can be represented and used in the form of production rules, is described. The implementation of this environment is briefly described. Author

N88-10817# Carleton Univ., Ottawa (Ontario). Dept. of Systems and Computer Engineering.
REAL-TIME EXPERT SYSTEMS: A STATUS REPORT
B. A. BOWEN *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 15 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

The control algorithm for complex physical plants is usually based on a model, either discrete or linear, which describes the appropriate response to data obtained from sensors located throughout the plant. Models of plant behavior are usually based on a Markov process assumption or on some linear system approximation. Many subtle characteristics beyond the range of the assumptions or approximations are either ignored or the appropriate response is obtained by fine-tuning after the control system is installed. A comprehensive state-of-the-art summary of the status, progress, issues and directions in the use of knowledge-based systems in real-time control applications is given. Author

N88-20182# Aeritalia S.p.A., Turin (Italy). Combat Aircraft Group.
DEVELOPMENT COST REDUCTION USING INTEGRATED CAE-CAD-CAM TECHNIQUES
DAVIDE FALCO *In* AGARD, Flight Vehicle Development Time and Cost Reduction 9 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The conventional process for new aircraft design and development is based on sequential analysis and test cycles. Using an integrated CAE-CAD-CAM technique it is possible to increase the depth of different configuration analyses, to reduce the cycle time and even the number of cycles required, and to achieve optimized design, thereby improving the product, shortening the overall development time, and reducing development costs. The capability of CAD systems to manipulate 3-D geometric models utilizing a standard components data base, allows the integrated development of aerodynamic and structural configurations, and of systems layout. A computerized mock-up developed at CAD permits the convergence on a unique mathematical model of different disciplines, facilitating integration between structures and equipment. The CAD total data base integrated with analysis and manufacturing permits direct data transfer from engineering to manufacturing (CAM) and in addition makes faster and cheaper the embodiment of modifications during the development phase. Author

N88-20191# British Aerospace Aircraft Group, Warton (England). Military Aircraft Div.
TIME AND COST REDUCTION THROUGH COMPUTER INTEGRATED MANUFACTURE
J. B. COX *In* AGARD, Flight Vehicle Development Time and Cost Reduction 7 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

CAD/CAM, since its introduction about 10 years ago, has provided only a limited increase in productivity and has had very little effect on the timespan from initiation of design to delivery of the first unit from production. Further productivity benefits and a reduction in the time taken to produce the first prototype can only be achieved by a more flexible approach to design and manufacture. This in turn puts a greater strain on the Company's support system and a much greater integration of the whole activities of the Company are required. Computer systems are a necessary means of producing the level of integration through Information Technology. This requirement is moving us from CAD/CAM to Computer Integrated Manufacture (CIM). The paper concludes with a review of the steps being taken within British Aerospace towards reducing project lead times and costs. Author

N88-23795# Naval Weapons Center, China Lake, CA.
DEVELOPING SYSTEMS USING STATE-OF-THE-ART CAD/CAM TECHNOLOGY
VERNON A. ANDERSON and DAVID J. BREWER (Space and Naval Warefare Systems Command, Charleston, S.C.) *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 7 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

Here, state-of-the-art CAD-CAM refers to mission-specific applications with the ability to describe a design that is independent of technology at certain levels; that is, which describes a design in a manner independent of any particular implementation, yet allows integrated verification across design boundaries. Such a high-level approach pays high dividends in transferring designs from one technology to another. Presented here are some structures useful for improving understanding of technology, systems, CAD/CAM, and communications across interfaces. A technology planning and communications framework concerning a hierarchical system schema is introduced for looking at the spectrum of user tasks in the life cycle of electronic products. The Navy's acquisition strategy and plans for computer-aided design/computer-aided manufacturing are presented. Author

N88-23798# British Aerospace Public Ltd. Co., Preston (England) Military Aircraft Div.
SOFTWARE ENGINEERING FOR THE BRITISH AEROSPACE EXPERIMENTAL AIRCRAFT PROGRAMME (EAP)
W. E. R. KELLAWAY *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 14 p (SEE N88-23767 17-06) Dec. 1987 Sponsored in part by the Ministry of Defence, United Kingdom
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The software engineering approach adopted by British Aerospace in the specification, design and implementation of the Avionics and Utility Systems Management software for the Experimental Aircraft Program (EAP) is described. The software life cycle and supporting methods and tools are described, in particular the Controlled Requirements Expression (CORE) method, supported by the CORE Work Station, and the PERSPECTIVE programming support environment. The considerable benefits obtained in both productivity and quality are highlighted and developments leading to a full Integrated Project Support Environment (IPSE) are indicated. Author

N88-23800# General Research Corp., Santa Barbara, CA.
A SOFTWARE LIFE CYCLE SUPPORT ENVIRONMENT
L. Y. BAJWA and FRANK S. LAMONICA (Rome Air Development Center, Griffiss AFB, N.Y.) *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 19 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

The Software Life Cycle Support Environment (SLCSE) is a distributed, computer-based environment of software development tools and methods which span the full spectrum of the software life cycle and are integrated through a common and consistent

user interface and a life cycle project data base. Primary features of the SLCSE are: (1) it supports both the development and management of complex mission-critical computer resources (MCCR) software systems; (2) it is multilingual, supporting the Air Force standard higher order languages including MIL-STD-1589B (JOVIAL J73) and MIL-STD-1815A (Ada); and (3) through its unifying framework, it enables the integration of both newly developed and existing software tools. The SLCSE development effort, highlights of SLCSE architecture, requirements and top-level design are discussed. The implementation appproach is described along with the results of the first build. Testing and verification plans are discussed and risk areas identified. Long-term plans to evolve the SLCSE beyond the current contractual requirements are discussed. Author

N88-29313# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
THREE DIMENSIONAL GRID GENERATION FOR COMPLEX CONFIGURATIONS: RECENT PROGRESS
JOSEPH F. THOMPSON, J. L. STEGER, and H. YOSHIHARA, ed. (Boeing Military Airplane Development, Seattle, Wash.) Mar. 1988 162 p
(AGARD-AG-309; ISBN-92-835-0451-8; AD-A196776) Avail: NTIS HC A08/MF A01

Some of the capabilities of the Computational Fluid Dynamics (CFD) community are surveyed for griding complex three dimensional configurations. The intent is to provide some insight as to the present state of grid generation for aircraft configurations in order to help assess whether this task presents a long term stumbling block to routine use of CFD in aerodynamic applications. A brief review is given of some of the techniques that are available for generating body conforming curvilinear grids. In order to assess capabilities in grid generation, colleagues at selected institutions were solicited to describe their experiences and difficulties in grid generation of complex configurations. For individual titles, see N88-29314 through N88-29325.

N88-29314# Boeing Military Airplane Development, Seattle, WA.
LESSONS LEARNED IN THE MESH GENERATION FOR PN/S CALCULATIONS
H. YOSHIHARA. *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 15-22 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

Experiences encountered in the 2D mesh generation with the elliptic differential equation method are described for the parabolized Navier-Stokes calculations over a generic fighter at a supersonic Mach number and for a wing/fuselage at hypersonic Mach numbers. Importance of the mesh quality is stressed, and the need of an improved cost effective treatment of the shocks is pointed out. Author

N88-29315*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THREE-DIMENSIONAL ELLIPTIC GRID GENERATION FOR AN F-16
REESE L. SORENSON *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 23-28 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01 CSCL 09B

A case history depicting the effort to generate a computational grid for the simulation of transonic flow about an F-16 aircraft at realistic flight conditions is presented. The flow solver for which this grid is designed is a zonal one, using the Reynolds averaged Navier-Stokes equations near the surface of the aircraft, and the Euler equations in regions removed from the aircraft. A body conforming global grid, suitable for the Euler equation, is first generated using 3-D Poisson equations having inhomogeneous terms modeled after the 2-D GRAPE code. Regions of the global grid are then designated for zonal refinement as appropriate to accurately model the flow physics. Grid spacing suitable for solution of the Navier-Stokes equations is generated in the refinement zones by simple subdivision of the given coarse grid intervals. That grid generation project is described, with particular emphasis on the global coarse grid. Author

N88-29316# Aircraft Research Association Ltd., Bedford (England).
COMPONENT ADAPTIVE GRID GENERATION FOR AIRCRAFT CONFIGURATIONS
N. P. WEATHERILL and J. A. SHAW *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 29-39 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

A method is presented which is capable of generating component adaptive grids. The approach is illustrated using wing-body-canard geometries but is applicable to a wide range of complex aerodynamic configurations. The new method of topology generation, combined with the approach taken to grid control, provide a powerful means of exploring the most suitable topology for a given geometry. Grid control parameters are available to the user to modify the grids for particular geometries but the system does not require the user to partake in long interactive sessions on a workstation to generate grids. The suitability of the component adaptive grids for flow simulation is demonstrated by comparing theoretical predictions with experiment. Author

N88-29317# General Dynamics Corp., Fort Worth, TX
GENERATION OF MULTIPLE BLOCK GRIDS FOR ARBITRARY 3D GEOMETRIES
J. P. STEINBRENNER, S. L. KARMAN, JR., and J. R. CHAWNER *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 40-55 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

A grid generation procedure was developed to create complex block grid systems, beginning with the generation of block surfaces, up to the generation of the full block volume grids. The multiple block concept is shown to facilitate the gridding of very complex geometries and also to allow larger sized grids to be run with a multiple block Euler solver. The entire grid generation process is broken into logical steps, each step is described in detail. Three examples of grid systems generated with these techniques are given, thereby validating the procedure. Finally, current research topics in grid generation and future plans are discussed. Author

N88-29318*# National Aeronautics and Space Administration Langley Research Center, Hampton, VA.
GRID GENERATION ON AND ABOUT A CRANKED-WING FIGHTER AIRCRAFT CONFIGURATION
ROBERT E. SMITH, JOAN I. PITTS, LARS-ERIK ERIKSSON, and MICHAEL R. WIESE (Computer Sciences Corp., Hampton, Va.) *In* AGARD, Three Dimensional Grid Generation for Complex Configuration: Recent Progress p 56-64 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01 CSCL 09B

Experiences at the NASA Langley Research Center generating grids about a cranked wing fighter aircraft configuration is described. A single block planar grid about the fuselage and canard used with a finite difference Navier-Stokes solver is also described. A dual block nonplanar grid about the complete configuration and used with a finite volume Euler solver is presented. The very important aspect of computing the aircraft surface grid, starting with a standardized model description, is also presented. Author

N88-29319# Messerschmitt-Boelkow G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Group.
GRID GENERATION FOR AN ADVANCED FIGHTER AIRCRAFT
A. EBERLE and W. SCHWARZ *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 65-76 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

The grid generation process for a realistic and complex fighter type aircraft is described. The method is based on the solution of biharmonic equations and uses a single block concept. Only a few user specified input parameters are necessary for the construction of the space grid and therefore this grid generation system is very simple to handle. The grid is intended for calculations with an Euler code at transonic and supersonic speeds. Author

N88-29320# Tennessee Univ. Space Inst., Tullahoma. Dept. of Engineering Science and Mechanics.
ALGEBRAIC GRID GENERATION FOR FIGHTER TYPE AIRCRAFT
JOHN STEINHOFF *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 77-84 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

A systematic procedure is presented for synthesizing a complex computational grid for fighter type aircraft out of a number of simpler elementary grids. This method is useful when a grid is required over an object which, though complex, consists of a number of simpler pieces, such as an aircraft with a number of lifting surfaces. The procedure presented allows a smooth complex grid to be generated which becomes exactly equal to each elementary grid as the surface corresponding to that elementary grid is approached. In this way, methods which may have previously been developed for each piece do not have to be changed and can be used as black boxes, whether they are algebraic, partial differential equation based, or whether the grids are just given numerically. This blending technique is only one of several tools which was used to generate effective grids. Other techniques include projection methods for generating surface grids. Some advantages and limitations of the method are discussed and examples are given of its use in generating complex fighter grids. Author

N88-29321# Mississippi State Univ., Mississippi State. Dept. of Aerospace Engineering.
COMPOSITE GRID GENERATION FOR AIRCRAFT CONFIGURATIONS WITH THE EAGLE CODE
JOE F. THOMPSON and LAWRENCE E. LIJEWSKI (Air Force Armament Lab., Eglin AFB, Fla.) *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 85-95 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

A general three dimensional grid generation code based on a composite block structure is discussed. The code can operate either as an algebraic generation system or as an elliptic generation system. Provision is made for orthogonality at boundaries and complete continuity at block interfaces. The code can operate in two or three dimensions, or on a curved surface. The input is structured to be user oriented, and arbitrary block configurations can be treated. Author

N88-29322# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. for Theoretical Fluid Mechanics.
ANALYTICAL SURFACES AND GRIDS
HELMUT SOBIECZKY *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 96-105 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

The use of analytical shape generation is described for wing-body configurations and flow boundary conditions. Flexibility in geometry definition allows for simple computational grid interpolation. A test case for experiment and code validation is illustrated. Author

N88-29323# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Theoretical Aerodynamics.
MESH GENERATION FOR INDUSTRIAL APPLICATION OF EULER AND NAVIER STOKES SOLVERS
W. FRITZ, W. HAASE, and W. SEIBERT *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 106-123 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

A considerable increase has been made in recent years in the ability to compute flow fields about three dimensional configurations. In order to reach their full potential, robust grid generation techniques for complicated aerodynamic configurations must be developed. Three different methods are presented which can be characterized as automatic grid generation for complete aircraft configurations, completely interactive grid generation and generation of solution adaptive grids for Navier-Stokes calculations. Although all the presented grid generation techniques use only elliptical grid generation, they show already that there is no unique grid generation technique. E.R.

N88-29324# Calspan Field Services, Inc., Arnold AFS, TN.
EXPERIENCE WITH THREE DIMENSIONAL COMPOSITE GRIDS
J. A. BENEK, T. L. DONEGAN, and N. E. SUHS *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 124-138 (SEE N88-29313 23-61) Mar. 1988 Previously announced as N87-26021
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

Experience with the three dimensional, chimera grid embedding scheme is described. Applications of the inviscid version to a multiple body configuration, a wing-body-tail configuration, and an estimate of wind tunnel wall interference are described. Applications to viscous flows include a 3-D cavity and another multi-body configuration. A variety of grid generators is used, and several embedding strategies are described. Author

N88-29325# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Entwurfsaerodynamik.
GRID GENERATION AROUND TRANSPORT AIRCRAFT CONFIGURATIONS USING A MULTI-BLOCK STRUCTURED COMPUTATIONAL DOMAIN
R. RADESPIEL *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 139-153 (SEE N88-29313 23-61) Mar. 1988
(AGARD-AG-309) Avail: NTIS HC A08/MF A01

A new grid generation code is described which is based on the multi-block approach. Grid generation around 3-D configurations is divided into 3 major parts, namely, surface definition, surface grid generation and field grid generation. Coons' patches are used to define the surfaces and their intersection lines. Surface grids and field grids are generated using the numerical solution of an elliptic system. An effective means for the control of the grid spacing was developed which is based on an iterative determination of the source terms in the elliptic system. The code is used to generate grids around a wing-body combination and a high bypass nacelle configuration. Author

N89-10049# Raytheon Co., Bedford, MA. Missile Systems Div.
COMPARISON OF STATISTICAL DIGITAL SIMULATION METHODS
PAUL ZARCHAN *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 16 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

The various statistical digital simulation methods used in the preliminary analysis and synthesis of a homing missile guidance system are compared. A unifying example is used to illustrate the advantages and computer costs of each of the methods. Author

N89-10050# Dynetics, Inc., Huntsville, AL.
A GENERIC SEEKER SIMULATION FOR THE EVALUATION OF ACTIVE RF GUIDANCE SYSTEMS
FRANK T. CAMPOS *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 9 p (SEE N89-10048 01-08) Jul. 1988
(Contract F08635-83-C-0123)
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

The essential features of a generic simulation of an active radio frequency (RF) air-to-air missile seeker is described. The concept of generic simulations is supported by the need for a common test-bed of system models and simulation technology capable of supporting advanced seeker development programs. An extensive library of target, environment, and RF seeker models was incorporated within a modular program structure featuring tri-level hierarchy of program control that allows the selective management of program options for specifying the fidelity and functional implementation of models used at the component, subsystem, and system levels. The Generic Seeker Simulation offers considerable flexibility for simulating a broad range of RF seeker configurations and has a significant potential for supporting the evaluation of competitive designs and advanced seeker technologies. Author

N89-10051# Magnavox Electronic Systems Co., Fort Wayne, IN. Control Systems Operation.
DIGITAL SIMULATION TECHNIQUES FOR END GAME PHENOMENA
MARTIN E. TANENHAUS and DUANE J. CART *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 37 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

This report is based on efforts to develop a color graphics based analytical methodology for determining end game performance of smart sensors on missiles and projectiles. These sensor systems defend against present and future target threats. The development of a computer based methodology to define and test weapon system sensor performance requirements, predict end game sensor and fuze burst point distributions, assess weapon system effectiveness, and evaluate advanced weapons design concepts is presented. A graphics driven target modeling methodology is presented, together with verification, correlation, and validation techniques. A complex radar target model with detailed graphics, radar cross section (RCS), glint, imagery analysis, and target Doppler signature output was developed. A sensor system signal processor model is developed and exercised with the target model to provide system performance assessments. Verifiable correlation between system model performance and real hardware was obtained. End game system function results are utilized in a weapons effectiveness simulation and appraisal.
Author

N89-10052# Raytheon Co., Bedford, MA.
DESIGN CRITERIA FOR HARDWARE-IN-THE-LOOP SIMULATION FACILITIES
S. J. POWERS and M. E. SISLE *In* AGARD, Guidance and Control Systems Simulation and Validation Techniques 10 p (SEE N89-10048 01-08) Jul. 1988
(AGARD-AG-273) Avail: NTIS HC A07/MF A01

The criteria used in the design of a Hardware-in-the-Loop (HIL) simulation facility are outlined. Although dealing with a missile interceptor facility, the criteria are directly applicable to any electronic weapon system simulation facility. The first step in the process is defining the role that the facility will play in the development cycle. Facility requirements which drive the model and data requirements are then defined and the facility design follows from the requirements. Following completion of the facility development is the conduct of system integration tests. Verification/validation criteria are established and met, the process is complete, allowing the facility operation to begin. Facility operation and maintenance become ongoing functions. Author

N89-11397# Boeing Computer Services Co., Seattle, WA.
ALGORITHM AND GENERAL SOFTWARE CONSIDERATIONS
KEN W. NEVES *In* AGARD, Computational Fluid Dynamics: Algorithms and Super Computers p 55-98 (SEE N89-11395 02-60) Mar. 1988
(AGARD-AG-311) Avail: NTIS HC A09/MF A01

This chapter of the study examines the relationship between hardware architecture and computational performance. The setting is scientific computation of a generic sense (i.e., application non-specific). In subsequent chapters, the general implications discussed here will be applied to algorithms specific to computational fluid dynamics and to the major computational approaches used in that field. In order to give meaningful appreciation of the concepts discussed, frequent use of examples on specific hardware architectures will be utilized. Quite often several machine types will be included, and several will not. The reasons for this are twofold: (1) it is not always possible to obtain exactly the same benchmark results across machine types, and (2) it is not our intent to give a definitive comparison of machine performance. These reasons may seem superficial at first glance, yet thay are fundamental to the reality of the state-of-the-art of computer metrics. Author

N89-11398# Technische Univ., Regensburg (Germany, F.R.).
VECTORIZATION OF FORTRAN PROGRAMS AT DO-LOOP LEVEL
W. GENTZSCH *In* AGARD, Computational Fluid Dynamics: Algorithms and Super Computers p 99-108 (SEE N89-11395 02-60) Mar. 1988
(AGARD-AG-311) Avail: NTIS HC A09/MF A01

In previous chapters the impact of computer hardware on algorithm performance was discusssed. It was made clear that the most effective use of the supercomputers comes from sound understanding of computer architecture and an appropriate computational strategy. In this and subsequent chapters, the focus will by on fluid dynamics applications. Today, and for some years to come, the major interface between the scientist and the computer will continue to be FORTRAN. Some common techniques are presented which are useful in dealing with code optimization within the critical loops of FORTRAN, and in Chapter 5 the important consequences of restructuring the linear algebra algorithms common in CFD applications. Finally, in Chapter 6, major applications will be reviewed from a computational perspective giving a broad-based approach utilizing proper FORTRAN, proper algorithms, and awareness of architectural dependencies. Here we restrict ourselves to discussing some helpful coding techniques, which are easy to understand and to implement. However, it should be emphasized that the selection of an appropriate algorithm is generally far more important than fancy programming techniques (see Chapter 5). Author

N89-11399# Technische Univ., Regensburg (Germany, F.R.).
RESTRUCTURING OF BASIC LINEAR ALGEBRAIC ALGORITHMS, CHAPTER 5
W. GENTZSCH *In* AGARD, Computational Fluid Dynamics: Algorithms and Super Computers p 109-139 (SEE N89-11395 02-60) Mar. 1988
(AGARD-AG-311) Avail: NTIS HC A09/MF A01

In the previous chapter the vectorization of typical do-loops arising in CFD problems was discussed. Until now, we have not considered the algebraic structure of the basic algorithm, by far the most important consideration. Indeed, a good algorithm poorly coded is usually preferable to a poor one optimally coded. For this reason, in the following, we turn our attention to the restructuring of some basic linear algebraic algorithms such as matrix*vector and matrix*matrix operations, linear recursions up to more complex algorithms and iterative methods for the solution of linear algebraic systems of equations with sparse matrices. Problems involving linear algebraic calculations consume large quantities of computer time. If substantial improvements can be made within the arithmetic section, a significant reduction in the overall computation time will be realized. Author

N89-18449# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
SOFTWARE PRODUCTIVITY THROUGH ADA ENGINES
RICK A. LONG *In* AGARD, Software Engineering and Its Application to Avionics 4 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The use of correct computer hardware to increase programmer productivity is explained. An Air Force program is used for specific information and examples. Author

N89-18450# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
SOFTWARE DEVELOPMENT GUIDELINES
DENICE S. JACOBS *In* AGARD, Software Engineering and Its Application to Avionics 2 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Due to the growing complexity of avionic systems, the development cycle for mission critical software has evolved into a collective process of organized tasks. These tasks are distinct levels of effort which are implemented by the developer to ensure the creation of a reliable, operational system. Four principle tasks are summarized which have proven to be excellent procedures for developing avionics software. The first and foremost task of the project manager is to establish a Configuration Control Board (CCB) as the central core of technical management. It consists of a group of key hardware and software engineers who mutually govern the status of system development, and incorporate design changes on an agreed-to basis. The second task is to logically

separate the software project into well-defined phases of development. This, too requires the cooperation of both hardware and software teams to work together in accordance with a master schedule. The third task is to create an automated data base which containes the latest interface specifications (ICDs) and system message definitions for use by the engineers. Finally, the last task is to procure hardware emulators and stand-alone test stations as an effective means of testing software prior to system integration and tests. Author

N89-18451# Thomson-CSF, Malakoff (France). RCM Div.
ON THE CONDITIONS AND LIMITS OF USER INTERVENTION IN DELIVERED SOFTWARE MANUFACTURER'S VIEWPOINT
JEAN R. CHARVOZ *In* AGARD, Software Engineering and Its Application to Avionics 12 p (SEE N89-18446 11-06) Nov. 1988 (AGARD-CP-439) Avail: NTIS HC A18/MF A01

High capacity data processing architectures are now available in avionics. The development of embedded software have become a major activity in most avionic equipment manufacturing companies. These companies are faced with challenges. To meet customer requirements, the manufacturer often has to satisfy different, and sometimes contradictory, conditions. These issues include: the characteristic development of equipment which includes software (types, activities, tasks, skills, and facilities); the equivalency of software modification to a partial redevelopment and the difficulties inherent; and the conditions under which a customer may modify the software of the equipment. Some answers are provided to aspects of the process of giving a user the autonomy to perform software modifications. Author

N89-18453# Computer Sciences Corp., Falls Church, VA.
CONVERSION TO ADA: DOES IT REALLY MAKE SENSE
ROBERT A. CONVERSE and MITCHELL J. BASSMAN *In* AGARD, Software Engineering and Its Application to Avionics 5 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Change is an integral part of any useful operational system. Changes are required for any number of reasons, ranging from minor errors that exist in the system to major system upgrades to meet totally new and different requirements. For the U.S. Department of Defense (DOD), the manner in which systems are changed is of significant interest. Major system upgrades occur in virtually every system at various times during their operational lifetime. One way to manage the changes and to reduce the long term costs associated with them is the use of the Ada programming. Avionics is an application area withing DOD for which the use of Ada is a serious consideration. However, in addition to reducing the long term costs, the avionic software must also meet strigent real-time performance and resource utilization requirements. Some of the issues associated with the use of Ada to accomplish system changes are addresssed. Background and general issues will be discussed as well as some concerns that are specific to avionics systems. Author

N89-18455# British Aerospace Aircraft Group, Preston (England). Military Aircraft Div.
EMBEDDING FORMAL METHODS IN SAFRA
ANDREW BRADLEY *In* AGARD, Software Engineering and Its Application to Avionics 9 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The SAFRA software development method was used extensively and successfully for the production of real-time avionic systems at BAe Warton. The method couples a powerful, yet simple, semi-formal specification (CORE) and design (MASCOT) approach to provide an environment covering the complete life cycle. Embedding formal methods into this established approach will combine requirements capture and structuring techniques with mathematically formal specification and designs, facilitating mathematical proof of safety critical elements. Following an overview of SAFRA, a brief introduction is provided to formal methods and identifies Z, a method founded on set theory and logic, for detailed investigation. An interface between semi-formal and formal techniques is defined and the results of applying the combined method to a number of avionic specification studies are summarized and discussed. It is concluded by considering the potential benefits and costs of adopting formal methods on large scale, avionic software projects. Author

N89-18456# Allied-Signal Aerospace Co., Fort Lauderdale, FL. Air Transport Avionics Div.
FORMALIZING A THEORY OF REAL-TIME SOFTWARE SPECIFICATION
ROBERT D. BUSSER *In* AGARD, Software Engineering and Its Application to Avionics 22 p (SEE N89-18446 11-06) Nov. 1988 (AGARD-CP-439) Avail: NTIS HC A18/MF A01

The approaches taken to specify the requirements and design of real-time embedded systems software range from not at all to informal textural specifications to semiformal graphics-based languages for data flow, control flow, state transition, and data structure diagrams to formal approaches such as VDM and HOS. Each approach has some problems when applied to the specification of large software systems. Part of the reason is that there are few formally defined models of the specification hierarchy commonly associated with requirements, design, and implementation specifications. Such a model is required as a point of reference in discussions about such specification issues and completeness and consistency analysis performed by some of the current generation CASE tools. A model can provide guidance in the identification of just what information to specify; regardless of the syntactic aspects of the specification approach used to capture this semantic information. In addition, such a model can be applied as the deductive inference model underlying an AI-assisted CASE environment capable of exercising a greater expert understanding of the information being specified. Such a model is presented in the form of a theory of Real-time Embedded System Specification (RESS). A partial vocabulary of the theory is presented along with the basic axioms and representative theorems. Author

N89-18457# Shape Technical Center, The Hague (Netherlands).
THE STATE OF PRACTICE IN ADA-BASED PROGRAM DESIGN LANGUAGES
LAWRENCE G. JONES *In* AGARD, Software Engineering and Its Application to Avionics 6 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The use of Ada in avionics and other systems is assuming more importance due to a growing body of national policies dictating its use in mission critical systems. This has created a need for software engineering techniques that incorporate Ada concepts so that the transition from a system design to an Ada implementation is more easily achieved. One of the most common techniques is to use an Ada-based program design language (ADL). The current state of practice in Ada-based program design languages is surveyed by examining some leading reports on the subject. Among the more important efforts, the surveys of existing ADLs conducted for the U.S. Naval Avionics Center (NAC), the Institute of Electrical and Electronics Engineers Recommended Practice for ADLs, the ADL guidelines produced for Transport Canada, and the ADL guidelines produced for NAC are discussed. It is noted that the state of practice is considered to be too immature for standardization. However, some of the major findings are summarized and point to future directions. Author

N89-18458# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
DEBUGGING DISTRIBUTED ADA AVIONICS SOFTWARE
MARC J. PITARYS *In* AGARD, Software Engineering and Its Application to Avionics 8 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Future avionics systems will consist of distributed fault-tolerant architectures. The operational flight software will be written in the Ada programming language and use a distributed operating system. Developing and maintaining this software requires new and innovative debugging techniques to reduce cost, time, and complexity. Two specific techniques are described. These are the dynamic trace buffers and the software Built-In-Support-Functions (BISFs). First the need for new approaches to debugging distributed Ada software is addressed. The implementation of each of the techniques is presented. The Avionics Laboratory is the only organization to successfully demonstrate both techniques with MIL-STD-1750A computers. Observations and recommendations for using these techniques will be reported. Author

N89-18459# Computer Technology Associates, Inc., Ridgecrest, CA.
AUTOMATED ADA CODE GENERATION FOR MILITARY AVIONICS
ROBERT S. ARDREY, II *In* AGARD, Software Engineering and Its Application to Avionics 9 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The experience with Ada-directed software development methodologies is presented. These include functional programming the use of class instances object-oriented design, and Ada as a program design language. Built upon prior experience, an automated Ada code generation environment is described. The environment addresses the enhancement of existing software tools, new development currently underway, and compiler support for military flight computers such as the AN/AYK-14. Finally, military avionics applications of such an environment are discussed. Predicted improvements in the areas of prototyping, productivity, reusability, and maintainability are examined. Author

N89-18460# Sparta, Inc., Laguna Hills, CA. Software and Systems Technology Div.
VERIFICATION AND VALIDATION OF FLIGHT CRITICAL SOFTWARE
PIO DEFEO and ANTHONY DETHOMAS (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.) *In* AGARD, Software Engineering and Its Application to Avionics 10 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The complexity and the fault tolerance requirements of flight critical systems are rapidly increasing. New techniques and methods must be developed and must be integrated with existing methods so that the rigorous technical objectives of the verification and validation process of such systems can be met at reasonable cost. Some of the advanced requirements of these systems are examined in critical areas for system architecture and software design. Some promising techniques are described which can effectively support architectural design and analysis and software development and verification. Author

N89-18461# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
GUIDELINES FOR EVALUATION OF SOFTWARE ENGINEERING TOOLS
ROBERT E. MARMELSTEIN *In* AGARD, Software Engineering and Its Application to Avionics 6 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Because the mandated use of inadequate software engineering tools in the software lifecycle can have devastating effects on program costs, the need for a taxonomy to evaluate these tools is readily apparent. This taxonomy should contain guidelines which are applicable to the design of a new tool or the selection of an existing one. A basic taxonomy is defined for evaluating software engineering tools. Author

N89-18462# Rome Air Development Center, Griffiss AFB, NY. Command and Control Software Technology Div.
RISE: REQUIREMENTS AND INCREMENTAL SPECIFICATION ENVIRONMENT
KEVIN M. BENNER *In* AGARD, Software Engineering and Its Application to Avionics 7 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

An environment for capturing requirements and incrementally developing a formal specification is introduced. This environment, called RISE, is based upon Place/Transition (P/T) Nets. The P/T nets are extended within RISE to support timing requirements and hierarchical decomposition as well as providing other extensions necessary for the development of software specifications. The main focus of this effort was to define the semantics of hierarchical decomposition of P/T nets. Author

N89-18463# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft and Helicopter Div.
THE MBB TEST STRATEGY AND TOOL SET FOR SOFTWARE AND SYSTEM INTEGRATION
HERMANN HESSEL and WALTER WAGNER *In* AGARD, Software Engineering and Its Application to Avionics 6 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Based on a generic system development concept a test strategy was established withing MBB Military Aircraft and Helicopter Division. In order to support this strategy a tool set was developed which is being used for all projects and throughout all development phases. Due to its free configurability it can easily be adapted to production line applications as well as to other purposes. Author

N89-18464# *DDC International A/S, Lyngby (Denmark).*
TOOLS FOR DEVELOPING REAL-TIME EMBEDDED SYSTEMS IN ADA: NEEDS, PORTABILITY AND EFFICIENCY
ELISABETH BROE CHRISTENSEN *In* AGARD, Software Engineering and Its Application to Avionics 4 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Ada offers some facilities, which were not part of older languages. To take advantage of Ada for real-time embedded applications, the development tools must support these facilities, and be done in an efficient manner. The experiences from a tool project, the DDC-I symbolic debugger project, which has as its goal to provide a tool which can fulfil the demands of real-time embedded applications in Ada is presented. Author

N89-18465# British Aerospace Aircraft Group, Warton (England). Military Aircraft Div.
THREE GENERATIONS OF SOFTWARE ENGINEERING FOR AIRBORNE SYSTEMS
A. O. WARD *In* AGARD, Software Engineering and Its Application to Avionics 11 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The serious practice of software engineering is a relatively recent phenomenon and there is a minimum of reported experience in the use of methods and tools to support its applications. The technology can be viewed as progressing through several generations typified by the form in which development information is stored and accessed and the nature of the life cycle. The former is described in terms of a file, data and a knowledge base, the latter as progressing from a phase to an object oriented life cycle. Experience with a typical first generation tool set is described briefly through the airborne software for the Experimental Aircraft Project. This is based largely on the use of structured methods for requirements and design, a programming support environment supporting the use of MASCOT and Pascal and rigorous management and control procedures. An advantageous cost benefit analysis of the project is reported. A move to the second generation of software engineering is being planned under the auspices of the Eurofighter Project by the adoption of an Integrated Project Support Environment (IPSE). The general characteristics of an IPSE are discussed including the tool interface and its relevance to emerging standardization activities such as CAIS and PCTE Plus. A longer term view of software is presented with an intimation of the scale and nature of future projects and a form of life cycle better suited to the needs. The requirements for software engineering to support artificial intelligence, safety critical applications, and rapid prototyping are reviewed. Author

N89-18466# Anchor Software Management, Falls Church, VA.
SOFTWARE READINESS PLANNING
JACK COOPER *In* AGARD, Software Engineering and Its Application to Avionics 6 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

A method is presented wherein the capability to support and make changes to avionics system software during the readiness phase of its life cycle can be guaranteed. In recognizing that the supportability of the software is completely determined during its development, the method centers around pre-development planning, decisions, and actions on the part of the avionics system's acquisition manager. Discussed are the software engineering considerations that must be included in the contract to facilitate the future supportability of the software. That is followed by a description of contractual requirements to be placed on the

software support environment used to develop the avionics software to ensure the life cycle supportability of the target avionics software. Two tools, a management Plan and a contracting Standard, that supported the method for ensuring software supportability are described. The Plan provides a vehicle for joint, customer and contractor, management of the developmental software support environment. The Standard provides the contractural life cycle supportability requirements. Author

N89-18467# Control Data Corp., Minneapolis, MN.
AN AVIONICS SOFTWARE EXPERT SYSTEM DESIGN
JUDY L. BRINK and RONALD B. HAYNES (Rome Air Development Center, Griffiss AFB, NY.) *In* AGARD, Software Engineering and Its Application to Avionics 8 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The scope is to define an expert software system, implemented in Ada, for avionics in the 1990's, using a table-driven design that was developed in a demonstration program as the prototype, in order to support tactical decision making applications. As a synopsis of what follows it will: point out the relevancy to the avionics community; give a historical example of a table-driven design in the area of reconnaissance management systems; describe the design logic behind this historical example by providing a single thread through the system; discuss the conceptual enhancements that need to be folded on top of this historical example, as an additional layer, in order to produce an expert software system; and provide a summary highlighting some reasons the avionics community should move in this direction from a software perspective. Author

N89-18473# Naval Weapons Center, China Lake, CA. Missile Software Branch.
CAN ADA (MIL-STD-1815A) FLY MISSILES
CARL W. HALL *In* AGARD, Software Engineering and Its Application to Avionics 6 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The transition of the MIL-STD-1815A (Ada) language and associated technology into the Navy missile domain beginning in October 1984 was explored. The project was funded by Independent Exploratory Development (IED) funds. It had a principal objective to develop operational software for a typical Navy missile in Ada, while examining the issues associated with deployment of the Department of Defense (DOD) standard language in a real-time missile environment. The project lasted 3 years and was finished in September 1987 with the Ada software running in a breadboard version of the missile guidance computer. The final version of the software has almost all the missile functions included with the exception of the safety module. Safety deals with the range requirements during testing and the data were not available. The computer and software are being moved to the Hardware-In-the Loop (HWIL) facility where they will be integrated with various missile hardware and a six degree-of-freedom simulation. Current plans are to seek funding to fly a test missile at the Naval Weapons Center range with a modified version of the IED Ada code. Author

N89-18474*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACCELERATED CONVERGENCE FOR SYNCHRONOUS APPROXIMATE AGREEMENT
J. P. KEARNS, S. K. PARK (College of William and Mary, Williamsburg, VA.), and J. A. SJOGREN *In* AGARD, Software Engineering and Its Application to Avionics 8 p (SEE N89-18446 11-06) Nov. 1988
(Contract NAG1-787)
(AGARD-CP-439) Avail: NTIS HC A18/MF A01 CSCL 09B

The protocol for synchronous approximate agreement presented by Dolev et. al. exhibits the undesirable property that a faulty processor, by the dissemination of a value arbitrarily far removed from the values held by good processors, may delay the termination of the protocol by an arbitrary amount of time. Such behavior is clearly undesirable in a fault tolerant dynamic system subject to hard real-time constraints. A mechanism is presented by which editing data suspected of being from Byzantine-failed processors can lead to quicker, predictable, convergence to an agreement value. Under specific assumptions about the nature of values transmitted by failed processors relative to those transmitted by good processors, a Monte Carlo simulation is presented whose qualitative results illustrate the trade-off between accelerated convergence and the accuracy of the value agreed upon. Author

N89-18475# Agusta Sistemi S.p.A., Tradate (Italy).
ROBUST ALGORITHM SYNCHRONIZES MODE CHANGES IN FAULT-TOLERANT ASYNCHRONOUS ARCHITECTURES
ANTONIO SILVA *In* AGARD, Software Engineering and Its Application to Avionics 8 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The need for protection against common-mode failures, in hardware and in software, as well as the need to cut hardware costs and complexity, has led to redundant asynchronous architectures. The resulting random phase sampled-data systems are loosely coupled, reducing fault propagation, but need to make homogeneous decisions whenever certain event combinations occur. Since decisions are basically boolean operations, a method was developed to achieve homogeneous agreement on discrete signals, without imposing constraints on input or architectural characteristics to the system designer. The method saves the critical problem of synchronized change of operational mode in avionic systems, where a safe all or none way of making decisions is of primary importance. Author

N89-18480# Bell Telephone Labs., Inc., Whippany, NJ.
FUNCTIONAL PROGRAMMING LANGUAGES AND MODERN MULTIPROCESSOR ARCHITECTURES: THE EMSP EXAMPLE
J. DENNIS SEALS and GERALD W. GRUBE *In* AGARD, Software Engineering and Its Application to Avionics 8 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Future military systems will require a mix of signal, data, control/decision processing at throughput levels ranging from 0.1 to 4 billion operations per second. Estimates of the embedded software to support these systems range from 0.5 to 10 million lines of code. Early in 1980, the Navy recognized the severity of these problems and awarded a contract to design a revolutionary computer architecture that would meet their signal processing needs through the year 2000. The result was the EMSP architecture that combines the programming simplicity of a functional language with the power of a modular, scalable, heterogeneous multiprocessor. The glue that binds these two attributes is a data-flow control mechanism that provides a transparent interface between the application user and the machine hardware. The successful integration of a functional graph language and a multiprocessor architecture is reported. Author

N89-18485# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Etudes et de Recherches en Informatique.
ROLE AND DESIGN OF A SOFTWARE ENGINEERING DATA BASE IN THE CONTEXT OF AN ADVANCED SUPPORT ENVIRONMENT
MICHEL LEMOINE and LAURENT POMMIER (Ecole Nationale Superieure de l'Aeronautique et de l'Espace, Toulouse, France) *In* AGARD, Software Engineering and Its Application to Avionics 11 p (SEE N89-18446 11-06) Nov. 1988 Sponsored by ESPRIT Programme
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The role and the design of a software engineering data base in an Advanced Support Environment are addressed. A first introduction recalls the evolution of the file mamagement system, from the earlier beginning of the operating system up to now where sophisticated ones are available. It is shown why the classical file managment system is not sufficient in the context of the software development process. Thus object management systems are under consideration. Their role is examined and for some software engineering environment, their main functionalities are exhibited. But because they are independent on the languages they support, the work occurs at the macroscopic semantics of the manipulated objects. Further more, they only concern static (or predefinied) properties of the development process. Thus there is great need for a software engineering data base in which more semantics can be taken into account, especially at the level of the object decription. This will guarantee the consistency of the information stored in a project data bases. Author

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COMPUTER SYSTEMS

Includes computer networks and special application computer systems.

N87-19924# Leicester Polytechnic (England).
APPLICATION OF LAN'S AND ELECTRONIC OFFICE TECHNIQUES IN THE LIBRARY
M. W. COLLIER *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 11 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

The local area network (LAN) is a method of connecting computers and peripherals at very high speed. The technology has been under development since the early seventies and started to become commercially available about 1980. Commercial development accelerated in the early eighties as microcomputers became used for business and professional purposes. Microcomputer LAN's are now a major sector of the office automation industry. This paper reviews the technology and leading types of microcomputer LAN and explores how the technology can be integrated with existing library systems. Normal office automation applications such as word processing, database management, spreadsheets and accounting systems can be implemented in a networked mode. Networking provides the additional benefits of connectivity and resource sharing. In the library context networking is particularly important for electronic mail, information transfer and information sharing. There is potential for integrating downloaded information from external databases into local systems. Office automation applications are fundamental to library and information management. Systems may be seen as sources of management information as well as a medium for transmission. An effective automated office is in effect a decision support system. An automated office is also composed of people, and the introduction of such pervasive technology is complex. Attention must be paid to the human factors which as yet are little understood. Author

N89-18476# International Business Machines Corp., Endicott, NY.
DEFINITIONS AND REQUIREMENTS FOR DISTRIBUTED REAL-TIME SYSTEMS
CHRISTINA BERGGREN *In* AGARD, Software Engineering and Its Application to Avionics 5 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The performance parameters are defined for distributed real-time control systems and the differences in requirements are described between these and the other major categories of distributed real-time systems: resource sharing. Examples of explicit values for the performance parameters are given for some applications. Finally, an evaluation is made of the applicability of existing and emerging communications standards to real-time distributed control systems. Author

N89-18479# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Dynamics Div.
TASK INTERACTIONS IN DISTRIBUTED MACHINES OF EMBEDDED COMPUTER SYSTEMS
D. FLEMMING and H. GRUNDNER *In* AGARD, Software Engineering and Its Application to Avionics 16 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

The programming and implementing of embedded real-time computer systems is one of the most difficult problems of data-processing technology. The parallel and non-deterministic actions within the systems are hard to describe and check. Nearly all languages designed for real-time applications, as e.g., real-time FORTRAN, Coral 66, and RTL/2 *are incomplete tools to solve* the problem of concurrency because of their inherently sequential nature. The programming language Ada offers constructs for the description of task interactions in a very abstract manner without relation on the architecture of the target machine. The *harmonization of a message drive distributing machine architecture* with the programming language Ada, is described. The problem of concurrency is described in general and a communication concept for task interactions is proposed. Analysis of the real-time requirements for future applications leads to the definition of a set of message types, where deterministic and undeterministic task interactions can be achieved. Based on this definition a distributed machine architecture is presented that consists of a network of computing units and an autonomous communication system, designed to reduce all administration work to a minimum. A special no-wait-send communication procedure is modeled in the Ada language. Restrictions and augmentations for Ada programming language are worked out subsequently and demonstrated by examples. It is shown that Ada has valuable constructs for the description of even hard real-time applications by defining the right system concept. This concept is based on a measage-driven distributed machine architecture and an autonomous communication procedure. Author

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CYBERNETICS

Includes feedback and control theory, artificial intelligence, robotics and expert systems.

N87-24945*# National Aeronautics and Space Administration Langley Research Center, Hampton, VA.
ARTIFICIAL INTELLIGENCE AND ITS IMPACT ON COMBAT AIRCRAFT
LAWRENCE M. OTT, KATHY ABBOT, ALFRED KLEIDER, D MOON, and JOHN RETELLE (Defense Advanced Research Projects Agency, Arlington, Va.) *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 4 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01 CSCL 09B

As the threat becomes more sophisticated and weapon systems more complex to meet the threat, the need for machines to assist the pilot in the assessment of information becomes paramount. This is particularly true in real-time, high stress situations. The advent of artificial intelligence (AI) technology offers the opportunity to make quantum advances in the application of machine technology. However, if AI systems are to find their way into combat aircraft, they must meet certain criteria. The systems must be responsive, reliable, easy to use, flexible, and understandable. These criteria are compared with the current status used in a combat airborne application. Current AI systems deal with nonreal time applications and require significant user interaction. On the other hand, aircraft applications require real time, minimum human interaction systems. In order to fill the gap between where technology is now and where it must be for aircraft applications, considerable government research is ongoing in NASA, DARPA, and three services. The ongoing research is briefly summarized. Finally, recognizing that AI technology is in its embryonic stage, and the aircraft needs are very demanding, a number of issues arise. These issues are delineated and findings are provided where appropriate. Author

N88-10813# Centre de Recherches de la Compagine Generale d'Electricite, Marcoussis (France).
GENERATING DIAGNOSTIC KNOWLEDGE FROM A STRUCTURAL AND FUNCTIONAL DESCRIPTION
JEAN-PASCAL AUBERT, JEAN-MICHEL CORNILLE, and ALAIN MELLER *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 4 p (SEE N88-10806 02-08) Aug. 1987 Sponsored by French Defense Ministry
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

The problem of diagnostic knowledge acquisition is discussed. A front-end to a diagnostic system under development that provides aids to the expert in the process of diagnosis rules design is presented. This front-end uses structural and functional modeling. It is thought to be general enough to be applied to other *applications.* Author

N88-10814# *Lear Siegler, Inc., Grand Rapids, MI. Instrument and Avionic Systems Div.*
A REVIEW OF THE KNOWLEDGE ENGINEERING PROCESS
MICHAEL W. BIRD *In* AGARD, Knowledge Based Concepts and Artificial Intelligence: Applications to Guidance and Control 12 p (SEE N88-10806 02-08) Aug. 1987
(AGARD-LS-155) Avail: NTIS HC A07/MF A01

An overview of all parts of the knowledge engineering process is given. The basic types of data structures used for representing knowledge in an expert system are described, including production rules and frames. The computer based tools available for assisting engineers in acquiring and testing knowledge bases are discussed. Also covered is the validation of expert systems. Author

N89-18482# Thomson-CSF, Issy les Moulineaux (France). Expert System Lab.
SPOCK: A TOOL FOR REAL TIME ARTIFICIAL INTELLIGENCE [SPOCK: UN OUTIL POUR L'INTELLIGENCE ARTIFICIELLE TEMPS REEL]
J. P. LACROIX, G. A. BERTHON, FRANCOIS FAGES (Thomson-CSF, Orsay, France), and P. REPUSSEAU *In* AGARD, Software Engineering and Its Application to Avionics 11 p (SEE N89-18446 11-06) Nov. 1988 In FRENCH, ENGLISH summary Translation was announced as N89-10574
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

Airborne expert systems must take into account very harsh real time conditions which, when combined with the environmental conditions of the object computer, require the development of new solutions. The proceduralization obtained by compiling the RETE algorithm toward symbolic, procedural, or real time oriented target languages provides a solution to the primary problems of airborne applications: speed requirements, memory control, harmonization of symbolic parts with the traditional portions of the applications. The approach is supported by the SPOCK family of tools (-LISP, C, LTR3, Ada) developed by the Central Research Laboratory of Thomson-Csf which offers significant improvements over presently available products. One of the SPOCK applications in Thomson-Csf is a helicopter mission and system which takes into consideration the threats and terrain, thanks to integration with an airborne cartographic data base. Author

N89-18484# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
MULTI-INPUT DECISION AID PROCEDURE: APPLICATION TO MULTI-SENSOR TARGET CLASSIFICATION [PROCEDURE D'AIDE A LA DECISION MULTI-INFORMATEURS APPLICATION A LA CLASSIFICATION MULTI-CAPTEURS DE CIBLES]
A. APPRIOU *In* AGARD, Software Engineering and Its Application to Avionics 15 p (SEE N89-18446 11-06) Nov. 1988 In FRENCH
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

A decision making process designed to handle the majority of selection problems associated with multiple information inputs is described beginning with both an objective and exhaustive *formulation of this class of problems. The process described,* characteristic of those incorporated into expert systems capable of carrying on different options in an interactive mode, is illustrated through an application to multi-sensor target classification. This application lends itself to discussion of the behavior of a number of techniques for data fusion and the adaptive formulation of the decision problem. An extension of the decision methods to a resource allocation process is presented. Starting from the simultaneous analysis of preliminary information about a certain number of situations, the resource allocation process allows the processing of one of these situations to be attributed to each of the input sensors, so as to provide the best evaluation of the ensemble of situations. A comparison of various open solutions is carried out by a simulation of the classification scenario. Author

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NUMERICAL ANALYSIS

Includes iteration, difference equations, and numerical approximation.

N87-16377# *Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.*
INTRODUCTION TO FINITE ELEMENT BASICS
A. J. MORRIS *In* AGARD Practical Application of Finite Element Analysis to Aircraft Structural Design 35 p (SEE N87-16376 08-39) Aug. 1986
(AGARD-LS-147) Avail: NTIS HC A07/MF A01

A solution technique which is numerically stable, easily programmed and can be adapted to a wide range of problem types without excessive interference by the user is provided by the finite element method, from a structural viewpoint. The essence of the finite element method involves dividing the structure into a suitable number of small pieces called finite elements. The intersections of the sides of the elements occur at nodal points or nodes and the interference between elements are called nodal lines and nodal planes. For structural problems involving static or dynamic applied loads, the behavior of the structure is defined in *terms of displacements and/or stresses. Within each of the* elements a pattern or shape is selected for the unknown displacement or stress. In the case of a displacement field the shape function defines the behavior of displacements within an element in terms of unknown quantities specified at the element nodes. These nodal values are known as nodal connection quantities and allow the deformation behavior in one element to be communicated to adjacent elements. In the case of an assumed stress field in the element the connection quantities are different but the underlying principle is the same. E.R.

N87-20205# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
***NEW NUMERICAL TECHNIQUES IN THE METHOD OF* SINGULARITIES FOR APPLICATION TO COMPLEX THREE-DIMENSIONAL CONFIGURATIONS [TECHNIQUES NUMERIQUES NOUVELLES DANS LES METHODES DE SINGULARITES POUR L'APPLICATION A DES CONFIGURATIONS TRIDIMENSIONNELLES COMPLEXES]**
T. H. LE, Y. MORCHOISNE, and J. RYAN *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 22 p (SEE N87-20199 13-02) Nov. 1986 In FRENCH Original language document was announced in IAA as A87-21085
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A singularity method for the analysis of steady irrotational inviscid incompressible flows around complex three-dimensional bodies is developed and demonstrated. The technique is based on numerical integration and a steepest-descent solution procedure and employs a simple lumping scheme to improve the accuracy while providing significantly lower computation times than conventional methods. Results for sample problems involving a helicopter fuselage and a wing are presented in tables and graphs. E.R.

N87-20211# *Naval Surface Weapons Center, Silver Spring, MD. Applied Mathematics Branch.*
A SECOND ORDER GODUNOV METHOD FOR TACTICAL MISSILES
A. B. WARDLAW, JR. and S. F. DAVIS *In* AGARD Applications of Computational Fluid Dynamics in Aeronautics 10 p (SEE N87-20199 13-02) Nov. 1986
(AGARD-CP-412) Avail: NTIS HC A19/MF A01

A second order Godunov scheme is described for steady supersonic flow. This scheme, which marches the solution in space, is cast in a finite volume formulation and uses a mesh generated by a multiple zone procedure. Second order accuracy is obtained by computing local slopes and adding a predictor step. The bow shock is fit using the information contained within the Riemann problem. The scheme is applied to body-alone and finned configurations for which measurements are available. Reasonable agreement is obtained between experiment and calculation without the use of artificial viscosity or special procedures. Author

N89-17741# Wayne State Univ., Detroit, MI. Dept. of Mathematics.
ON FUNCTIONAL APPROACH TO RANDOM WAVE PROPAGATION PROBLEMS
P. L. CHOW *In* AGARD, Scattering and Propagation in Random Media 6 p (SEE N89-17706 10-31) Mar. 1988 Sponsored by NSF, Washington, DC
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The method of functional integration for wave propagation through random media is presented. The method is applied to calculate the coherent and mutual coherent functions for a parabolic wave. It is shown that a correction to the parabolic Markovian approximation can be easily made in this setting. Then the method is also applied to the random Helmholtz equation. It is possible to solve this problem by either Feynman's path integral or Wiener's integral. Asymptotic evaluation of such functional integrals is described. Examples and general remarks are provided. Author

N89-17742# Cambridge Univ. (England). Dept. of Applied Mathematics and Theoretical Physics.
NUMERICAL SIMULATION OF WAVE PROPAGATION IN RANDOM MEDIA
MARK SPIVACK *In* AGARD, Scattering and Propagation in Random Media 5 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Numerical simulation of random wave propagation has numerous applications. It enables the examination of individual features of the wave-field and the modeling of actual experiments. Statistical quantities such as average power spectra of intensity fluctuations can also be obtained for comparison with theory. Some of the techniques and uses of numerical simulation are explained and some of the results which emerge are described. Author

N89-17745# Pennsylvania State Univ., University Park. Center for the Engineering of Electronic and Acoustic Materials.
MULTIPLE SCATTERING OF WAVES IN RANDOM MEDIA CONTAINING NON-SPHERICAL SCATTERERS
VASUNDARA V. VARADAN, VIJAY K. VARADAN, and YUSHIEH MA *In* AGARD, Scattering and Propagation in Random Media 8 p (SEE N89-17706 10-31) Mar. 1988
(Contract DAAG29-84-K-0187; DAAG29-85-K-0234)
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The effect of multiple scattering, scatterer geometry, statistics of the positional and orientational distribution functions on the propagation of time harmonic electromagnetic waves in a medium containing a random distribution of nonspherical scatterers are considered. Some of the features that complicate the analysis are: the size of the scatterers is comparable to the wavelength of the propagating wave; the volume fraction occupied by the scatterers need not necessarily be small; and the impedance mismatch between the scatterers and the host medium need not necessarily be small. These in turn necessitate some of the effects to be examined, namely: detailed modeling of scatterer geometry and scatterer response, multiple scattering effects, and the effects of correlations. Some recent results using nonspherical statistics for the second moment of the field are presented. The pair correlation function for spheroidal particles was generated by Monte Carlo simulation as a function of the distance between then and the direction of the vector joining their centers. At present the pair correlation function is being generated for randomly oriented spheroids and the effects of interparticle forces are considered as well as high order correlation functions for clusters of particles. All of these were incorporated into the multiple scattering calculations and compared with available experimental results. Author

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STATISTICS AND PROBABILITY

Includes data sampling and smoothing; Monte Carlo method; and stochastic processes.

N89-17611# Sverdrup Technology, Inc., Eglin AFB, FL. Operations Research Dept.
STATISTICAL TECHNIQUES APPLIED TO ANALYSIS OF AIMPOINT DISTRIBUTIONS
V. DARRYL THORNTON and JOSEPH M. CONRAD *In* AGARD, Guidance and Control of Precision Guided Weapons 8 p (SEE N89-17605 10-15) Nov. 1988
(AGARD-CP-435) Avail: NTIS HC A05/MF A01

The intent is to illustrate the application of several statistical techniques that seek to maximize the amount of information gained. A stepwise multiple regression technique is presented that assists in the identification of significant parameters. Having identified these parameters, a Chi-square goodness-of-fit technique is used to test the hypothesis that the form of the proposed aimpoint distribution is, as an example, bivariate normal. Finally, a second regression technique is presented that generates coefficients corresponding to those parameters that were found to be the most significant. Using these coefficients, sensor performance parameters may then be predicted in those areas where data is sparse. Author

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SYSTEMS ANALYSIS

Includes mathematical modeling; network analysis; and operations research.

N87-16004# Science Applications International Corp., Huntsville, AL.
LETHAL AIR DEFENSE SUPPRESSION TECHNOLOGY BASE DEFINITION
HAROLD L. PASTRICK, JOHN A. FRECH, WILLIAM R. DAY, and ANTHONY BIELE (Air Force Armament Lab., Eglin AFB, Fla.) *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 10 p (SEE N87-16000 08-15) Jun. 1986
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

One of the major thrusts of the Air Force Armament Laboratory is to develop technologies for the advanced weapons required to accomplish lethal defense suppression. In order to develop the long range investment strategy for this thrust, a Technology Base Definition Study for lethal defense suppression was conducted. A major product was a Long-Range Integrated Technology Plan which: identifies specific technology efforts; outlines their required maturity dates to meet the envisioned weapon system needs; and then establishes the investment strategy required to meet the thrust objectives. In addition to, and in support of the development of the long-range plan, a threat survey, a user survey, a system survey, and a technology survey, as well as a cost and operational effectiveness analysis, was conducted and published as separate reports. It was concluded that the required technologies to achieve a cost effective weapon system would best be directed toward a long-range, semi-ballistic missile with a dispenser/submunition warhead. Six major technology areas were described for further research and development exploitation through the year 1998 and a total of eleven elements were defined in the 12 year planning cycle. Author

N87-16006# National Aerospace Lab., Amsterdam (Netherlands).
TACTICAL MISSION PLANNING AND MANAGEMENT
P. J. M. URLINGS and A. L. SPIJKERVET *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 9 p (SEE N87-16000 08-15) Jun. 1986 Previously announced as N87-14198
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

The operational requirements for automation of tactical mission planning and management are summarized. Based on these requirements, the CAMPAL-system is reviewed. Analysis software packages are highlighted, since they provide the CAMPAL-system with planning features for penetration and attack. Developments in tactical mission planning and management suggested by advances in knowledge engineering and expert systems are discussed. ESA

N87-16009# Electronique Serge Dassault, Saint Cloud (France).
GUIDED STAND-OFF WEAPONS AND THE EVALUATION OF MEANS FOR LAUNCH CALCULATION: THE APPLICATION OF NEW TECHNIQUES [LES ARMES GUIDEES TIREES A DISTANCE DE SECURITE ET L'EVOLUTION DES MOYENS DE CALCUL EMBARQUE: L'APPORT DES TECHNIQUES NOUVELLES]
J. P. QUEMARD *In* AGARD Guidance, Control and Positioning of Future Precision Guided Stand-Off Weapons Systems 8 p (SEE N87-16000 08-15) Oct. 1985 In FRENCH
(AGARD-CP-388) Avail: NTIS HC A12/MF A01

The future development and utilization of guided standoff weapons is examined with particular emphasis on the development of required system software. Possible computer/software architectures are described and the utilization of artificial intelligence techniques is discussed. B.G.

N87-24940# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
ADVANCED COMPUTER AIDS IN THE PLANNING AND EXECUTION OF AIR WARFARE AND GROUND STRIKE OPERATIONS
Feb. 1987 140 p In ENGLISH and FRENCH Meeting held in Konjsberg, Norway, 12-16 May 1986 Original contains color illustrations
(AGARD-CP-404; ISBN-92-835-0410-0; AD-A182096) Avail: NTIS HC A07/MF A01

The pace and complexity of modern air warfare have reached the point where advanced computer aids are essential to assist the aircrew and the commander on the ground. Computers are now used extensively in the operation and control of specific equipment, such as advanced weapon systems, surveillance radars, electronic warfare and communications systems. However, there are still many areas which rely heavily on human decision making. The increasing use of Artificial Intelligence (AI) techniques, including Intelligent Knowledge Based Systems (IKBS) and Expert Systems will at one extreme allow decision making to be increasingly automated or controlled by non-expert personnel, and at the other extreme greatly extend the capabilities of military commanders. The successful application of computers should provide improved effectiveness, flexibility, and reliability resulting in a saving of resources and personnel. For individual titles, see N87-24941 through N87-24955.

N87-24941# Software Sciences Ltd., Farnborough (England). Electronic Warfare Dept.
THE USE OF KNOWLEDGE BASED SYSTEMS TECHNIQUES IN ESM PROCESSING
J. H. PALFREYMAN *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 8 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

The Electronic Support Measures (ESM) System attempts to detect, analyze, and classify sources of radio and radar emissions in the environment. The ESM system provides valuable emitter classification information to the host platform's Command and Control System or associated Electronic Countermeasures (ECM) equipment. However, the current generation of Automatic ESM systems often produce ambiguous or incorrect emitter classifications in the adverse conditions of actual conflict. The application of Knowledge Based Systems techniques to ESM processing are described and the development and evaluation of a Knowledge Based ESM system model aimed specifically at improving the emitter classification capability of automatic ESM are outlined. Author

N87-24942# Rome Air Development Center, Griffiss AFB, NY.
DARPA'S AIRLAND BATTLE MANAGEMENT PROGRAM AND USAF'S TACTICAL EXPERT MISSION PLANNER (TEMPLAR)
PETER F. H. PRIEST, II *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 6 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

The Defense Advanced Research Projects Agency (DARPA) has a long history of supporting research in the areas of Artificial Intelligence (AI). The DARPA Strategic Computing Program is developing an AI technology base upon which several applications programs are being built including the AirLand Battle Management Program (ALBM). The ALBM program office is cofunding the U.S. Air Force's first major AI application: Rome Air Development Center's Tactical Expert Mission PLAnneR (TEMPLAR). The TEMPLAR program is an advanced development level effort that is building upon demonstrated systems at the exploratory development level as well as the Strategic Computing tech base. The TEMPLAR program and its links to the AirLand Battle Management and Strategic Computing Programs are described. Author

N87-24943# Rome Air Development Center, Griffiss AFB, NY.
KRS: A KNOWLEDGE-BASED MISSION PLANNER
KEVIN M. BENNER and MICHAEL L. HILTON *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 7 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

The KRS program is a knowledge-based system for planning offensive-counter-air missions. The KRS aides human planners in preparing Air Tasking Orders and can either be used interactively as a plan verifier or autonomously as a plan generator. The KRS informs the user of any logical or doctrinal inconsistencies in a plan, and keeps track of resources and target status. Users can communicate with KRS via a natural language interface, pop-up menus, or a mouse pointing device. An overview of the KRS's capabilities, its knowledge representation schemes, how KRS verifies plans, and how plans are automatically generated, are presented. Author

N87-24944# Rome Air Development Center, Griffiss AFB, NY
DECISION AID FOR THREAT PENETRATION ANALYSIS
ROBERT J. KRUCHTEN *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 7 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

A concept is described for a threat penetration aid. A proof-of-concept version of this aid was built at RADC on a Symbolics 3670 Lisp processing system. Route planning aids were created in the past to find a path through an area of ground threats. Unfortunately these aids tend to be limited by a narrow perspective of the threat environment and a mathematical approach that makes it difficult to add features. The intent of this effort was to create an aid that used heuristic reasoning to simplify the analysis and which had a more global perspective of the environment than the existing aids. Although there is recent work, most notably a TRW effort for in-flight replanning, that offers a more global perspective of the environment than existing aids, the approach used is unique. The concept presented offers great increases in speed over present route planning aids at a slight loss of precision. In addition, the aid goes beyond simple route optimization and can grow to directly assist in choosing tactics, electronic warfare applications, or saturation techniques. It also can quickly add, delete, modify, or move threats. It can take on these additional tasks by exploiting its speed advantage and data structure. The basic architecture of the aid, some of its limitations, its advantages, its growth potential, and finally some recommendations for application development and further research are described. Author

N87-24947# Naval Air Systems Command, Washington, DC
INTEGRATED MULTISENSOR TARGETING
PETER G. KRUEGER, ERNESTO BENITES, DOUGLAS W. COWAN, W. RODNEY DITZLER, and ALFRED G. SUTTON (Naval Weapons Center, China Lake, Calif.) *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 9 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

The integrated multisensor targeting effort is a United States Navy Exploratory Development program directed at the development and demonstration of multisensor targeting algorithms for air-to-air application. The program for developing the capability is described. The current algorithm development is presented. The simulation tool and the real-time system which support the development and demonstration of the algorithms, respectively, also are described, and finally the plans for testing the capability are discussed briefly. Author

N87-24951# Naval Weapons Center, China Lake, CA.
CONSOLIDATED LAND ATTACK MISSION PLANNING STATION (CLAMPS)
ROBERT T. HINTZ, M. J. BOYD, and D. LUBBEN *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 14 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

The proposed mission planning station described is a result of a Naval Weapons Center discretionary funded study performed in conjunction with the AV-8B Program Office in 1985. The approach described draws heavily on the development and deployment of digital map technology for use on modern attack aircraft. The characteristics of the digital map are derived from a draft product specification currently being prepared for submission to the Defense Mapping Agency (DMA), and the AV-8B requirements document for a digital map capability. The envisioned digital map would utilize optical disk storage for the map, and additional solid state storage for the annotation generated by the planning station. The mission planning station is shown in three configurations ranging from a baseline capability (which may even be appropriate for an individual aircraft), up to a fully capable station capable of interacting with other digital data bases and even generating its own optical disk. Author

N87-24952# National Aerospace Lab., Amsterdam (Netherlands).
AUTOMATION STRATEGY AND RESULTS FOR AN AIRBASE COMMAND AND CONTROL INFORMATION SYSTEM (ABCCIS)
R. P. DEMOEL and W. N. VANDRANEN (Royal Netherlands Air Force, The Hague.) *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 18 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

Automation is considered the appropriate way to improve the effectivity of preparation and deployment of weapon systems in the increasingly complex scene of battle. This automation is aiming for the support of the activities, because, according to the opinion of the RNLAF, human intellectural capacity is essential to a balanced commercial and control process. Human intelligence and creativity combined with speed and storage capacity of the computer may improve the quality of the preparation and the effectivity of the deployment of weapon systems. Author

N87-24953# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
CURRENT STATE OF AN EXPERT SYSTEM [TENUE A JOUR DE SITUATION PAR SYSTEME EXPERT]
GERARD KITTEN and LOIC LEGUISQUET *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 4 p (SEE N87-24940 18-66) Feb. 1987 *In FRENCH*
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

Artificial intelligence methods are discussed in the context of decision aid systems employed by the french tactical air force. In particular, the development and use of an expert system for military C3I (command, control, communications and intelligence) is addressed. M.G.

N87-24954# Electronic System G.m.b.H., Munich (Germany, F.R.)
COMPUTER AIDED SENSOR PLACEMENT OPTIMIZATION
A. KAINZINGER and W. RATH *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 7 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

The problem of optimal sensor placement increases with the mobility of the sensors. Threats e.g., caused by missile technologies lead to sensor systems, where some of the sensors are highly mobile. Thus the optimization of sensor placement for a given surveillance area becomes a complex and time critical task if constraints (operations areas, terrain nodulation, terrain accessability, sensor capabilities, tactical objectives, and assumed tactical objective of the WP forces) are taken into account. A layer model is presented for the computer aided stepwise optimization of sensor placement. The computer tool is based on digitized terrain data containing information about the height and cultures. The layer model is based on interactive procedures and automatic decision guidance. The software can be installed on minicomputers with a color display and color printer thus making it a mobile transportation tool which can be used online in the field. Author

N87-24955# Marconi Avionics Ltd., Rochester (England). Airborne Display Div.
AN INTEGRATED AIRCRAFT NAVIGATION AND DISPLAY SYSTEM UTILISING AN ON-BOARD COMPOSITE DATA BASE
M. L. BUSBRIDGE and D. J. PULESTON *In* AGARD Advanced Computer Aids in the Planning and Execution of Air Warfare and Ground Strike Operations 4 p (SEE N87-24940 18-66) Feb. 1987
(AGARD-CP-404) Avail: NTIS HC A07/MF A01

It is likely that future aircraft will contain a central data base containing feature details, ground elevation, low flying obstruction data, intelligence, and mission data. Recent advances in technology have made it possible to implement such a data base within an aircraft. The existence of a central data base facilitates many functions for both low level ground attack and air defense aircraft. These functions include: improved moving map displays, precision navigation systems, covert radar shadowing, surface to air missile site intervisibility, and perspective terrain displays for use in adverse visibility conditions. The integration of such a system is currently being finalized and forms part of an ongoing flight trials program in fixed wing jet aircraft. Author

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ACOUSTICS

Includes sound generation, transmission, and attenuation.

N89-17737# Cambridge Univ. (England). Ocean Acoustics Group.
INTENSITY FLUCTUATIONS DUE TO MOVING POINT SOURCES
B. J. USCINSKI *In* AGARD, Scattering and Propagation in Random Media 7 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

An understanding of point sources in random media is essential if dealing with real sources, and effects such as source motion. Reliable theory now exists for the intensity fluctuations due to point sources in such media. Numerical simulations of such fluctuations agree with theoretical results. The intensity fluctuation theory and simulations were extended to deal with the case of a moving source and observer. It is shown that as regards ensemble averaged quantities such as the intensity fluctuation spectra there is reciprocity between motion of the source and that of the observer. However, such reciprocity does not exist if one is dealing with the detailed fluctuation pattern arising in a particular realization of a random medium. Author

N89-17740# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Electrical Engineering.
ON THE APPLICABILITY OF CONTINUOUS SCATTERING METHODS TO DISCRETE SCATTERING PROBLEMS
IOANNIS M. BESIERIS *In* AGARD, Scattering and Propagation in Random Media 6 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The equivalence between continuous and discrete scattering modeling was examined at two statistical levels: the direct interaction/ladder approximation (continuous) - Twersky approach (discrete), and the first order smoothing approximation (continuous, discrete). Full first and second order moment equivalence was established only at the level of the first order smoothing (or bilocal) approximation and, even then, for soft scatterers with weak transition operators. Author

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OPTICS

Includes light phenomena; and optical devices.

N87-13273# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propulsion Panel.
GUIDED OPTICAL STRUCTURES IN THE MILITARY ENVIRONMENT
H. HODARA, ed. and P. CROSIGNANI, ed. May 1986 310 p Meeting held in Istanbul, Turkey, 23-27 Sep. 1985
(AGARD-CP-383; ISBN-92-835-0391-0; AD-A171227) Avail: NTIS HC A14/MF A01

A new technology has arisen and is expanding quickly; single mode structures in the form of optical fibers and planar waveguides operating at long wavelength, 1.3 micron and beyond, with minimum attenuation and dispersion. Fibers with attenuation below 0.5 dB/km, and bandwidths in the hundreds of GHz-Km have opened up *long* distance, repeaterless transmission on land and underwater. In addition, the single mode structure has bred a new class of passive devices: sensors capable of detecting sound, magnetic field, motion, temperature, humidity and many other characteristics, all of them approaching the theoretical detection limit. New active components are developing: single mode, high efficiency, long life chips operating at room temperature, electro-optic switches and components capable of generating new frequencies through Raman scattering and other nonlinear phenomena. For individual titles see N87-13274 through N87-13306.

N87-13274# Naval Research Lab., Washington, DC.
PROGRESS IN OPTICAL FIBER SENSORS
T. G. GIALLORENZI *In* AGARD Guided Optical Structures in the Military Environment 13 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

A review of the status of Optical Fiber Sensor Technology is presented and the effects of laser noise and demodulation techniques on performance are reviewed. Recent work on the development of fiber telemetry scheme for use with optical fiber sensors is also detailed. Author

N87-13276# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
COMPARISON OF RING LASER AND FIBER-OPTIC GYRO TECHNOLOGY
E. UDD, S. F. WATANABE, and R. F. CAHILL *In* AGARD Guided Optical Structures in the Military Environment 14 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Substantial progress has been made in recent years toward the development of producible fiber-optic rotation sensors. These devices have the potential of being the solid-state replacement for many applications currently using mechanical gyro technology. Ring laser gyro technology which has been under development for approximately 23 years is now being introduced into commercial and military aircraft for inertial navigation. The fundamentals of the usage of Sagnac interferometry for rotation sensing is reviewed as well as the differences between fiber-optic gyro and ring laser gyro technology. Examples are given of applications where fiber-optic gyro or ring laser gyro technology is particularly suitable. Distinctions are made between analog fiber-optic gyros which offer the lowest possible cost but are limited in performance capability and digital fiber-optic gyros which offer the wide dynamic range and accurate scale factor correction required for more stringent applications. Author

N87-13277# Litton Systems (Canada) Ltd., Rexdale, (Ontario). Advanced Optical Systems Group.
CLOSED LOOP FIBER OPTIC GYRO
D. H. LEWIS, B. BEDNARZ, J. A. DANKOWYCH, K. JEW, G. JOSLIN, and W. A. YOUNG *In* AGARD Guided Optical Structures in the Military Environment 10 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

A breadboard closed loop gyroscope using ordinary single mode fiber and a multi-mode diode laser is described. Closed loop rotation rate bias stability data are presented for both short term and long term. The performance of the gyro is displayed in the frequency domain as well as in the time domain. The performance achieved was a rotation rate noise of 5 deg/hr for 1 sec. integration, 0.55 deg/hr for 100 second integration and an extrapolated drift of 0.09 deg/hr. The long term (6 hours) bias stability was 1 deg/hr. Author

N87-13278# Plessey Co. Ltd., Romsey (England).
PROGRESS WITH MULTIPLEXED SENSOR ARRAYS BASED ON REFLECTION AT SPLICED JOINTS BETWEEN SENSORS
J. P. DAKIN, C. A. WADE, and P. B. WITHERS *In* AGARD Guided Optical Structures in the Military Environment 6 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Recent progress made in developing a time-division-multiplexed, fiber optic hydrophone array using optical time domain reflectometry (OTDR) techniques is reported. Recently, improvements have been made in four main areas: (1) development of partially reflecting splices; (2) development of a high power single mode gas laser for use in the present system; (3) development of a balanced-optical-path arrangement to allow shorter coherence length sources to be used in future systems; and (4) development of an *all-fiber* frequency shifter, with the ultimate aim of producing a complete all-fiber system. E.R.

N87-13279# Plessey Co. Ltd., Romsey (England).
MAGNETIC AND PRESSURE SENSORS USING THE COMPENSATED POLARIMETRIC SENSOR CONFIGURATION
J. P. DAKIN, C. R. BATCHELLOR, and J. A. REX *In* AGARD Guided Opitcal Structures in the Military Environment 7 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The identical lengths of high birefringence fiber spliced together with a 90 deg axial rotation to couple their orthogonal birefringent axes form the basis of a compensated polarimetric optical fiber sensor. This can be used to detect differential strains in the two fiber lengths caused by such phenomena as hydrostatic pressure or magnetic fields (the strain being introduced by magnetostrictive material bonded to the fiber). Magnetic and pressure sensors were constructed using this principle and show good sensitivity yet better stability then Mach-Zehnder arrangements. Author

N87-13280# Consiglio Nazionale delle Ricerche, Florence (Italy). Istituto de Ricerca sulle Onde Elettromagnetiche.
FIBER OPTIC DEVICE FOR TEMPERATURE REMOTE SENSING
A. M. SCHEGGI, M. BRENCI, G. CONFORTI, F. COSI, R. FALCIAI, and A. G. MIGNANI *In* AGARD Guided Optical Structures in the Military Environment 5 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

An optical-fiber temperature sensor is presented which is based on light amplitude modulation induced by a thermosensitive cladding applied on the distal end of the fiber. The experimental set-up for detecting and processing the signal is described, and the measured characteristics of the thermometer are reported. Author

N87-13281# National Bureau of Standards, Boulder, CO.
OPTICAL FIBER SENSORS FOR THE MEASUREMENT OF PULSED ELECTRIC CURRENTS
G. W. DAY, J. D. O. MCFADDEN, L. R. VEESER (Los Alamos National Lab., N. Mex.), G. I. CHANDLER, and R. W. CERNOSEK (Sandia National Labs., Albuquerque, N. Mex.) *In* AGARD Guided Optical Structures in the Military Environment 9 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Recent progress in the design of fiber sensors for pulsed electric currents is reviewed. Several of the most useful sensor configurations are described and compared. Models are used to predict the transfer function of these sensors, their sensitivity to non-ideal fiber properties, particularly linear birefringence, and methods for overcoming these problems. Other recent research is examined to suggest the prospect for sensors with improved sensitivity and stability. Author

N87-13282# *Fondazione Ugo Bordoni, Rome (Italy).* Istituo Superiore P. T.
NONLINEAR ELLIPSE ROTATION IN A LOW-BIREFRINGENCE OPTICAL FIBER
B. CROSIGNANI, S. TRILLO, P. DIPORTO, and S. WABNITZ *In* AGARD Guided Optical Structures in the Military Environment 3 p (SEE N87-13273 04-74) May 1986 Prepared in cooperation with Rome Univ., Italy
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The rotation of the polarization ellipse taking place in a low-birefringence single mode optical fiber and associated with the nonlinear optical Kerr effect is theoretically investigated. A detailed description of a proposed experiment for measuring the nonlinear refractive index through the ellipse rotation is also furnished. Author

N87 13283# Thomson-CSF, Orsay (France). Lab. Central de Recherches.
PROGRESS IN OPTICAL FIBER GYROSCOPES USING INTEGRATED OPTICS
H. C. LEFEVRE, J. P. BETTINI, S. VATOUX, and M. PAPUCHON *In* AGARD Guided Optical Structures in the Military Environment 13 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

A quarter of a liter brass-board of a fibergyro using a multifunction integrated optic circuit (splitter, polarizer and phase modulator), a superluminescent diode and 250 meters of polarization holding fiber is described. The photon noise limited random walk performance is 0.004 deg/sq. rt. H. A simple model to evaluate birefringence induced non-reciprocities, and an original method of signal processing, the digital phase ramp, to solve the problem of scale factor linearity and accuracy are also presented. Author

N87-13284# Bell Telephone Labs., Inc., Murray Hill, NJ.
WAVELENGTH DIVISION MULTIPLEXING AT 1.5 MICRONS FOR HIGH CAPACITY OPTICAL TRANSMISSION
J. HEGARTY, N. A. OLSSON, and R. A. LOGAN *In* AGARD Guided Optical Structures in the Military Environment 8 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

A method is described for multiplexing several channels of information, closely spaced in wavelength, together in one single-mode fiber. The results are reported of a recent 10-channel experiment at 1.5 micrometers in which 10 distributed feedback lasers, modulated at 2 Gbits/s, were multiplexed together and transmitted over 68.3 km of fiber giving a system capacity of 1.37 terabit-km/s. The channel spacing was 1.35 nm and the multiplexer insertion loss was 3 db. Crosstalk, including Raman crosstalk, was found to be negligible. Author

N87-13285# Consiglio Nazionale delle Ricerche, Florence (Italy). Istituto di Recerca sulle Onde Elettromagnetiche.
A SPHERICAL WAVEGUIDE MULTIPLEXER-DEMULTIPLEXER
V. RUSSO, S. SOTTINI, G. C. RIGHINI, and S. TRIGARI *In* AGARD Guided Optical Structures in the Military Environment 8 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

A wavelength multiplexer-demultiplexer (MUX - DEMUX) which can work also a tapping element was suggested and tested. This device is based on the imaging properties of a hemispheric geodesic lens. The aberrations of this lens were evaluated and some examples of the potential performance of the device are given: in particular the MUX - DEMUX seems to be quite interesting in the case of monomode fibers, showing a diffraction limited performance. Experimental tests are in progress, utilizing a spherical waveguide fabricated by ion exchange on a glass substrate, and gratings with 540 or 1200 grooves/mm. The results already available are quite encouraging and confirm the expected advantages of this approach with respect to previous devices. Author

N87-13287# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
OPTICAL QUADRATURE DEMODULATOR FOR COHERENT DETECTION AND SENSOR APPLICATIONS
S. F. WATANABE, A. A. JOSEPH, H. B. TURNER, S. A. HOLMES, and J. T. FREIDAH *In* AGARD Guided Optical Structures in the Military Environment 6 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

A new device was designed, built and demonstrated which provides exceptional performance in a very small, potentially very low cost unit. Balanced quadrature detection for homodyne or heterodyne detection of phase or frequency encoded signal information is accomplished with microradian phase sensitivities over a broad range of environments and for a broad dynamic range of signal levels and frequencies. Results of current development testing are presented along with brief discussions of potential applications to coherent detection for interferometers, sensors, and communications. Author

N87-13288# *Siemens A.G., Munich (Germany, F.R.).* Research Labs.
EFFECTS OF OPTICAL FEEDBACK ON THE PERFORMANCE OF HIGH DATA RATE SINGLE-MODE FIBER SYSTEMS
R. KEIL, K. MATHYSSEK, and E. HOERMANN *In* AGARD Guided Optical Structures in the Military Environment 15 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Performance measurements data accomplished on a 678 Mbit/s single-mode fiber optic transmission system for various laser diode structures and more importantly under different near- and far-end optical feedback conditions are presented. Specifically, for two integral coupling schemes i.e., the drawn fiber taper with a lens and hemispherically ended graded index fiber lens (GRINFLENS) the near-end optical feedback are modelled and simple method for its experimental assessment are given. Feedback induced variations of lasing spectra and of mode partition noise and their influences on bit error rate (BER) data are experimentally determined for a dispersive single-mode fiber transmission link with the two coupling arrangements. Comparative measurements were done with a butt-coupled fiber and with a non-dispersive fiber system. Furthermore, far-end reflections from a connector joint and their quantitative influence on BER data were investigated. Author

N87-13289# Barr and Stroud Ltd., Glasgow (Scotland).
PERFORMANCE OF INTEGRATED OPTICAL FREQUENCY SHIFTERS PIGTAILED TO HIGH BIREFRINGENCE FIBRES USING ION-MILLED GROOVES
I. ANDONOVIC, W. JOHNSTONE, D. N. MACFADYEN, A. MCDONACH, M. S. NER, and S. BEAUMONT *In* AGARD Guided Optical Structures in the Military Environment 8 p (SEE N87-13273 04-74) May 1986 Prepared in cooperation with Glasgow Univ., Scotland
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The practical application of lithium niobate integrated optical devices in the severe military environments that will be experienced by the fiber optic gyroscope, requires the development of a cheap, efficient and robust means of interconnecting optical fibers and integrated optical chips. One technique for fiber to chip coupling is the use of ion-milled alignment grooves in the Lithium Niobate substrate to accurately locate the fiber end with the end of the waveguide. This technique uses a photolithographic process for the most precise alignment stages and is therefore amenable to mass production and automation. Efficient coupling of light was observed between optical fibers chemically etched to a diameter of about ten microns and waveguides formed by the indiffusion of

titanium. The use of chemically etched optical fibers and ion-milled grooves allows a high packing density of chip/fiber connections, offereing space saving in terms of device lengths as well as lateral separation. Results are presented for the coupling of light to integrated optical waveguides from high birefringence optical fibers using ion-milled alignment grooves, and the degree of polarisation preservation achieved is related to the performance of integrated optical phase modulators. Author

N87-13290# Arizona Univ., Tucson. Optical Sciences Center.
NONLINEAR PLANAR GUIDED WAVE INTERACTIONS AND DEVICES
G. I. STEGEMAN, C. T. SEATON, and H. G. WINFUL (GTE Labs., Inc., Waltham, Mass.) *In* AGARD Guided Optical Structures in the Military Environment 9 p (SEE N87-13273 04-74) May 1986 (AGARD-CP-383) Avail: NTIS HC A14/MF A01

A variety of applications of third-order nonlinear integrated optics to optical signal processing are discussed. These include guided wave devices based on an intensity-dependent refractive index such as upper and lower threshold devices, all-optical switching devices, all-optical modulation devices, optical logic, and optical bistability. Multiple waveforms mixing with degenerate four-wave mixing to produce signal convolution and time inversion on a picosecond time scale are also discussed. Author

N87-13292# Arizona Univ., Tucson. Optical Sciences Center.
INTEGRATED OPTICS OPTICAL LIMITERS
C. T. SEATON, J. D. VALERA, and G. I. STEGEMAN *In* AGARD Guided Optical Structures in the Military Environment 7 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Two novel, low-power, guided-wave optical limiters were demonstrated. Both are based on intensity-dependent refractive indices and involve phenomena unique to optical waveguides. The first utilizes newly discovered nonlinear guided waves that exhibit optical-limiting action for a film bounded by a nonlinear medium. The second relies on an intensity-dependent reduction in coupling efficiency when waveguide modes are excited by prism or grating couplers. In both cases, preliminary experiments have demonstrated optical limiting action. Author

N87-13293# *ANT Nachrichtentechnik, Backnang* (Germany, F.R.).
PIN-FET PREAMPLIFIER FOR HIGH-SPEED OPTICAL TRANSMISSION SYSTEMS
B. SCHWADERER *In* AGARD Guided Optical Structures in the Military Environment 6 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The design of a hybrid integrated PIN-FET transimpedance preamplifier is given for long-haul optical transmission systems at 1.3 micrometers wavelength with bit rates of 140 Mbit/s and 565 Mbit/s. The preamplifier uses a GaInAs/InP PIN-photodiode with a dark current of less than 10 nA, a high spectral responsivity of greater than 0.7 A/W at 5V bias supply and a GaAs-MESFET with 45 mS transconductance and about 0.7 pF input capacitance. Using transimpedance-resistors of 50 kilo-ohm and 25 kilo-ohm the design goals of receiver sensitivities are -43 dBm for the 140 Mbit/s system and -36.7 dBm for the 565 Mbit/s system respectively for BER equal to or less than 10(-9). The measured values of - 42.8 dBm and - 35.8 dBm including connector losses are within the predicted ranges. Author

N87-13295# Siemens A.G., Munich (Germany, F.R.). Research Labs
ACOUSTOOPTIC SPECTRUM ANALYZER USING A PLANAR BRAGG-CELL
M. STOCKMANN and P. CLEMENS *In* AGARD Guided Optical Structures in the Military Environment 5 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The design principles and the performance characteristics of a miniaturized acoustooptic RF-spectrum analyzer are presented. The device yields a time-band-width-product of more than 300. Using a planar Bragg-cell fabricated on a LiNbO3 substrate and air between Bragg-cell and detector array the time-bandwidth-product was doubled compared to the minibulk as well as the integrated optic spectrum analyzer for the same device length. The time resolution of the spectrum analyzer is 33 usec and its linear dynamic range 28 dB. Author

N87-13296# Naval Research Lab., Washington, DC. Optical Sciences Div.
PREPARATION AND PROPERTIES OF INFRARED TRANSMITTING HEAVY METAL FLUORIDE GLASS OPTICAL FIBERS
D. C. TRAN *In* AGARD Guided Optical Structures in the Military Environment 6 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

In present silica fiber technology, optical attenuation at the intrinsic minimum level of about 0.15 dB/km at 1.6 micrometer has been attained. Non-oxide glasses based on heavy metal fluorides potentially can offer intrinsic minimum losses several orders of magnitude lower than that of silica, owing to a lower Rayleigh scattering loss contribution and an extended infrared absorption edge. As a result, heavy metal fluoride glasses are most promising for long distance repeaterless optical communication heavy metal fluoride glasses are most promising for long distance repeaterless optical communication systems. The published literature on fluoride glasses and fiber is studied to provide a complete review of the present state-of-the-art in the field. Candidate fluoride glasses for fiberization are evaluated on the basis of their infrared transparency as well as their glass forming ability. The synthesis of high optical quality bulk fluoride glasses by conventional casting and the fabrication of fibers using both preform and crucible techniques are discussed. The optical properties of the fluoride glass fiber are evaluated based on the absorption loss contribution associated with hydroxyl groups and transition metal/rare-earth impurities, and on the scattering loss component arising from both Rayleigh scattering and processing induced defects such as microcrystallization, phase separation and particle inclusions. Author

N87-13297# Standard Telecommunication Labs. Ltd., Harlow (England).
GLASS FIBRES FOR TRANSMISSION IN THE 8-12 MICROMETERS WAVEBAND
N. J. PITT and M. G. SCOTT *In* AGARD Guided Optical Structures in the Military Environment 8 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Chalcogenide glasses, crystalline halides and hollow waveguides were assessed for transmission in the 8 to 12 micrometer waveband. Of these, chalcogenide glasses were selected for development of fiber optic materials. The bulk properties of a range of glasses were studied and compositions chosen to optimize transmission and thermal stability. The role of major impurities and the procedures used to minimise them are described. Selected compositions were drawn into long lengths of polymer coated fiber with diameters controlled accurately up to 500 micrometers. Current fibers transmit at CO2 laser wavelengths with losses of 5 to 10 dB/m but potential for substantial improvement still exists. Mechanical testing has shown that with suitable coatings chalcogenide fibers are flexible enough to sustain a bend radius of the order of 1 cm. Author

N87-13298# Stanford Univ., CA. Crystal Science Div.
SINGLE CRYSTAL FIBERS
R. S. FEIGELSON *In* AGARD Guided Optical Structures in the Military Environment 9 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Single crystal fibers are just now emerging as a new frontier in both materials science and device technology. Various methods have already been developed for the preparation of single crystal fibers of a wide range of materials with useful properties. Along with discussions of fiber growth methods and potential applications for single crystal fibers, current research on the growth of laser, nonlinear optic, and IR transmitting single crystal fibers are also discussed. Author

N87-13299# Rennes Univ. (France). Lab. de Chimie Minerale D.

FLUORIDE GLASSES FOR INFRARED WAVEGUIDES [VERRES FLUORES POUR GUIDES D'ONDE INFRA ROUGE]

J. LUCAS *In* AGARD Guided Optical Structures in the Military Environment 7 p (SEE N87-13273 04-74) May 1986 In FRENCH

(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The realization of optical waveguides is more promising beginning with materials in the glassy state than to begin with polycrystalline or monocrystalline materials. At the present time, the glasses which correspond to the best compromise between the bandwidth of transmission, the ultra-transparence potential, low diffusion loss, and fiber preparation techniques are the fluoride glasses. The tetrafluoride glasses with a zirconium base permits transmission through fiber of up to 4 microns, those with a base of the heavy metals (thorium, indium, rare earths, etc.) up to 5 microns. The potential applications in long distance telecommunications (considering very low theoretical losses, 10(-3) dB/km) are discussed as well as short distance applications involving collection technologies and energy transport. Author

N87-13300# British Telecom Research Labs., Ipswich (England).

WIDE BANDWIDTH, LONG DISTANCE FIBRE-OPTIC COMMUNICATION SYSTEMS

S. D. WALKER, L. C. BLANK, and L. BICKERS *In* AGARD Guided Optical Structures in the Military Environment 9 p (SEE N87-13273 04-74) May 1986

(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Recent advances in laser, fiber and receiver technology have allowed a series of unrepeated optical transmission system experiments to be carried out. These spans ranged from 90 km to 250 km at line-rates from 34 Mbit/s to 2 Gbit/s. At data-rates of 34 Mbit/s and 140 Mbit/s, a single-line 1.525 micrometers distributed feedback laser was used in conjunction with step-index monomode fiber spans up to 251.6 km. In a second set of experiments, a 1.55 micron multi-longitudinal-mode laser gave error-free transmission over lengths of dispersion-shifted fiber up to 233 km. For gigabit transmission experiments, a 1.535 micron single-line laser and dispersion-shifted fiber provided a further systen option which resulted in a recent fully-regenerated 2 Gbit/s, 90 km trial featuring commercially-available GaAs logic components. The various system configurations implemented are described and the technical options for further long-span, unrepeatered optical transmission experiments using current and developmental direct-detection technology in the 1.5 micron wavelength region are reviewed. Author

N87-13301# TRW, Inc., Redondo Beach, CA. Fiber Optic Communications.

PERFORMANCE OF RF FIBER OPTIC LINKS

T. R. JOSEPH and W. E. STEPHENS *In* AGARD Guided Optical Structures in the Military Environment 12 p (SEE N87-13273 04-74) May 1986

(AGARD-CP-383) Avail: NTIS HC A14/MF A01

RF fiber optic links have numerous applications to microwave systems. To fully exploit their usefulness, the RF system designer must understand their properties in terms of the performance parameters that are used to describe the terminal properties of other RF components such as loss, signal to noise, linearity, and dynamics. The performance of direct and external modulation fiber optic links in terms of those parameters are explained. Specific examples of a 4.1 to 4.7 GHz direct modulation link and a 2.0 to 12.0 GHz external modulation link are used. Author

N87-13302# Shape Technical Center, The Hague (Netherlands).

FIBER OPTICS: A SURVIVABLE AND COST-EFFECTIVE TRANSMISSION MEDIUM FOR TERRESTRIAL NETWORKS

M. ASLAM *In* AGARD Guided Optical Structures in the Military Environment 10 p (SEE N87-13273 04-74) May 1986

(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The performance of a fiber-optic transmission system is affected by nuclear radiation. The nuclear scenario is discussed vis the terrestrial network, the essential characteristics are identified, and on this basis the principles for the design of a strategic communication fiber-optic cable system are derived. The details of a cost analysis applicable to various scenarios are also given; the costs of each scenario are compared with those of a microwave line-of-site system of approximately the same capacity. Author

N87-13303# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Dynamics Div.

SINGLE-MODE-FIBERS FOR FIBEROPTIC-GUIDED MISSILES: A COMPARISON WITH GRADED-INDEX MULTIMODE FIBERS

K. H. NIEDERHOFER and W. D. SCHUCK *In* AGARD Guided Optical Structures in the Military Environment 8 p (SEE N87-13273 04-74) May 1986

(AGARD-CP-383) Avail: NTIS HC A14/MF A01

For a few years there have been activities in the application of optical fibers as a broadband, secure transmission medium between a ground-station and tactical missiles for ranges of about 10 km. The idea is to put the gunner's eye, i.e., a suitable imaging device, into the missile to provide a lock-on-after-launch capability together with a man-in-the-loop option. A key problem is the rapid payout of the fiber from the missile during flight. Several successful flight test campaigns have been carried out, where Kevlar-reinforced graded-index multimode fibers have been used for transmission of command- and TV-signals. The affects of additional attenuation resulting from the reinforcement, the bobbin-technology and payout process are well controlled. For the first development of fiberoptic guidance systems single-mode transmission was not taken into account, since the suitable components were expensive, sensible and not readily available. Today the single-mode technology is quite advanced and offers some benefits compared with multimode transmission. The most important points are the higher bandwidth and the lower attenuation. As long as the missile range is below 10 km, this is no decisive advantage, but it encourages the extension of the missile range to much more than 10 km. The comparison of costs gives no clear-cut statement, but the production costs for single-mode fibers tend to be below that of multimode fibers. If the hardness against nuclear radiation is compared, single-mode fibers give the better results. Author

N87-13304# Hughes Research Labs., Malibu, CA.

LIGHTWAVE TECHNOLOGY IN FUTURE RADAR EQUIPMENT DESIGNS

C. M. GEE, A. E. POPA, and H. W. YEN *In* AGARD Guided Optical Structures in the Military Environment 8 p (SEE N87-13273 04-74) May 1986

(AGARD-CP-383) Avail: NTIS HC A14/MF A01

Lightwave device technology can be implemented in future active aperture radar arrays. Transmitter and receiver components for a fiber optic antenna feed manifold in which the transceiver modules are connected to a central computer are reviewed. Present link signal to noise limitations imposed by the performance of these components are analyzed, and promising trends in component development are discussed. Author

N87-13305# Army Communications-Electronics Command, Fort Monmouth, N.J.

TACTICAL FIBER OPTIC ASSEMBLY REQUIREMENTS

V. E. KALOMIRIS *In* AGARD Guided Optical Structures in the military Environment 9 p (SEE N87-13273 04-74) May 1986

(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The unique features of militarized fiber optic assemblies are outlined. The stringent requirements that make tactical deployment a challenge to the fiber optic industry are summarized. The requirements are broken down to the component level: fiber, cable and connector. These demands on components are necessary to assure successful system operation. The compilation of specifications is presented in tabular form to serve as a reference for those interested in satisfying a host of ground systems needs. The significance of the performance of the cable assembly in the performance of the optical subsystem is also described. In addition, the requirements that the transceivers have to meet are reported and a comparison of the tactical and fixed plant is presented.

E.R.

N87-13306# Bell Communications Research, Inc., Morristown, NJ. Exchange Network Research Div.
A HYBRID TRANSMISSION SCHEME ON SINGLE MODE FIBERS FOR TACTICAL COMMUNICATIONS
S. S. CHENG *In* AGARD Guided Optical Structures in the Military Environment 6 p (SEE N87-13273 04-74) May 1986
(AGARD-CP-383) Avail: NTIS HC A14/MF A01

The availability of single-mode fibers and long wavelength devices enables the system designers to consider new link design with much improved performance not presently available in either the multimode fiber or the traditional metallic conductor systems. A hybrid transmission scheme is proposed on single-mode fibers in a star configuration. At the command post, a primary laser and its standby laser running at the cw mode are followed by an optical splitter. Each output port is then externally modulated for downstream transmission. At each remote site, a dedicated LED is used for upstream transmission where the bandwidth requirement and therefore the dispersion penalty is generally lower. The cost, reliability and flexibility of this hybrid transmission scheme are examined. The use of bidirectional WDM devices and remote external modulators with polarization control is described as two potential variations to enhance this basic hybrid scheme. The deployment of such a system will provide cost effective transmission links in a tactical environment suitable for high bandwidth analog and digital transmission. Author

N87-18747# Naval Weapons Center, China Lake, CA.
CONSIDERATIONS IN UTILIZING IR SIGNATURES Abstract Only
WAYNE H. TANAKA *In* AGARD Multifunction Radar for Airborne Applications 1 p (SEE N87-18721 11-32) Jul. 1986
(AGARD-CP-381) Avail: NTIS HC A10/MF A01

The relationships of RF and IR systems, characteristics of both active and passive IR sensor data, and applications of laser radar sensors are discussed and illustrated with signature data. The radar equation and how it is used by both the RF and laser radar communities are shown including a carrier-to-noise budget analysis performed for both technologies for a proposed altimeter development. This leads to a consideration of the basic features that an active and passive IR sensor can exploit from a target. Issues of background rejection are raised. A general discussion of the types of uses the DOD is considering for laser radars follows. These include altimetry, Doppler navigation, obstacle avoidance for avionics, and remote sensing lidar. Examples of signatures included are forward-looking-infrared (FLIR) data of ships taken under Navy Target Signatures Program (TSP) auspices, active CO2 laser radar signatures of ships, again taken under TSP auspices, within the last two years, and laser radar signatures of tanks and vehicles. Author

N87-21186# Sandia National Labs., Albuquerque, NM.
SAPPHIRE FIBER OPTIC TEMPERATURE PROBE
D. A. TICHENOR, K. R. HENCKEN, and R. W. BICKES, JR. *In* AGARD Advanced Instrumentation for Aero Engine Components 5 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

A sapphire fiber optic pyrometer was developed for use in combustion environments. Two configurations of the device are described. One is designed to measure rapid gas temperature fluctuations and the other is designed to measure the rapid temperature rise in a confined pyrotechnic prior to ignition. The key element in the device is a high temperature optical fiber made of single-crystal alumina (sapphire) with a thin film of platinum deposited on one end. Temperature is derived from the intensity of thermal radiation emitted by the platinum and collected by the fiber. The device is capable of measuring rapid gas temperature fluctuations, in excess of 10kHz, in harsh environments where thermocouple life is severely limited by oxidation, corrosion, or erosion. A second configuration of the device collects infrared radiation directly from a solid object and operates in the mid-infrared to detect lower temperatures. The temperature of a confined pyrotechnic has been measured in the range from 370 to 1100 K at heating rates greater than 100 K per microsecond. Author

N87-29476# British Aerospace Public Ltd. Co., Bracknell (England). Electronic Systems and Equipment Div.
THE BAE (BRACKNELL) AUTOMATIC DETECTION, TRACKING AND CLASSIFICATION SYSTEM
C. J. SAMWELL and G. A. CAIN *In* AGARD, Advances in Guidance and Control Systems and Technology 10 p (SEE N87-29474 24-04) Jul. 1987
(AGARD-CP-411) Avail: NTIS HC A07/MF A01

BAe Bracknell has designed and built real-time electro-optical digital tracking systems for 8 years. Tracking systems were purchased by the MOD and evaluated on MOD missile and target tracking trials. The BAe detection and tracking system uses images from infrared and TV sensors, mounted on a 2-axis platform, to detect and determine the angular position of an object with respect to the sensor boresight (boresight errors). These boresight errors are used to control the position of the platform such that the sensor tracks the object. The first and second generation centroid and correlation tracking systems have undergone several revisions. A third-generation system is described which provides the following facilities: image enhancement and segmentation, automatic detection of multiple objects, tracking of multiple objects, automatic acquisition of detected objects, automatic decoy/obscuration avoidance, and classification of objects. Author

N89-17707# Fondazione Ugo Bordoni, Rome (Italy).
COUPLED-MODE THEORY APPROACH TO DEPOLARIZATION ASSOCIATED WITH PROPAGATION IN TURBULENT MEDIA
B. CROSIGNANI and P. DIPORTO *In* AGARD, Scattering and Propagation in Random Media 5 p (SEE N89-17706 10-31) Mar. 1988 Prepared in cooperation with Aquila Univ., Italy
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The problem of light depolarization in a turbulent atmosphere is revisited by means of the coupled-mode theory. This allows in particular the evaluation of the depolarization ratio for a plane wave and compares its expression with that obtained in the frame of two distinct approaches predicting different behaviors. Author

N89-17708# Washington Univ., Seattle. Dept of Electrical Engineering.
EXPERIMENT AND THEORY FOR BACKSCATTERING ENHANCEMENT AND IMAGING IN RANDOM MEDIA
AKIRA ISHIMARU and YASUO KUGA *In* AGARD, Scattering and Propagation in Random Media 10 p (SEE N89-17706 10-31) Mar. 1988 Sponsored in part by Army Research Office, Washington, DC and NSF, Washington, DC
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

When a wave is incident on a dense distribution of discrete scatterers, turbulent media, or rough surfaces, the backscattering is enhanced under certain conditions giving a sharp peak in the backward direction. It is shown experimentally and theoretically that the angular width of the peak is related to the transport coefficient and that the enhancement is caused by the constructive interference of two waves traveling through the same particles in opposite directions. This phenomenon is identified as the weak Anderson localization. The backscattering enhancement can occur from turbulence or rough surfaces which are caused by several mechanisms. A measure of the quality of the image transmission is expressed by the modulation transfer function (MTF). It is shown experimental and theoretical studies on MTF and speckle interferometry based on the fourth order and short-exposure MTF which can produce diffraction-limited images through random scatterers. Author

N89-17711# Rome Air Development Center, Hanscom AFB, MA. Electromagnetics Directorate.
REGIONS OF VALIDITY FOR SOME ROUGH SURFACE SCATTERING MODELS
ROBERT J. PAPA and JOHN F. LENNON *In* AGARD, Scattering and Propagation in Random Media 16 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The objective is to examine the regions of validity that apply to the use of various models for describing rough surface scattering. The first area to be examined is how a small slope condition allows an integral representation of the physical optics (PO) cross section to be formed that does not require the high frequency geometric optics (GO) restriction. Next, for forward scattering, the extension of the roughness dependence of the PO scattering cross

section from the case of Gaussian surface and correlation to a range of surfaces with different height statistics and correlation functions. This dependence is then examined for the small perturbation method (SPM) regime as well. Finally, the forward scattering PO results are extended to the case where the azimuthal angle theta sub s is not equal to 0 degrees. Author

N89-17716# Nebraska Univ., Lincoln. Dept. of Electrical Engineering.
MULTIPLE SCATTERING EFFECTS OF RANDOM DISTRIBUTIONS OF IRREGULARLY SHAPED PARTICLES ON INFRARED AND OPTICAL PROPAGATION
EZEKIEL BAHAR and MARY ANN FITZWATER *In* AGARD, Scattering and Propagation in Random Media 15 p (SEE N89-17706 10-31) Mar. 1988
(Contract DAAG29-82-K-0123; NSF ECS-85-15794)
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Scattering and depolarization by layers of randomly distributed particles of irregular shape and finite conductivity are determined for infrared and optical electromagnetic excitations. The irregularly shaped particles considered here are spheres with random rough surfaces. The spheres are characterized by their two dimensional surface height spectral density functions or autocorrelation functions. Circularly and linearly polarized excitations at normal incidence as well as vertically and horizontally polarized excitations at oblique incidence are considered. The co-polarized and cross-polarized incoherent diffuse specific intensities (modified Stokes parameters) are determined by solving the vector form of the equations of radiative transfer. To this end the full wave approach which accounts for diffuse scattering as well as specular scattering in a self-consistent manner is used to evaluate the extinction cross sections as well as the scattering (phase) matrix for the irregularly shaped particles. Both single-scatter and multiple-scatter incoherent specific intensities are evaluated for particles with smooth as well as rough surfaces. It is shown that the particle surface roughness can have a significant effect on the diffuse specific intensities. The phenomenon of enhanced backscatter is also examined. Author

N89-17718# Royal Signals and Radar Establishment, Malvern (England).
GENERATION AND PROPERTIES OF SELF-SIMILAR STOCHASTIC PROCESSES WITH APPLICATION TO RAY PROPAGATION IN RANDOM MEDIA
J. H. JEFFERSON and J. D. ANDERSON *In* AGARD, Scattering and Propagation in Random Media 19 p (SEE N89-17706 10-31) Mar. 1988
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

The importance of random media containing many length scales, and propagation of waves in such media is now widely recognized. Specific mathematical models to generate stochastic processes which have self-similar properties will be analyzed. Examples are presented graphically to illustrate similarities and differences between processes with various degrees of roughness and it is shown how they are related to fractional integration and fractal dimension. Such processes are non-Markovian, in general, and both causal and noncausal models are shown to be stochastically equivalent. Their use in modeling the scattering of waves from rough surfaces, particularly in the geometrical optics limit, will be discussed and the effects of inner and outer scales investigated. Finally, the generalization to two and three dimensions is considered together with application to ray propagation in extended random media. Author

N89-17721# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
OPTICAL IMAGERY ACROSS ATMOSPHERIC TURBULENCE [IMAGERIE OPTIQUE A TRAVERS LA TURBULENCE ATMOSPHERIQUE]
G. ROUSSET, J. C. FONTANELLA, J. PRIMOT, and A. SEVE *In* AGARD, Scattering and Propagation in Random Media 13 p (SEE N89-17706 10-31) Mar. 1988 In FRENCH Previously announced in IAA as A87-46754
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Three techniques for obtaining images with a resolution at the diffraction limit are compared to study the effects of atmospheric turbulence on the formation of optical images. The simplest method, the Knox and Thompson (1974) algorithm (based on a speckle interferometry method), requires the statistical properties of the turbulence to be stable, and involves the treatment of a large number of images. The deconvolution method, based on a wave front analysis, and the adaptive optic method, the most promising of the three candidates, require the presence of a highly luminescent source in the isoplanetary field in order to analyze the wave front. B.G.

N89-17722# British Aerospace Public Ltd. Co., Bristol (England). Naval and Electronic Systems Div.
INFRARED ATMOSPHERIC TRANSMISSION/EMISSION MEASUREMENT IN A MARITIME ENVIRONMENT
G. J. BISHOP and I. W. LARKIN *In* AGARD, Scattering and Propagation in Random Media 12 p (SEE N89-17706 10-31) Mar. 1988 Sponsored by Ministry of Defence, United Kingdom
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

In 1985 a program of collaborative electro-optical research was agreed between the Admiralty Research Establishment (ARE) and British Aerospace, co-ordinated by the Naval and Electronic Systems Division at Bristol. The object of this research was to gather trials data on the performance of electro-optical systems in a maritime environment. In order to achieve this objective, it was important to measure the atmospheric transmission/emission close to the sea surface in a variety of weather conditions. During the course of the trail considerable experience was gained in the operation of various imaging sensors, especially in calibration and measurement techniques. The need to obtain calibrated measurements of atmospheric transmission/emission between the electro-optic sensor and any trial target is to be emphasized. How these measurements were made is described and the results compared to those predicted by the Lowtran 5 atmospheric model. How ozone absorption will affect the design of a passive surveillance system working in the ultraviolet band is also described. Author

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PLASMA PHYSICS

Includes magnetohydrodynamics and plasma fusion.

N88-13222# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PREPARATION OF QUALIFICATION TESTS OF A PLASMA GENERATOR FOR THE FEEDING OF A HYPERSONIC WIND TUNNEL [PREPARATION D'ESSAIS PROBATOIRES D'UN GENERATEUR DE PLASMA POUR L'ALIMENTATION D'UNE SOUFFLERIE HYPERSONIQUE]
H. CONSIGNY, C. PACOU, O. PAPIRNYK, PH. SAGNIER, and J. P. CHEVALLIER *In* AGARD, Aerodynamics of Hypersonic Lifting Vehicles 14 p (SEE N88-13219 05-02) Nov. 1987
In FRENCH Previously announced in IAA as A87-44341
(AGARD-CP-428) Avail: NTIS HC A24/MF A01

Qualification tests have validated the use of a plasma generator as the feed for the R6 CH hypersonic wind tunnel that is to be employed for the Hermes project. In the first part of the study, a blast pipe using existing elements and fulfilling the conditions necessary for sounding (as determined by flow calculations), is developed. A gas flow rate of 0.26 kg/s and a gas power of 2,090,000 W are projected for an intake with a 1 sq cm cross section. Probe instrumentation for the measurement of dynamic pressure, local mass flow, and enthalpy were developed to verify the homogeneity of the flow. IAA

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ADMINISTRATION AND MANAGEMENT

Includes management planning and research.

N88-20173# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
FLIGHT VEHICLE DEVELOPMENT TIME AND COST REDUCTION
Sep. 1987 308 p In ENGLISH and FRENCH Conference held in Toulouse, France, 11-14 May 1987
(AGARD-CP-424; ISBN-92-835-0432-1; AD-A198663) Avail: NTIS HC A14/MF A01

These proceedings contain the papers presented at the AGARD Flight Mechanics Panel Symposium on Flight Vehicle Development Time and Cost Reduction held in Toulouse, France, from 11 to 14 May 1987. There is a current perception that time and especially the cost of new systems are increasing at an ever accelerating rate that is greater than the rate of improvement of the capabilities of the machines. The purpose of this symposium was to provide a forum to identify and discuss the elements contributing to increased time and cost development, and to decide what can be done to stop and reverse the trend. Another aim of the Symposium is to encourage others in the nontechnical area to join with the technical people in attacking those problems, showing what technologies can do to reduce development time and cost growth, and by highlighting key areas to be addressed to reverse the trend. For individual titles, see N88-20174 through N88-20201.

N88-20174# Army Aviation Systems Command, Saint Louis, MO.
RISK REDUCTION COST AVOIDANCE FOR FULL SCALE DEVELOPMENT BEGINS WITH CONCEPT FORMULATION
CHARLES C. CRAWFORD, JR. *In* AGARD. Flight Vehicle Development Time and Cost Reduction 7 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Critical areas are considered, which must be addressed to reduce the technical risk early enough in the Concept Formulation process to avoid undue costs during the Full Scale Development (FSD) program. The context includes not only the definition of the traditional Required Operational Capability (ROC), Operational and Organizational Concepts, and the determination of the Best Technical Approach (BTA), but also a Preliminary Design Phase of the configuration(s) determined to be the BTA. Traditional cost drivers are first, requirements that may be more stringent than the minimum essential to perform the mission and secondly, design changes, after prototype fabrication, usually resulting in flight test delays, that stretch out the program. Design changes in the flight test phase are often made in a near panic environment to minimize the schedule impact. The problems tend to be typical even with a proactive government/industry development team effort. Suggested work efforts to avoid these types of problems in future developments are made to increase the potential of a new Weapons System flying off the drawing board within cost and on schedule. Author

N88-20175# Textron Bell Helicopter, Fort Worth, TX. Cost Analysis Engineering.
DEVELOPMENT SAVINGS THROUGH PARAMETRIC MODELING OF PROGRAM COSTS
PATRICIA J. LESLIE and ERIC G. LILLEY *In* AGARD. Flight Vehicle Development Time and Cost Reduction 3 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Parametric modeling has been applied successfully to most facets of the weapon system preliminary design process. In the area of cost estimating, many parametric techniques are available to project production cost from system characteristics. However, development cost is usually estimated using grass roots techniques, a time-consuming and expensive approach. This paper proposes the application of parametric cost estimating to the derivation of development cost. Historical data from the individual contractor's experience is used as a basis for the model. Both system characteristics and program requirements are analyzed as potential cost drivers. Program alternatives can be evaluated based on a quantitative assessment of financial risk, using equations sensitive to changes in requirements. The development cost model provides the opportunity to base decisions on sound information and to avoid the expensive iteration of grass roots estimating early in the concept formulation stage. The result is a significant savings in development cost. Author

N88-20176# Ministry of Defence, London (England).
PICKING WINNERS: PARAMETRIC COST ESTIMATING AND PROJECT MANAGEMENT
P. G. PUGH *In* AGARD. Flight Vehicle Development Time and Cost Reduction 21 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Project managers and development engineers might well be excused for thinking that they have more than enough cost estimates already. After all the content of any major development program is always broken down into numerous work packages and the cost of these individually estimated in fine detail. Then, as the work proceeds, these very detailed bottom-up estimates are continually refined and have a large claim on the attention of project managers. However, there is another form of cost estimating which can be used from the very inception of a project and which brings large returns from modest effort. Traditional methods assist attempts to control the costs of an on-going project towards some pre-set target. The methods described here are directed more at the initial selection of projects and the setting of feasible cost targets for them. In brief, their role is to pick winners from the range of competing alternatives which present themselves before a major project is begun. At the least, these methods give greater assurance that the chosen solution will be viable in terms of its being attempted within realistic cost restraints. Author

N88-20177# Service Techniques des Programmes Aeronautiques, Paris (France).
PARAMETRIC STUDY OF THE TOTAL COST OF AIRCRAFT MODERNIZATION IN TERMS OF DEVELOPMENT AND EQUIPMENT SERIES COSTS [ETUDE PARAMETRIQUE DU COUT TOTAL DE LA MODERNISATION DUN AERONEF EN FONCTION DU COUT DE DEVELOPPEMENT ET DE SERIE DES EQUIPEMENTS]
J. P. BAYLE *In* AGARD. Flight Vehicle Development Time and Cost Reduction 4 p (SEE N88-20173 12-81) Sep. 1987 In FRENCH
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

An aircraft is reconfigured once or twice in the course of its modernization in order to adapt to the evolving technology and threat environment, and more often than not to improve weapon systems and supply new detection equipment. A statistical study showed the total cost of a modernization program to be tied quasi-linearly to the development cost of new equipment and their series cost. Also, the values of certain ratios are practically constant. This global method intrisically allows one to estimate the confidence level of a program budgetary evaluation. Author

N88-20178# Northrop Corp., Hawthorne, CA. Aircraft Div.
THE INCREASED TIME AND COST OF DEVELOPMENT: CAUSES AND (SOME) REMEDIES
JOSEPH T. GALLAGHER *In* AGARD. Flight Vehicle Development Time and Cost Reduction 9 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The increased time and cost of development of aircraft are discussed. Concurrently, methods of reducing time and cost are examined. The evolution of air vehicle production is presented to provide the background surrounding technological advances. The increased time and cost associated with these advances are discussed in relation to methods of gaining time and cost reductions. New military fighter aircraft have grown increasingly more sophisticated in response to new or anticipated enemy threats. Growth in aircraft capability has coincided with advancements in technologies, including propulsion, aerodynamic design, control systems, structural materials, and avionics. A full-scale development program, as a precursor to production, must not only evolve a design which meets the defined performance requirements, but one which is capable of being produced at acceptable cost using established production processes.

Recognition of the increased burden of operating and support costs for military aircraft has resulted in a concentration of focus on requirements for supportability in the aircraft design. The high cost of today's aircraft has caused the imposition of longer service life requirements with a resultant emphasis on structural integrity and fatigue life. Author

N88-20181# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Villaroche (France).
WHAT CAN BE DONE TO FACE GROWING DEVELOPMENT COSTS [COMMENT FAIRE FACE A LACCROISSEMENT DES COUTS DE DEVELOPPEMENT]
CLAUDE HENOCQUE *In* AGARD. Flight Vehicle Development Time and Cost Reduction 4 p (SEE N88-20173 12-81) Sep. 1987 In FRENCH
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The growth of development costs, driven by the need for improved system capabilities, can be controlled by better program management and a reliance on modern methods of design, production, and testing. A major priority is to reduce volume and unitary costs of prototype fabrication and evaluation by: (1) controlling the design process so that simple verification techniques can be used for testing, (2) improving the efficiency of tests, and (3) reducing unitary costs of prototypes by analyzing the values of design concepts and reducing development time through the use of computer aided design and fabrication techniques. Author

N88-20184# Aeronautical Systems Div., Wright-Patterson AFB, OH. Directorate of Avionics Engineering.
AVIONICS ACQUISITION, TRENDS AND FUTURE APPROACHES
RONALD B. LONGBRAKE *In* AGARD. Flight Vehicle Development Time and Cost Reduction 11 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The current and future direction of the U.S. Air Force avionics is discussed. While the paper discusses primarily tactical aircraft avionics, the findings and conclusions are applicable across USAF systems. The paper covers the acquisition methodology, the background and trends of avionics and future approaches. The basic influences are operational needs, availability, survivability, available technology, cost and schedules. The challenge is to provide effective avionics in a budget constrained world. To accomplish this requires emphasis on providing performance to counter the threat, flexibility for diverse use and basing, cost and schedule realism, and systems capable of being upgraded through planned growth as the threat changes. It has been shown that the 5 to 10 percent improvements in performance can increase the cost 20 to 50 percent, therefore, sufficient and not best performance should be the goal. While initial acquisition cost is of concern, life cycle cost is even more important. To keep life cycle costs down and have an effective system during combat, maintenance concepts need serious attention. To accomplish these objectives, the discrete avionics systems of the past must be replaced with integrated avionics responsive to crew needs, increasing threats and fiscal constraints. Future needs will cause continued increases in avionics cost. The use of new technologies, new avionics system integration and architecture techniques, use of common hardware, modular and reusable software and improving the environment in which the avionics must operate, can control the life cycle cost of avionics while meeting needs of future systems. Author

N88-20185# British Aerospace Public Ltd. Co., Lancashire (England).
REDUCING TIME REQUIRED FOR THE DEVELOPMENT OF AVIONIC SYSTEMS
W. R. SCARFE and K. GRANTHAM *In* AGARD. Flight Vehicle Development Time and Cost Reduction 12 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The current rapid increase in avionic complexity causes difficulties in both defining and implementing the system requirement. Errors in the requirement and in its implementation lead inevitably to an extension in the time necessary for system development and consequently to an increase in the cost of the developed system. This paper describes the avionic system onboard the Experimental Aircraft Programme (EAP) and the design process used on that system. In particular the effectiveness of: (1) rapid prototyping as a means to arrive at a sensible requirement, and (2) implementation via the use of Semi-Automated Functional Requirement Analysis (SAFRA), is outlined. A resume of the results from the EAP is used to show that this structured approach to design using both rapid prototyping and SAFRA does reduce the time required for avionic system development. Author

N88-20187# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
SYSTEMS ANALYSIS AND SIMULATION TECHNIQUES: ESSENTIAL TOOLS FOR BALANCED COMPLEX WEAPON SYSTEM DESIGNS IN TERMS OF PERFORMANCE AND COST
KURT FETTELSCHOSS *In* AGARD. Flight Vehicle Development Time and Cost Reduction 12 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

In line with the speed of overall technical evolution, the requirements for weapon systems are steadily increasing. The required levels of performance lead to complex and expensive technical solutions. The resulting cost of the single weapon system, together with the demand for sufficient quantities, increasingly conflicts with budget limitations. For an effective cost control, the cost driving requirements have to be identified and analyzed before the weapon system design begins. The major tool for this task is an integrated analysis of technical parameters, operational aspects and life cycle cost based on mathematical simulation, tailored to the amount of available information. This integrated analysis leads to recommendations for the single weapon system and the necessary quantities for given scenarios. By involving the customer early enough, the staff requirements for the weapon system can then be influenced in such a way that the design can be balanced in terms of performance and cost. Author

N88-20188# Societe Nationale Industrielle Aerospatiale, Toulouse (France). Lab. d'Essais du Bureau d'Etudes.
THE USE OF SIMULATION IN THE DEVELOPMENT OF THE AIRBUS [LAPORT DE LA SIMULATION DANS LE DEVELOPPEMENT DES AIRBUS]
C. PEDESTARRES *In* AGARD. Flight Vehicle Development Time and Cost Reduction 6 p (SEE N88-20173 12-81) Sep. 1987 In FRENCH
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The steady increase in the complexity of systems and their close integration in modern aircraft results in a continuous growth in the volume of tasks associated with the design study and the validation of systems integration on the aircraft. Simulation constitutes one response to this constraint in that it allows: (1) the detailed definition of the overall system architecture and principles without notable interruption in the development process; and (2) the validation and adjustment of systems designs resulting from these definitions early enough in the course of the program to permit necessary changes without adversely affecting development costs and schedules. For more than twenty years Aerospatiale has employed simulation techniques in various development tasks including prospective analysis to guide long-term studies, development simulation for detailed systems definition, and integration simulation for the validation, adjustment, and optimization of systems in their flight-ready form. Aerospatiale's use of simulation is discussed with particular reference to the A-320 Airbus development program. Author

N88-20189# Boeing Military Airplane Development, Wichita, KS Manufacturing Technology.
PROTOTYPE MANUFACTURING TECHNIQUES FOR REDUCING COST, SCHEDULE, AND TECHNICAL RISK
M. SCOTT SCHUESSLER and JOSEPH C. WILLIAMS *In* AGARD. Flight Vehicle Development Time and Cost Reduction 14 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Programs involving the manufacture of prototype hardware offer rewards to those companies willing to accept the challenge. Boeing Military Aircraft Company (BMAC) has excelled at meeting these challenges with a proven record of successful development programs. In addition, future programs will use neoteric technologies and disciplines such as Computer-Integrated Manufacturing (CIM) to direct and integrate all required fabrication

and assembly processes. Logic, innovation blended with tradition, and careful planning are the keys to BMAC's success. Author

N88-20192# Air Force Flight Test Center, Edwards AFB, CA.
MINIMIZING DEVELOPMENT FLIGHT TEST TIME AND COST IN THE US AIR FORCE
CHARLES E. ADOLPH *In* AGARD. Flight Vehicle Development Time and Cost Reduction 8 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Flight testing has undergone some major changes in the past 20 years. The largest single technical change, the need to evaluate software-intensive systems, resulted from advances in computer technology. Test management concepts have changed as well. These changes were influenced in part by technology and in part by a need for the Air Force to become more involved early in the test process. Today's avionics systems present both a quantum leap in capability and a quantum jump in test requirements. With workload growing both in magnitude and complexity, the challenge is to meet the increased demands cost-effectively and safely. For software-intensive systems, a ground-based simulation dedicated to the support of the flight test program is essential. This paper summarizes today's methods of operation which are geared to minimizing development time and costs. The focus of this process is on productivity -- doing the right testing in the proper sequence in the most efficient and safest possible manner. Author

N88-20193# Boeing Vertol Co., Philadelphia, PA.
IMPROVED FLIGHT TEST PRODUCTIVITY USING ADVANCED ON LINE DATA SYSTEMS
PHIL DUNFORD *In* AGARD. Flight Vehicle Development Time and Cost Reduction 20 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

This paper highlights the improvement made over the last two decades in the methods used to gather, assimilate and process flight test data. It discusses the development cost reductions that can be realized from the use of real time data systems and real time analysis software and relates the use of today's powerful computing capabilities to the V-22 program requirements. The paper briefly discusses the increased emphasis on the role of simulation in real time analysis procedures. Author

N88-20194# Aeronautica Macchi S.p.A., Varese (Italy). Engineering.
USE OF DEMONSTRATION/VALIDATION PROTOTYPES: IMPACT ON TOTAL DEVELOPMENT COSTS AND TIMES
ALBERTO NOTARI *In* AGARD. Flight Vehicle Development Time and Cost Reduction 4 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The development of a new type of military aircraft involves technical risks and uncertainties that are the greater than more advanced the design solutions adopted. The recourse to a pre-development program envisaging the fabrication of demonstration/validation prototypes before proceeding to the full scale development phase is a known possibility, and a solution that was and is adopted both in the U.S. and Europe. Results obtained by use of the demonstration/validation prototypes have been, in some instances, the subject of thorough analyses, confirming the validity and convenience of these prototypes to the end of reducing the overall time span of the acquisition cycle and its costs, especially when the development was marked by significant technological advances. An attempt is made to identify the conditions that should determine the convenience and success of a pre-development program, and the advantages and disadvantages that resorting to such a program entail are reexamined in the present market situation and in a European industrial context. Author

N88-20195# Aeronautica Macchi S.p.A., Varese (Italy).
ENGINEERING MANAGEMENT FOR VALIDATION PROTOTYPE PHASE
ALESSANDRO NEVIANI *In* AGARD. Flight Vehicle Development Time and Cost Reduction 11 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The success and effectiveness of a concept of demonstration-validation through the use of prototypes depend essentially on the contractor's engineering management activities, which must be carefully tailored to the goals of the program. Special importance goes to the activities for the definition of the most cost-effective prototype configuration, of planning, coordination and integration of the different specialty areas, of reduction and simplification of the formal qualification documentation and decision processes. This requires that the customer include flexibility in his contract, and that the contractor adapt his organization by establishing an efficient task force led by a dedicated system engineering structure. Essential factors for success are also a correct choice of key people for the organizational structure, and the completeness of the conceptual studies representing a basis for realistic planning of the prototype definition, development and evaluation activities. The evaluation of the benefits obtainable in terms of complete development costs and time by using the suggested policies and techniques can be qualitative only, significant and homogeneous comparison data being scarce. Author

N88-20196# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Group.
SCHEDULE AND COST CONTROL OF DEVELOPMENT
KARL-HEINZ ENGLEITNER *In* AGARD. Flight Vehicle Development Time and Cost Reduction 13 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The increase in cost and time for the development of an aircraft is a fact in most of the aircraft production programs performed to date. This paper will demonstrate the various reasons for the increases and how to plan an aircraft development program to avoid them. Therefore, possibilities for program execution in terms of adapted program philosophy and management aspects are shown as well as the contractual and economic environment. Further, the tools available for the planning and control of program execution on the basis of the chosen program philisophy are presented. In normal development programs the increase in cost and time comes not from technical problems and risks, but result from contractual, economic, and management decisions which are set by the customer and the contractor even before the initiation of an aircraft development program. Author

N88-20197# Barry (Theodore) and Associates, Los Angeles, CA.
PEOPLE, PROCEDURES, PERFORMANCE: THE KEYS TO IMPROVING THE DEVELOPMENT ENVIRONMENT
CHARLES D. SCALES *In* AGARD. Flight Vehicle Development Time and Cost Reduction 13 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

A growing management issue over the past 20 years in the U.S. Aerospace and Defense industry is the ever-increasing percentage of total product labor cost attributable to the professional work force. Therefore, the challenge of improving the performance and productivity of these workers, especially in a development environment, is now and will remain a most critical element in a firm's overall profitability. The paper begins with an overview of white collar productivity, its growing importance in the Aerospace and Defense industry, its resistance to the more traditional approaches to productivity improvement, and the challenges facing managers who try to attack it. The author explodes some of the popular myths surrounding the issue, and then sets forth a model to help managers understand and thus control the elements comprising white collar productivity. The paper then recounts a case study in which the model was used with great success by a major aerospace manufacturer. The paper concludes with a list of techniques for successful implementation of white collar productivity improvement programs. Author

N88-20198# Naval Air Systems Command, Washington, DC.
THE EFFECTS OF TWO CARLUCCI INITIATIVES CONCURRENCY AND STREAMLINING, ON THE TEST AND EVALUATION PHASE OF SYSTEM ACQUISITIONS
R. PARKINSON *In* AGARD. Flight Vehicle Development Time and Cost Reduction 12 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

History has swung through the arc of a pendulum with the post World War II concurrent test and production at one apex and the 1970s fly-before-buy at the other. As a result of two of the initiatives of the Secretary of Defense, manifested in

concurrency and streamlining, the pendulum is now moving back toward more concurrency, particularly in the attempt to have concurrent test and evaluation by the various testers. Streamlining is implemented in all programs, but there has not yet been a program that has gone through the full acquisition test and evaluation phase having been streamlined from its initiation. Both initiatives have brought savings but there is concern that the support infrastructure which required the execution of the initiatives may not be in place when the program does not meet its cost schedule or performance requirements. Author

N88-20199# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
ACCELERATION OF PROTOTYPE DEVELOPMENT AND REDUCTION OF COST BY MULTIDISCIPLINARY INTEGRATION
J. Y. LAZARD *In* AGARD. Flight Vehicle Development Time and Cost Reduction 4 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

Since its creation Avions Marcel Dassault-Breguet Aviation (AMD/BA) has built 92 prototype aircraft, the last being the Rafale, a new technology demonstrator, forerunner of future combat aircraft. The industrial policy of the company, pursued with continuity and perserverance, has always involved a very fast development, followed by a rapid industrialization and the realization of high quality products. However, with the ever increasing complexity of modern aircraft, maintaining this orientation has required an adequate new organization and the development of several unique technical tools. Author

N88-20200# Societe Nationale Industrielle Aerospatiale, Marignane (France). Div. Helicopteres.
ORGANIZATION OF HELICOPTER DEVELOPMENT ACTIVITIES WITH A VIEW TOWARD REDUCTION OF COSTS AND CYCLES [ORGANISATION DES ACTIVITES DE DEVELOPPEMENT DHELICOPTERES EN VUE DE REDUIRE LES COUTS ET LES CYCLES]
AUGUSTE DESMONCEAUX *In* AGARD. Flight Vehicle Development Time and Cost Reduction 15 p (SEE N88-20173 12-81) Sep. 1987 In FRENCH
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

In recent years, helicopter development costs and cycles have increased greatly in relation to production costs. *In fact, the* increase in specification demands requires greater and greater efforts directed towards performance, materials, operational capabilities of components, and increasingly sophisticated systems. For these reasons, it is important to reduce the cycles and development costs in order to bring overall development efforts back into a reasonable balance. Such a reduction can be achieved through the proper definition of the tasks that should be performed in the course of a predevelopment phase, wherein the objectives are well specified and the determination of technical performance characteristics results from the best compromise between obtainable performance capabilities and the technical risks involved. This predevelopment phase is followed by a development program in which the design, fabrication and testing overlap in an attempt to limit the risks at each stage. Naturally, the flexibility should be sufficient so as to continually maintain the best compromise between design, product fabrication and testing.
Author

N88-20201# Ministry of Defence, London (England).
THE INFLUENCE OF INFRASTRUCTURE ON THE COSTS AND TIMESCALES OF COLLABORATIVE PROGRAMMES
R. GARRETT *In* AGARD. Flight Vehicle Development Time and Cost Reduction 7 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

International collaboration can give substantial financial advantages, particularly in development, but there are features of past programs which have also given rise to increased total costs. This has reduced the advantage in terms of whole life costs to a relatively small (but useful) percentage. No general assessment of the benefits is yet possible since there are insufficient, similar programs on which to conduct statistical analysis; each program proposal needs to be judged on its own merits. Although perfect collaboration, with no additional costs, is unlikely to be achieved there is room for a substantial additional saving to be made in comparison with those achieved to date. One possible means of making these extra savings would be by setting up permanent collaborative institutions in industry and between governments.
Author

N88-23803# Rockwell International Corp., Lakewood, CA. Aircraft Operations.
COHERENT FUNCTIONAL DEVELOPMENT: KEY TO SUCCESSFUL FUTURE SYSTEM INTEGRATION
BRUCE L. HOUSE *In* AGARD, The Design, Development and Testing of Complex Avionics Systems 22 p (SEE N88-23767 17-06) Dec. 1987
(AGARD-CP-417) Avail: NTIS HC A18/MF A01

An advanced, computer based engineering design methodology and tool set which enables and enhances complex system, subsystem and component design, analysis, integration and verification/validation testing in an operational context is described. When fully implemented, functional development by means of manipulation of coherently derived time-line state data, in a dynamic, high fidelity and operational contex, will enable concurrent, fully integrated, rapid prototyping and subsequent detailed design synthesis of the avionics, vehicle, weapons and crew systems components of a total weapon system. Author

N88-30466# Glasgow Univ. (Scotland). Business School.
TECHNICAL CHANGE NEEDS ORGANIZATIONAL CHANGE
DAVID BODDY *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 5 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

It is shown that effective performance cannot be assured simply by installing expensive, state of the art technology. The studies of many applications of computing and information technology have included both successful and unsuccessful examples. The clear practical lesson from this work is that the successful cases were usually those where technical change was accompanied by appropriate organizational change. The less successful ones were generally those where project were dominated by technical considerations, with little of no thought given to organizational ones. These lessons seem as relevant to defence installations as to the civilian ones in which the research was conducted. The common characteristic is that all organizations are confronted by technical developments, which are intended to help them meet their objectives. For them to succeed in that task, it appears that management needs to ensure that three big hurdles are successfully crossed. These are: managing the project, setting the right objectives; and changing the organization. Each of these hurdles will be outlined in turn, and some proposals on how they can be overcome are suggested. Author

N89-10666# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
PERFORMANCE ASSESSMENT REGISTER
1988 152 p
(AGARD-R-763; AD-A200523) Avail: NTIS HC A08/MF A01

This Report presents the results of the first phase of AGARD Aerospace Medical Panel Working Group 12 on Human Performance Assessment Methods. The major goal of Working Group 12 is to develop a standardized test battery, satisfying conventional psychometric criteria such as reliability, validity, and sensitivity, for which an extensive data base may be compiled. Each member of the Working Group sent a simple questionnaire to researchers in his own country who are active in performance testing. The responses have been collated in the form of this Report, which, it is hoped, will facilitate the communication between laboratories necessary for the success of the subsequent standardization program. Author

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DOCUMENTATION AND INFORMATION SCIENCE

Includes information management; information storage and retrieval technology; technical writing; graphic arts; and micrography.

N86-28793# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
THE VALUE OF INFORMATION AS AN INTEGRAL PART OF AEROSPACE AND DEFENCE R AND D PROGRAMMES
Jan. 1986 96 p Meeting held in Cheltenham, England, 4-5 Sep. 1985
(AGARD-CP-385; ISBN-92-835-0389-9; AD-A166641) Avail: NTIS HC A05/MF A01

The management and use of scientific and technical information in the R and D process is examined from the perspective of policy makers, program managers, and researchers. Aspects considered at the meeting included the need to incorporate information as an integral part of the R and D process, the value of information in reducing the cost and preventing the duplication of research, improvements in the sharing of information resources among the NATO countries, and requirements for the future. For individual titles see N86-28794 through N86-28803.

N86-28794# British Aerospace Public Ltd. Co., Weybridge (England). Divisional Technical Directorate.
THE POLICY MAKER LOOKS AT INFORMATION
J. B. SCOTT-WILSON and J. P. HASINSKI *In its* The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 9 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

The policy making heirarchy within British Aerospace is described and the information routes to and from an intermediate level policy maker (Divisional Technical Director) are examined. The information paths for two typical research projects are considered as examples: the use of aluminum/lithium alloys as structural materials and the initiation and development of a new aircraft project. Information quality and the use of automated techniques by policy makers are also discussed. N. G.

N86-28795# NATO Integrated Communications System Management Agency, Brussels (Belgium).
A PROGRAMME MANAGER'S NEEDS FOR INFORMATION
I. MASON-SMITH *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 8 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

The underlying basis for the information need of the program manager within the NATO Integrated Communications System Agency (NICSMA) is examined in some detail, in terms of the role of that agency as exemplified by its current charter. The various specific needs of the program planner working within this framework are then identified and critically reviewed. Finally, the paper notes the expanding role of the remodelled agency (NACISA) to include the development of both communications and information systems for NATO; in this context, the urgent need to re-examine the basic information requirements of the Agency is encouraged and proposals sought. Author

N86-28796# Raitt (D. I.), Den Haag (Netherlands).
THE INFORMATION NEEDS OF SCIENTISTS AND ENGINEERS IN AEROSPACE
D. I. RAITT *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 5 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

A brief description of a recent research project to ascertain the communication and information-seeking and use habits of scientists and engineers working in aerospace research establishments and other organizations is given. Relevant organizations studied include DFVLR, NLR, CNES and ESA. Following an overview of the basic characteristics of scientists and engineers, a review of the project's major findings as they relate to the type of information required by scientists and engineers, its availability, the sources - both oral and written - from which the information is obtained and the scientists and engineers awareness of them, how they keep up-to-date, the time spent seeking information, the use made of the library and the communication patterns of scientists and engineers, is then given. Some general suggestions for improving the communication and information flow within organizations to the satisfaction of practicing scientists and engineers are made. Author

N86-28797# Office of the Under Secretary of Defense for Research and Engineering, Washington, DC. Research and Laboratory Management.
INFORMATION SERVICES: PROS AND CONS
L. YOUNG *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 8 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

A strong science and technology base is a national necessity in a competitive world, and adequate communication is a prerequisite for it. An individual, be it a policy maker, program manager, a bench scientist or engineer resorts to the information system if he believes it will save him or her time to first consult the written record rather than to undertake a repetitious experiment or investigation. The three components to an effective information service are the sources (those who provide or produce information), the users (those who need the information) and the professional information specialists (those who bind the whole system together). The cooperation toward information exchange of all those connected with research and development must be enlisted in support of the system of which they are a part. Author

N86-28798# Engineering Sciences Data Unit, London (England).
THE COSTS OF NOT HAVING REFINED INFORMATION
A. J. BARRETT *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 9 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

The adequacy of the information resources, which are called upon for support at decision points in the research-design-production-marketing process, can in part be measured by their scope, the presence or absence of information within that scope and, increasingly, by the extent to which they offer refinement in terms of the timeliness and quality of the information which can be retrieved. Timeliness in the present context relates not so much to the response time of the information system as to the extent to which that system is tuned to the volatility of the information which it contains. Likewise, the quality of information is not to be judged only by its relevance and authenticity but also by the convenience of its form of presentation in the view of the decision maker who has need of it. The main focal points of the paper are the costs, disruption and other losses which arise from a lack of knowledge of previous work, the use of out-of-date technical information and, in particular, the extent to which the use of insufficiently refined numerical data leads to the under-, or over-, design of hardware. These are illustrated by a number of quantified examples. The transition from an industrially based to an information or service based society highlights the growing needs of the R&D decision maker and others for systems which will provide high quality numerical and factual data. However, substantiation of these needs may never be available in terms of evidence of direct future benefits as distinct from evidence of historic losses. More dynamic means of demonstrating the impact of information quality upon the interests of the decision maker must be devised and guidelines for two such projects are suggested. Author

N86-28799# King Research, Inc., Rockville, MD.
MEASURING THE VALUE OF INFORMATION AND INFORMATION SYSTEMS, SERVICES AND PRODUCTS
D. W. KING and J. M. GRIFFITHS *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 15 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

An approach for measuring the value of information and information systems, services and products is presented. Results of four research projects that have measured value of recorded information used by professional such as scientists, engineers,

managers, etc. are also discussed. Furthermore, data are given on the value of such systems and services as a bibliographic database of international publications, online search systems and libraries. The approach used to measure value includes several perspectives. The first perspective is what users are willing to pay for information in terms of money (if exchanged) and the price paid by users in terms of their time and effort to get and read the information. Once information is read and assimilated, there are many purposes for which it might be used such as in one's work, to educate oneself or others, to satisfy one's curiosity, etc. The consequential value resulting from information use is partially measured by the savings that are derived from information use. Higher order values are how the consequential value affects the user's organization and, in turn, society. Author

N86-28800# National Defence Headquarters, Ottawa (Ontario). Directorate of Industry and Univ. Programs.
INTERNATIONAL INFORMATION EXCHANGE PROGRAMMES ARE NECESSARY
A. S. REEVES *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 5 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

The economic and cultural ties between Canada, the U.S. and European nations are enhanced by various means of information exchange between and among countries. The benefits of two different but interconnected processes of technology transfer are discussed: the alerting of allies to information available and the exchange of document literature. Since concern about national security and proprietary information may preclude defence research and development programs from publishing; as do other disciplines, in the open literature, special exchange agreements are necessary. The programs which have existed for some years among various NATO countries usually limit the subject areas of common interest to be discussed, and the organizations to be included. This process is illustrated using the Canadian situation. Some of the existing Canadian exchange agreements are examined, showing how they operate, the types of information which are included, the routes by which information is passed from one country to another. The ways in which information passes through the documentation centers to become a valuable service to the end users and thus enhance research and development productivity are detailed. Specific examples of the use of international information exchange programs to some major defence projects are shown. The release of information is beneficial to the releasing country as well as to the receiving country because of the increased visibility of the information and the resulting reciprocal transfer of related data.
M.G.

N86-28801# Royal Library of Belgium, Brussels.
THE IDEAL INFORMATION SYSTEM? WHAT DOES THE USER REALLY WANT?
G. M. VANAUTRYVE *In* AGARD The Value of Information as as Integral Part of Aerospace and Defence R and D Programmes 4 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

In planning future information systems, it is of utmost importance to take into account the user who finally decides on the success of the systems. So far, system improvements have mainly been implemented with the experienced user in mind. Therefore, if the information systems want to get a better penetration, they will have to implement interfaces facilitating the accessibility of the information by the non-experienced user. Also, access to those idealized information systems could be improved through better cooperation between telecommunication authorities. Author

N86-28802# BULL, Louveciennes (France).
NEW TECHNOLOGIES FOR IMPROVED INFORMATION SYSTEMS AND SERVICES
G. GAUTHIER-VILLARS *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 12 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

Information data bases are growing exponentially both because of the number of records and because of the type of data. The number of occurrences encompassed by a data base has an evident influence on its volume, but as one moves from coded data to textual data and to images the need for space grows as well. Data is dear to the user. It is expensive to capture and it is important that it reaches all applications which needs it. So to keep the whole problem of data management under control storage, processing and transfer techniques evolve rapidly. This paper is focused on three important technological breakthroughs in each of these domains: a new storage technique, the optical disc; a new way to process data, the expert systems; and a new way to exchange data, with query languages. Author

N86-28803# Fachinformationszentrum fuer Energie, Physik, Mathematik G.m.b.H., Eggenstein-Leopoldshafen (Germany, F.R.). Energy and Technology Div.
INFORMATION RESOURCES MANAGEMENT IN THE R AND D ENVIRONMENT
K. BUERK *In* AGARD The Value of Information as an Integral Part of Aerospace and Defence R and D Programmes 4 p (SEE N86-28793 19-82) Jan. 1986
(AGARD-CP-385) Avail: NTIS HC A05/MF A01

Efficient management of highly specialized information is a permanent task of optimization, whereby framework conditions may constantly change on account of various influencing factors. Owing to their special significance, the following has to be considered in particular: user needs, available resources, and information techniques. The task of optimization, due to its complexity, cannot be solved model-like, but only approximately and pragmatically. Illustrated by the example of the Federal Republic of Germany and the Fachinformationszentrum Energie Physik Mathematik (FIZ) the attempt to find a practical solution is demonstrated. In this context it is shown which role a National Information Center plays within international and national cooperation including workshaning, and how information supply and dissemination of information works in the case of central information services by FIZ, and decentral dissemination of information in research centers. Illustrated by the examples of database production, online services of bibliographic, numeric and full-text databases and the concept of the International Information Network for Science and Technology (STN International), the importance of the use of the most modern information techiques is demonstrated. Author

N87-19923# Logistics Management Inst., Bethesda, MD
BIBLIOGRAPHIC NETWORKS AND MICROCOMPUTER APPLICATIONS FOR AEROSPACE AND DEFENSE SCIENTIFIC AND TECHNICAL INFORMATION
RICHARD W. HARTT *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 16 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

Bibliographic networks provide the means for sharing information resources among geographically dispersed libraries. As part of a bibliographic network, a single library can access a wide variety of bibliographic information, participate in shared cataloging, and acquire holdings (purchase or loan). Described here are: (1) the functions and operations of libraries supporting aerospace and defense scientific and technical work; (2) the environment and characteristics of bibliographic networks; and (3) the automated system capabilities required for network participation. A discussion of the use of microcomputers as cost-effective, yet powerful tools for exploiting bibliographic network resources is included. An automated system being developed for U.S. Department of Defense technical libraries is described. This system integrates local library functions with capabilities for accessing bibliographic network resources, both government and commercial. Author

N87-19926# Atomic Energy Research Establishment, Harwell (England).
KNOWLEDGE BASED SYSTEMS IN INFORMATION WORK
L. F. CROALL *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 3 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

The impact of artificial intelligence on the use of computer based systems in information work is discussed. The background to artificial intelligence is briefly discussed, followed by examples of some of the possible applications. Particular consideration is given to the ACHILLES system developed at Harwell which provides corrosion information. Author

N87-19927# Gurnsey (J.), Wembley (England).
MICROCOMPUTERS IN INFORMATION RESOURCE SHARING: TWO FULL TEXT SYSTEMS
J. GURNSEY *In* AGARD The Application of Microcomputers to Aerospace and Defence Scientific and Technical Information Work 12 p (SEE N87-19920 12-60) Oct. 1986
(AGARD-LS-149) Avail: NTIS HC A06/MF A01

Full text database use in Europe has been slow to develop, due in part to the narrow definition commonly adopted. In its widest sense, full text may be used to comprise all databases, textual or numeric, which are complete in themselves and do not merely refer the user onward to the primary literature. A range of factors - market structure, language, economics, copyright and others - influences the emergence of full text services in Europe, and the effect of these factors is often quite different from that on the bibliographic market, and indeed on North American full text developments. Technological changes in computers, storage technology and software, both within and outside the online industry affect the use of full text sources. In particular, since full text tends to emphasize the importance of decentralized information services, innovations in CD-ROM and magnetic media deserve consideration as they ease the creation of practical selections from large text sources for particular users, and also create opportunities and so influence the scope of data available in full text mode. Author

N87-21189# Naval Air Propulsion Test Center, Trenton, NJ.
HIGH RESPONSE DATA ACQUISITION SYSTEM
MARK K. FALL and HENRY P. DRESS *In* AGARD Advanced Instrumentation for Aero Engine Components 11 p (SEE N87-21170 14-31) Nov. 1986
(AGARD-CP-399) Avail: NTIS HC A24/MF A01

High response instrumentation is used frequently in gas turbine engine testing to determine the transient and dynamic behavior of various engine and component parameters. The Naval Air Propulsion Center (NAPC) enhanced its data acquisition and analysis capability in April 1983 with a new digital high response data acquisition system which eliminated many of the problems inherent with older analog data acquisition and analytical methods. This system has the capability of acquiring multiple parameters simultaneously at an aggregate sampling rate of up to 48,000 samples per second with on-line digitization and real time recording on a private data disk. The NAPC offline data analysis system provides same-day access to the data with the capability to display the data in various tabular and graphical formats. Analytical techniques available include time zero analysis, high pass, low pass, and band pass digital filtering, and power spectral density analysis using fast fourier transformations. Author

N87-26675# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
PLANNING AND DESIGNING EFFECTIVE DEFENCE AND RELATED INFORMATION SERVICES
Apr. 1987 116 p In ENGLISH and FRENCH Meeting held in Ankara, Turkey, 10-11 Sep. 1986
(AGARD-CP-416; ISBN-92-835-0417-8; AD-A184833) Avail: NTIS HC A06/MF A01

The planning and designing of effective defense and related information services are discussed. The information scene in Turkey, the benefits of scientific and technical information services, determining user needs, planning, security considerations, and sources of information for a defense information service are among the topics discussed. For individual titles, see N87-26676 through N87-26685.

N87-26676# Ministry of National Defence, Ankara (Turkey). Dept. of Research and Development.
THE INFORMATION SCENE IN TURKEY
O. KAYA, N. TUNCER, and E. URUNDUL (Scientific and Technical Research Council of Turkey, Ankara.) *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 3 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

After a brief overview of the Turkish information scene and library system, the three most important information centers are described in detail. General problems and shortcomings in the information process are discussed. Specifically, the lack of consciousness and appreciation of the importance of information is stressed. Author

N87-26677# American Inst. of Aeronautics and Astronautics, New York, NY. Technical Information Services.
BENEFITS OF SCIENTIFIC AND TECHNICAL INFORMATION SERVICES FOR AEROSPACE AND DEFENSE
BARBARA LAWRENCE *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 4 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

The benefits of having an aerospace and defense scientific and technical information service are considered based on an understanding of the literature in the field. The functions of a centralized information center and the nature of the research and development process are discussed. Author

N87-26678# National Defence Headquarters, Ottawa (Ontario). Directorate Scientific Information Services.
A MODEL OF A DEFENCE INFORMATION SERVICE AS SEEN BY THE USER
BARBARA F. AUBREY *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 5 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

The characteristics which make up a typical defense information service in the mid 1980's are described. In outlining its goals, organization, facilities and services, the differences between a defense information service and a traditional library are highlighted. As a systematic manager of information needed by a nation's defense community, this service has requirements over and above those of a library in the types of information collected, in furniture and equipment, and in the variety of services offered. Services provided by defense information agencies in identifying, acquiring, organizing, subject analyzing, announcing and disseminating recorded knowledge are illustrated through a number of mini-scenarios describing typical situations in which a potential user of a defense information service may find himself. Author

N87-26679# Technisch Documentatie en Informatie Centrum voor de Krijgsmacht, The Hague (Netherlands).
USER NEEDS AND HOW TO DETERMINE THEM
G. M. BREAS *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 2 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

Three ways of studying user needs and the accompanying ways to determine them are discussed. Knowledge of the potential users, analysis of the information itself and analysis of the form in which the information will be disseminated are discussed.
Author

N87-26680# National Technical Information Service, Springfield, VA.
STRATEGIC PLANNING PROCESS AT THE NATIONAL TECHNICAL INFORMATION SERVICE
JOSEPH F. CAPONIO and DONALD S. BUDOWSKY *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 6 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

External trends such as the growth of the information society, the increasing economic value of information, the growth of research and development, funding, and advances in automation have dictated the need for information services to have a strong commitment to strategic planning. These trends are discussed and the strategic planning process at the National Technical Information Service (NTIS) is outlined. Author

N87-26681# Dokumentationszentrum der Bundeswehr, Bonn (Germany, F.R.).
SECURITY CONSIDERATIONS, DEFENCE-RELATED AND COMMERCIAL
HELMUT BRAUN *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 12 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

A number of topics associated with the management and handling of classified documents and documents under commercial confidentiality in a defense information center are discussed. These questions are considered: Should one operate a classified data base or keep the data in it unclassified? How do you produce unclassified references to classified documents. The restrictions imposed upon documents with statements limiting their distribution are discussed, and the differences between unclassified and unlimited are explained. Author

N87-26682# Dokumentationszentrum der Bundeswehr, Bonn (Germany, F.R.).
THE RESOURCES REQUIRED TO RUN AN INFORMATION SERVICE
JAN MUELLER *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 18 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

Conceptual, manpower, material and financial components are described and discussed as the resources of an information and documentation (I and D) service. The special role of infrastructure is also examined. Author

N87-26683# Centre de Documentation de l'Armement, Paris (France). Dept. Banques de Donnees-Methodes et Relations Exterieures.
SOURCES OF INFORMATION FOR A DEFENSE INFORMATION SERVICE [LES SOURCES D'INFORMATION DANS UN SERVICE D'INFORMATION DE LA DEFENSE]
ALBERT YANEZ *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 8 p (SEE N87-26675 20-82) Apr. 1987 In FRENCH
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

A topology of information sources of use to a defense information community is presented. Sources are classified and examined with regard to localization (internal defense sources, domestic, and foreign), level of organization, information content, type of utilization, and type of support. Author

N87-26684# Laborelec, Linkebeek (Belgium)
THE TREATMENT OF GREY LITERATURE [LE TRAITEMENT DE LA LITTERATURE GRISE]
CLAUDE J. SALMON *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 7 p (SEE N87-26675 20-82) Apr. 1987 In FRENCH
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

Grey literature represents a vast quantity of documents in all fields including scientific and technical, sociological and economic. Although not all the documents comprising grey literature are of the same quality, their value is unquestionable, for many they represent the principle source of information. The characteristics of grey literature are outlined and the advantages of these documents as an information source are discussed. Problems concerning identification, acquisition and collection, and normalization and bibliographic control are defined. The processing of grey literature in Belgium and within the System for Information on Grey Literature in Europe (SIGLE) is described. Author

N87-26685# Defence Research Information Centre, Glasgow (Scotland).
TELLING THE USER WHAT IS AVAILABLE: ANNOUNCEMENT AND SEARCH
C. D. ADAMS *In* Advisory Group for Aerospace Research and Planning and Designing Effective Defence and Related Information Services 8 p (SEE N87-26675 20-82) Apr. 1987
(AGARD-CP-416) Avail: NTIS HC A06/MF A01

The various means by which an information service can make users aware of documents which are available are discussed. Regular announcement of document holdings and searches of document holdings in response to specific inquiries are discussed. The various types of current awareness and search service are described and are illustrated by reference to the Defense Research Information Center (DRIC) which provides these services to the United Kingdom defense community. Author

N87-29511# International Business Machines Corp., Gaithersburg, MD.
STARS, POLYGONS AND CLUSTERS
ROBERT O. TUREK and JOEL S. GREENSTEIN (Clemson Univ., S.C.) *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 7 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

One technique for displaying a set of quantitative variables is to represent the values graphically in the form of a polygon or star, allowing the observer to visually handle complex information quickly, as a whole. Such displays have been used in various areas, for data exploration and presentation, and in status displays; they are also suited to categorization and identification tasks. For polygon displays to be reliably used, they should be capable of being interpreted consistently. An experimental investigation was undertaken to ascertain the effect of variation in certain visual features of the display on the consistency with which untrained subjects categorize information presented as polygons. Variables included background information, shading of figures, and form. Subjects performed a categorization task on several sets of data; the results were analyzed on the basis of consistency between individuals and consistency with certain standard clustering algorithms. Implications for display design include the effects of distinctive patterns on similarity judgements, of the nature of the data represented, and of the interaction of variables. Author

N87-29512# Aerospace Medical Research Labs., Wright-Patterson AFB, OH. Human Engineering Div.
AN ASSESSMENT OF VARIABLE FORMAT INFORMATION PRESENTATION
J. A. FORESTER *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 13 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Three experiments testing the feasibility of varying information display formats as task demands change in complex multitask environments were conducted. A multiple resource model of human information processing was used as a guide for determining how best to represent task relevant information under changing conditions and the general validity of certain aspects of the model was assessed. Experiment 1 investigated the usefulness of a basic dual task environment for testing the variable format approach and Experiment 2 demonstrated that the technique was successful under simple task conditions. Experiment 3 increased the complexity of the base dual task by including a third task in an adaptive system context. The results from Experiment 3 supported the use of variable formats in complex adaptive systems and were consistent with the tenets of multiple resource theory. Experiment 3 also indicated the importance of considering individual differences in the design of adaptive systems. The overall approach attempts to improve human processing efficiency by capitalizing on current knowledge of human information processing characteristics and capabilities. Author

N87-29513# Naval Aerospace Medical Research Lab., Pensacola, FL.
PERCEPTUAL PROCESSING CAPABILITIES RELEVANT TO DESIGN OF VISUAL DISPLAYS FOR INFORMATION MANAGEMENT IN ADVANCED AIRBORNE WEAPON SYSTEMS
TOMMY R. MORRISON *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 9 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

A review of P-3C Tactical Coordinator task analytic data provided the basis for developing an experimental paradigm for investigating cognitive processing demands characteristic of Naval aviation displays. Stepwise regression analyses of the obtained data provided assessment of processing times associated with the various display demands and regression equations for predicting

performance. The results provide human performance data relevant to human factors and design engineers involved in developing visual displays to enhance information management in advance airborne weapon systems. Author

N87-29514# Royal Air Force Inst of Aviation Medicine, Farnborough (England).
PERCEPTUAL ORGANISATION AND INFORMATION MANAGEMENT
R. M. TAYLOR *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 28 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

The changing requirements for information processing and control and the development of the information management function are reviewed through the history of the aircraft cockpit. Information management was once entirely carried out by the pilot but now this function seems likely to be shared between the pilot and adaptive automation. Human information management begins with perceptual organization. Gestalt thinking on perceptual organization is reviewed with reference to the information processing approach to human cognition and in particular to the operations of selective attention, working memory and the linking of perception and thought. Perception can be facilitated through the design of information displays. The influence of the principles of perceptual organization on the design of the dialogue across the human machine interface is reviewed with particular reference to the integration and differentiation of flight information. Three experiments are reported that are relevant to the use of color as an organizational factor in complex pictorial computer generated displays. Author

N87-29515# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
INFORMATION MANAGEMENT IN THE ARMY BATTLEFIELD HELICOPTER
C. P. GIBSON and D. WILLIAMS *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 13 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Considerable experience in the design of mission management systems has been gained in recent years. Flight trials have shown that careful design of these systems can result in considerable time savings in executing many of the tasks performed by the crew during tactical operations. In addition, flight trials were also conducted to evaluate the potential benefits of a simple tactical situation display presented on a color cathode ray tube. These trials have given valuable insight into the applications and requirements of this type of display. The experience gained was applied to the development of a complete system for installation in a helicopter with a MIL-STD-1553B databus avionics system to enable further flight trials addressing system integration and man machine interface optimization. A flexible ground station was also developed to allow investigation of optimizing methods for premission programming of the system and tactical situation display via a solid state data transfer device. Author

N87-29517# Mitre Corp., Bedford, MA.
ADVANCED INFORMATION MANAGEMENT AND DECISION MAKING IN AIRBORNE EARLY WARNING AND CONTROL (AEW&C) TRAINING SYSTEMS
L. M. ROSA, E. L. ESTOCHEN, J. L. BOTTOMLEY, and M. J. HEBERT *In* AGARD, Information Management and Decision Making in Advanced Airborne Weapon Systems 12 p (SEE N87-29503 24-06) Feb. 1987
(AGARD-CP-414) Avail: NTIS HC A14/MF A01

Fundamental concepts are developed for the application of information management and artificial intelligence-based decision making technology to current and future surveillance, command, control and communication training systems. Specific emphasis is placed upon Airborne Early Warning and Control (AEW and C) training systems using the E-3 Mission Simulator as the analysis example. Present Mission Simulator capabilities are discussed along with ongoing improvement programs. Training inadequacies and instructor workload problems are highlighted. Advanced information management and artificial intelligence techniques are proposed to overcome these and other training deficiencies and to increase instructor efficiency. Extensions of these techniques for operational system use are also presented. Author

N88-30458# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
BARRIERS TO INFORMATION TRANSFER AND APPROACHES TOWARD THEIR REDUCTION
Mar. 1988 110 p In ENGLISH and FRENCH Meeting held in Washington, D.C., 23-24 Sep. 1987
(AGARD-CP-430; ISBN-92-835-0449-6; AD-A194653) Avail: NTIS HC A06/MF A01

Topics addressed include: an overview of the barriers to the international transfer of information, particularly in aerospace and defence; linguistic, political, and economic barriers; the use of technology to overcome these and other barriers, e.g., machine translation, links between disparate databases and teleconferencing; the importance of standards; and the need to change organizations when introducing or changing technology to prevent internal barriers reducing the acceptance and the use of the new technology. For individual titles, see N88-30459 through N88-30467.

N88-30459# Commissariat a l'Energie Atomique, Gif-sur-Yvette (France).
LINGUISTIC AND CULTURAL BARRIERS TO THE TRANSFER OF INFORMATION
ROLAND LARUE *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 7 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

The relative importance of languages in the world in 1987 is described showing that the world population makes use of about ten languages, each of which covers an area of the globe. The trends are revealed by an analysis of population density and socio-economic balances. The use of language is studied in the field of science and technology, according to the type of communication (written or spoken) and the contents (from mathematics to technology) and the tendencies are shown. The attempts which were made to overcome the linguistic barrier - such as the introduction of a single common language (esperanto or English) or the development of the study of foreign languages are examined. The detailed analysis of the cultural barrier is carried out by several approaches (sociological, psychosociological, psychoanalytic, and psycholinguistic) in order to reveal the genuine individual and collective stakes. Future trends, such as the working of the Commission of the European Communities with its nine official languages are discussed, and some predictions are put forward on the linguistic state of the world at the beginning of the 21st century. Author

N88-30460# Congressional Research Service, Washington, DC. Science Policy Research Div.
POLITICAL AND ECONOMIC BARRIERS TO INFORMATION TRANSFER
JANE BORTNICK *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 4 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

As international computer/communications networks proliferate, the issue of limits to information transfer becomes more critical. Individual businesses and even entire industries depend upon the ability to transfer information on a global basis in a timely and cost-effective basis. Additionally, international cooperation in science and technology involves greater international collaboration and joint efforts. Barriers that threaten this capability ultimately reduce the growth of markets and limit innovation. For this reason, efforts are underway in bilateral and multinational negotiations to reduce barriers and establish consensus guidelines in areas ranging from privacy to trade. Some of the specific limitations to information transfer, including privacy, trade restrictions, national security, and telecommunications regulations are focused on. It also highlights international efforts to reduce these barriers and establish common approaches to facilitate information transfer. Author

N88-30461# Saarland Univ., Saarbrucken (Germany, F.R.).
LINGUISTIC-TECHNICAL ASPECTS OF MACHINE TRANSLATION
HARALD H. ZIMMERMANN *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 7 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

To allow comparison of computer aided translation (CAT) and machine translation (MT) systems, essential criteria and typical exponents of the various concepts are presented. Among the most important criteria of differentiation are the following: translation of complete texts (including titles, abstracts) vs lexical aid for translation; all-round translation vs translation of specialized fields and texts; bilingual translation vs multilingual translation; user-oriented vs administrator-oriented expansion of dictionaries and systems; and portability. Included essential critieria for evaluation are: quality of the raw (also called informative) translation, advantages/disadvantages as opposed to human translation; embedding in a user environment (data bases, indexing and retrieval, word processing, electronic publishing); user friendliness; costs of development and installation; and running costs and effects of realization. Author

N88-30462# Defense Technical Information Center, Alexandria, VA.
INFORMATION RETRIEVAL SYSTEMS EVOLVE-ADVANCES FOR EASIER AND MORE SUCCESSFUL USE
GLADYS COTTER *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 14 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

The advances which are being made in information retrieval systems to assist end-users and information specialists to overcome the critical barriers which make it difficult for them to exploit the power of these systems are described. Technology which is being applied to allow users to interact with information retrieval systems with greater ease and more successful results is identified. To illustrate this process, the efforts of the U.S. Defense Technical Information Center to develop and implement an integrated, functional scientific and technical information network are described. This network was purposefully designed to incorporate both end-users and their information management intermediaries in a complementary manner making them resolute partners in the work and its rewards. The uses of technology modules (artificial intelligence, expert systems, gateways, user-friendly interfaces) to overcome user barriers are described. Author

N88-30463# Atlantic Refining Co., Philadelphia, PA. ARCOvision Services.
INFORMATION TECHNOLOGY TO FACILITATE GROUP INTERACTION
CYNTHIA A. SAVAGE *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 3 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

Atlantic Richfield has successfully operated an interactive, full-motion video teleconferencing system since September of 1983. The system, named ARCOvision, is for internal use only and consists of six locations in the United States including Alaska. The implementation, capabilities, equipment, and costs related to the ARCOvision system will be discussed. Author

N88-30464# Department of the Secretary of State, Ottawa (Ontario).
WORDS: KEYS OR BARRIERS TO INFORMATION TRANSFER
SUZANNE RICHER *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 4 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

Terms can create or resolve barriers in the processes pertaining to the transfer of knowledge and the access to information. Selecting words to organize, process, and retrieve data leads to the establishment of hierarchies. The building of thesauri provides for tools enabling the organization of concepts. National and international guidelines were developed for the establishment of monolingual and multilingual thesauri. New words find their way in solid hierarchies. The introduction mechanisms for new words rely on cross-referencing to already established and recognized terms. Manual and machine indexing provide the same basic tools, machine indexing being, in many cases, more feasible. Standardized terms are compiled in special listings such as the glossaries prepared and published by NATO. The linguistic quality norms of standardized terminologies are limited to the specialized objectives of such terminologies. Terminological barriers are costly and should therefore be reduced in order not to hinder the transfer of knowledge and access to information data. Author

N88-30465# National Scientific and Technical Documentation Center, Brussels (Belgium). Belgian Translation Centre.
LINGUISTIC BARRIERS: TRANSLATION PROBLEMS
I. CLEMENS *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 6 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

Linguistic problems are in close connection with information problems. They therefore are examined jointly in order to solve the terminological problems and to reach the documentary mass. The problems of comprehension of the texts by the specialist are examined as well as the difficulty raised by the translator. Linguistic problems are examined according to characteristics of the unilingual and multilingual countries and according to the groups of languages. The existing means to reduce linguistic barrier and implied institutions are considered from the point of view of the user, and of the translator. The translator is the keyman to overcome linguistic barrier. The translator is confronted with the problems of scientific and technical text comprehension, of search for information and technical terms sources, of adaptation to the modern work methods. The use of data processing provides him some help and multiple possibilities of the translation process. Among the known method of translation, computer-assisted translation seems currently the most performing: use of a PC for translation processes as such, use of computerized dictionaries and bibliographical data bases as multilingual terminology sources reliable and up-to-date. The whole of raised measures makes it possible to reduce linguistic difficulties of the information user and to ensure an effective help to the transfer. Author

N88-30467# National Library of Canada, Ottawa (Ontario).
USING STANDARDS TO BREAK DOWN INFORMATION TRANSFER BARRIERS
CYNTHIA J. DURANCE *In* AGARD, Barriers to Information Transfer and Approaches Toward Their Reduction 5 p (SEE N88-30458 24-82) Mar. 1988
(AGARD-CP-430) Avail: NTIS HC A06/MF A01

Standards for representing and encoding data as well as standards for the interconnection of systems having different hardware and software are both essential for effective electronic information transfer. To date, although major strides were made internationally on standards in both the data and telecommunications areas, much remains to be done before effective electronic information transfer can take place either nationally or internationally. The difficulties in achieving approved standards internationally are addressed, and some new standard that potentially will have a positive impact on information transfer such as those pertaining to an electronic publishing. It also addresses the Open Systems Interconnection Reference Model, a suite of telecommunications standards which hold great promise for the interconnection of systems with different hardware and software. Finally, the work that was done to date to implement these standards for library and information applications and challenges for the future are discussed. Author

N89-11401# Boeing Computer Services Co., Seattle, WA
AN INFORMAL GLOSSARY OF TERMS USED IN SUPERCOMPUTING, APPENDIX A
K. NEVES *In* AGARD, Computational Fluid Dynamics: Algorithms and Super Computers 7 p (SEE N89-11395 02-60) Mar. 1988
(AGARD-AG-311) Avail: NTIS HC A09/MF A01

This informal glossary associated with supercomputers evolved casually. The primary draft was made in 1986 by the IEEE Subcommittee on Supercomputing. In addition, terms have been added and revised. Any rapidly advancing field generates its own new terminology. The new terms arise by applying new meanings to older terms as well as through the coining of new terminology. The process is dynamic and often results in dual meanings of

commonly used words and sometimes just plain fuzzy definitions. Nevertheless, it is believed that this tabulation will: (1) help both novices and experts to better communicate, and (2) provide input to more formal dictionary/definition writing processes. Author

N89-11625# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Technical Information Panel.
EVALUATING THE EFFECTIVENESS OF INFORMATION CENTRES AND SERVICES
Sep. 1988 93 p Lecture series held in Luxembourg, 5-6 Sep. 1988, in Athens, Greece, 8-9 Sep. 1988, and in Lisbon, Portugal, 12-13 Sep. 1988
(AGARD-LS-160; ISBN-92-835-0479-8; AD-A202498) Avail: NTIS HC A05/MF A01

The current state-of-the-art of evaluating information centers and services is presented in both theoretical and practical perspectives. Case studies are used to demonstrate successful evaluation projects from different countries and to focus on specific evaluation methods and measures. In addition to providing a thorough basis for determining the most appropriate evaluation methods and measures for a given situation and potential problems that can arise in using them, the presentations include discussions of what to do once the evaluation is done. Various strategies are proposed for altering the centers and services so that effectiveness is improved. Political, organizational and practical aspects of evaluation projects are covered so that evaluation is seen from a broader context. For individual titles, see N89-11626 through N89-11632.

N89-11626# King Research, Inc., Rockville, MD.
EVALUATING THE EFFECTIVENESS OF INFORMATION USE
DONALD W. KING and JOSE-MARIE GRIFFITHS *In* AGARD, Evaluating the Effectiveness of Information Centres and Services 5 p (SEE N89-11625 02-82) Sep. 1988
(AGARD-LS-160) Avail: NTIS HC A05/MF A01

An approach to evaluating the use, usefulness and value of published/recorded information on the work of its users is described. The reading patterns of professionals and the application of information derived from reading is discussed in detail. Several different indicators of productivity of professionals are developed and correlated with the amount of reading that is done. Finally, several different perspectives on the value of information centers to the professionals they serve are presented. Author

N89-11627# Loughborough Univ. of Technology (England).
MEASURES, METHODS AND MODELS EMPLOYED IN EVALUATING THE EFFECTIVENESS OF INFORMATION CENTERS AND SERVICES
A. J. MEADOWS *In* AGARD, Evaluating the Effectiveness of Information Centres and Services 16 p (SEE N89-11625 02-82) Sep. 1988
(AGARD-LS-160) Avail: NTIS HC A05/MF A01

Evaluating the effectiveness of organizations and of the services they offer always depends on assuming some kind of model. The main purpose of modeling is to abstract elements from real-life activities in such a way that these activities can be more readily understood, and so better organised and planned. Models may be used for a variety of purposes; for example, to pinpoint which parts of a system should be sampled to provide an adequate picture of the whole. The drawback of all models is that they reflect only a part of reality, and so can only be used in a limited context. In consequence, models must be explicity formulated and their limitations understood before any evaluation exercise is attempted. The model helps decide what performance measures can usefully be made. For example, a qualitative model may not be appropriate for guiding assessment in terms of quantitative performance measures. Both model and measures therefore have been chosen in the light of the desired outcome from the evaluation. The methodology, is, in turn primarily determined by the model and measures chosen. Author

N89-11628# Polytechnic of Central London (England). Information Research Group.
EUROPEAN EXAMPLES OF EVALUATING THE EFFECTIVENESS OF INFORMATION CENTRES AND SERVICES
JOHN MARTYN *In* AGARD, Evaluating the Effectiveness of Information Centres and Services 15 p (SEE N89-11625 02-82) Sep 1988
(AGARD-LS-160) Avail: NTIS HC A05/MF A01

There are usually three viewpoints from which an information system, service or product can be evaluated. The first is that of the system or service producers, who will generally be assessing the extent to which their product meets its assigned objectives, and who will be particularly concerned with the improvement of efficiency and effectiveness. Such evaluations do not usually involve comparisons with competing services. The second viewpoint is that of the actual or potential users, whose concern is with the extent to which a system or service meets their perceived needs, and its related cost. This assessment often involves comparisons between services. The third viewpoint, particulary in public-sector operations, is that of the system sponsors, who wish to assess how well a system or service succeeds in meeting policy objectives, some of which may not be explicit. Quantitative evaluative data are often hard to capture, and difficult to interpret. In some European work, a more subjective approach has been taken, using qualitative information supported by such numerical data as may be gathered, to arrive by a judgmental process to an assessment which takes account of the political factors inevitably affecting any evaluation other than the most basic. Author

N89-11629# King Research, Inc., Rockville, MD.
EVALUATING THE PERFORMANCE OF INFORMATION CENTRE STAFF
JOSE-MARIE GRIFFITHS and DONALD W. KING *In* AGARD, Evaluating the Effectiveness of Information Centres and Services 11 p (SEE N89-11625 02-82) Sep. 1988
(AGARD-LS-160) Avail: NTIS HC A05/MF A01

The framework for evaluation described in 'A Framework for Evaluating the Effectiveness of Information Centers and Services' for evaluating staff performance is used. Information center staff are a major resource affecting the overall performance and effectiveness of services provided. Various measures of staff performance are discussed (including quantities, quality and timeliness of staff outputs), and the relationship between staff performance and the effectiveness of services (from a user perspective) is demonstrated. Finally, alternative methods for measuring staff performance are described. Author

N89-11630# King Research, Inc., Rockville, MD.
EVALUATING PERFORMANCE OF INFORMATION CENTRE OPERATIONS AND SERVICES
JOSE-MARIE GRIFFITHS and DONALD W. KING *In* AGARD, Evaluating the Effectiveness of Information Centres and Services 8 p (SEE N89-11625 02-82) Sep. 1988
(AGARD-LS-160) Avail: NTIS HC A05/MF A01

Evaluation of information center resources (e.g. staff, equipment, facilities, etc.) is discussed in terms of input costs, output performance, and productivity. Examples of evaluation of information services (e.g., access to technical reports and other publications, online bibliographic searches, published searches, etc.) are presented in terms of their inout costs and output performance. The linking of resource attributes or charactersitics (e.g., staff competencies, equipment capabilities, facility layout, etc.) to service input costs and output performance (e.g. quality and timeliness of services) is demonstrated. Thus, Center managers can make decisions about resources or allocation of funds involving resources in terms of services involved. A management information system for center management is also described. Author

N89-11631# King Research, Inc., Rockville, MD.
A FRAMEWORK FOR EVALUATING THE EFFECTIVENESS OF INFORMATION CENTRES AND SERVICES
DONALD W. KING and JOSE-MARIE GRIFFITHS *In* AGARD, Evaluating the Effectiveness of Information Centres and Services 14 p (SEE N89-11625 02-82) Sep. 1988
(AGARD-LS-160) Avail: NTIS HC A05/MF A01

Evaluation is a subject of considerable attention at the current time. Three principal aspects of evaluation and information are

presented here. The first involves the evaluation of information workers and services. The second deals with evaluation from the perspective of users served, their organizations and higher levels of aggregation such as to industries, sectors, the entire nation and all nations. The third aspect is how information and information services affect users. Several levels within information service centers are described. One can perform evaluation at each of these levels (i.e, resource components, activities, services and products, functions and information units). That is, at each level one can measure input of resources (i.e, capital, labor, technology, information, etc.) and output quantities produced. Such output divided by input can provide estimates or indicators of productivity. The output of information services is one of several input resources to users. The extent to which this input affects output and productivity is of considerable interest. As shown in Figure 1 on the next page, the input resources (including information) affect user activities, their functions, their organizations, and so on, up to the point that aggregated information use and subsequent productivity affects national goals. Below we attempt to show how these interrelationships work. First, several definitions are given.
Author

N89-11632# Bell Telephone Labs., Inc., Murray Hill, NJ. Libraries and Information Systems.
EVALUATING FOR INFORMATION CENTER PLANNING
W. DAVID PENNIMAN *In* AGARD, Evaluating the Effectiveness of Information Centres and Services 3 p (SEE N89-11625 02-82) Sep. 1988
(AGARD-LS-160) Avail: NTIS HC A05/MF A01

A business-oriented approach to information center planning and evaluation is presented. The need for output measures a quantitative expression of service value is described and a method of planning incorporating these concepts is provided. Both top-down and bottom-up planning responsibilities are identified and the specific steps involved in a business planning process are given. The competitive nature of information service is emphasized throughout.
Author

N89-18478# Software Sciences Ltd., Farnborough (England).
MULTI-LEVEL PARALLEL PROCESSING FOR VERY HIGH PERFORMANCE REAL-TIME DATABASE MANAGEMENT
PETER R. TILLMAN, RAY GILES, and IAN WAKLEY *In* AGARD, Software Engineering and Its Application to Avionics 11 p (SEE N89-18446 11-06) Nov. 1988
(AGARD-CP-439) Avail: NTIS HC A18/MF A01

During the period 1980 to 1984 the software sciences staff, together with the UK MOD research scientists, built and demonstrated a real-time relational database system named ADDAM, which ran up to 50 transactions per second on a network of 16 bit minicomputers. Since then, the company has embarked on a private venture development to scale up the throughput to over 1000 transactions per second. This development has required the adoption of a highly parallel processing architecture. The node software was completely redesigned so that the database can be partitioned in a single node, to enable multiple transactions to run in parallel, or one transaction to run against different parts of the database in parallel. The hardware design utilizes an array of Inmos Transputers which will deliver a nominal performance of 120 mips per node. The overall design of the system and the benefits available from adopting such a solution to the design of military real time systems is described. It also discusses the design issue which the Transputer architecture raises, the database management protocol design and the approach to maintaining database integrity in the face of concurrent parallel transactions.
Author

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ECONOMICS AND COST ANALYSIS

Includes cost effectiveness studies.

N88-20179# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Helicopter and Military Aircraft Group.
REASONS FOR INCREASING DEVELOPMENT COST OF ROTARY WING AIRCRAFT AND IDEAS TO REVERSE THE TREND
VOLKER VONTEIN *In* AGARD. Flight Vehicle Development Time and Cost Reduction 15 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

General cost trends of complex systems, such as helicopters, are described. Then, the influence of requirements and complexity on the cost of helicopters are discussed. After an analysis of cost trends and of negative effects relative to helicopter development cost ideas to reverse the trend are presented. In this context, besides the generally used classical methods of good engineering practice, other methods, such as cost engineering and international cooperation, are dealt with. In summary, good engineering judgment combined with proper planning and management still is the best method to keep costs under control.
Author

N88-20180# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
THE JUDGEMENT AND EVALUATION OF LONG-TERM INVESTMENTS DEMONSTRATED BY MEANS OF A CIVIL AIRCRAFT PROGRAM
W. ZABKA *In* AGARD. Flight Vehicle Development Time and Cost Reduction 9 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The economic characteristics of the civil aircraft industry are unique in terms of the magnitude of investment and the risks involved. Civil aircraft programs represent complex risk ventures accomplished in an environment of constantly changing market conditions, competitive actions, and technological alternatives. Economic aspects of the civil aircraft industry to be considered when preparing a decision for a new aircraft program are considered. Subjects discussed are organized under three major sections. The first provides a short overview of the economic realities of the civil aircraft business. The second major section focusses on how to comprehend adequately all these factors in one transparent calculation in order to describe the main criteria milestones in a civil aircraft program, with special emphasis on financial aspects. The third section deals with the separate discussion of the influencing factors and their changes. Special emphasis is placed on the impact of development costs and development lead time.
Author

N88-20183# General Electric Co., Lynn, MA. Turboshaft Engine Products Dept.
OPTIMIZING POWERPLANT DESIGN AND DEVELOPMENT CYCLES
LOUIS A. BEVILACQUA and H. GERARD DONOHIE *In* AGARD. Flight Vehicle Development Time and Cost Reduction 10 p (SEE N88-20173 12-81) Sep. 1987
(AGARD-CP-424) Avail: NTIS HC A14/MF A01

The cost of engine development programs has been increasing. The time required to complete these programs has also increased, but this is not so clear - nor so dramatic - because the added time has been placed at the front end with R and D and demonstrator programs. Since these tend to reduce the risk of Full Scale Developments the assessment is that the total time required for engine development has not increased significantly. While it is not sure that the increasing cost trend can be reversed - or even slowed down - views as to cause and recommendations are made to control the trend. Also identified are alternatives. In this regard the derivative engine approach is cited as having strong potential for significant reductions in both time and cost.
Author

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SPACE RADIATION

Includes cosmic radiation; and inner and outer earth's radiation belts.

N89-17749# Cambridge Univ. (England).
REMOTE SENSING OF INTERPLANETARY SHOCKS USING A SCINTILLATION METHOD
A. HEWISH *In* AGARD, Scattering and Propagation in Random Media 6 p (SEE N89-17706 10-31) *Mar. 1988*
(AGARD-CP-419) Avail: NTIS HC A23/MF A01

Energetic interplanetary disturbances originating at the Sun cause geomagnetic storms when they reach the Earth. The disturbances affect radio communication, damage electrical power grid networks, increase the atmospheric density and drag on satellites, and are accompanied by showers of energetic particles which present radiation hazards to manned spacecraft. A ground-based method for locating and tracking transients in interplanetary space long before they reach the Earth is described. Continuous observations of transients during a two year period near sunspot maximum have demonstrated the potential of the technique for predicting geomagnetic storms and new information on the zones of the solar disk from which transients originate was given. The latter contradicts some widely held theories in solar-terrestrial physics and shows that a major revision of ideas is needed. Contrary to expectations, it was found that open-magnetic field regions known as coronal holes are the dormant sources of the most powerful interplanetary shocks. This result conflicts with the solar flare theory of geomagnetic storms.
Author

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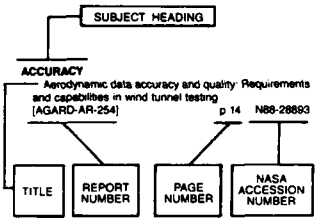

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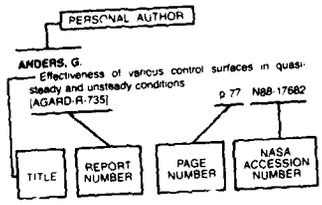

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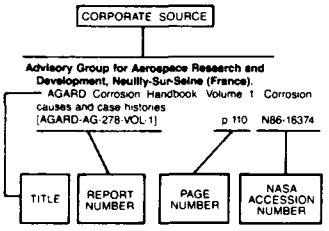

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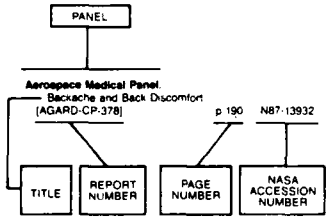

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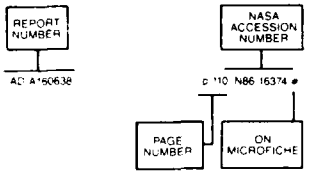

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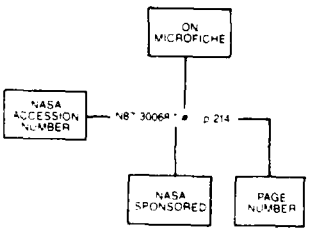

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