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AGARD-INDEX 83-85

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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARD Index of Publications 1983-1985

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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD INDEX OF PUBLICATIONS

1983–1985

This Index has been prepared as part of the programme of the Technical Information Panel of AGARD.

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- 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;
- 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);
- 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;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

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Published June 1987

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ISBN 92-835-1550-1

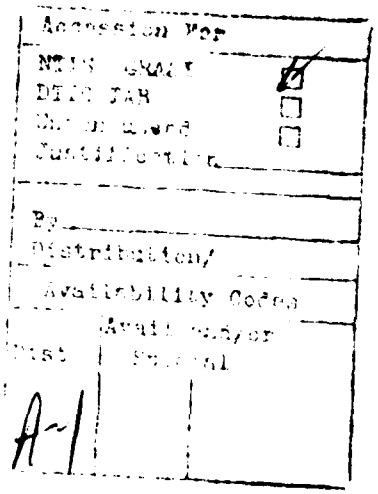
Printed by Specialised Printing Services Limited
40 Chigwell Lane, Loughton, Essex IG10 3TZ

PREFACE

This volume provides abstracts and indexes for AGARD publications published during the period 1983 – 1985. By an arrangement with the 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 its abstract journals and bibliographies. The major subject divisions are listed in the Table of Contents, 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.

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



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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).

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

03 AIR TRANSPORTATION AND SAFETY N.A.
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14 GROUND SUPPORT SYSTEMS AND FACILITIES (SPACE) N.A.
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ENGINEERING

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45 ENVIRONMENT POLLUTION N.A.
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PHYSICS

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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 and political science; and urban technology and transportation.

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

81 ADMINISTRATION AND MANAGEMENT **N.A.**
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82 DOCUMENTATION AND INFORMATION SCIENCE **239**
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83 ECONOMICS AND COST ANALYSIS **N.A.**
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SPACE SCIENCES

Includes space sciences (general); astronomy; astrophysics; lunar and planetary exploration; solar physics; and space radiation.
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90 ASTROPHYSICS **N.A.**
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91 LUNAR AND PLANETARY EXPLORATION **N.A.**
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92 SOLAR PHYSICS **N.A.**
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93 SPACE RADIATION **N.A.**
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GENERAL

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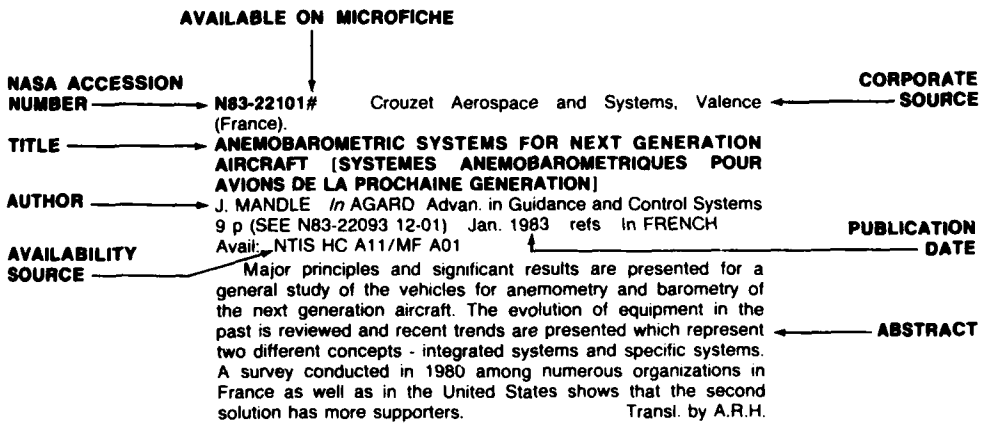
TYPICAL CITATION AND ABSTRACT



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ABSTRACT SECTION

01

AERONAUTICS (GENERAL)

N83-22093# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ADVANCES IN GUIDANCE AND CONTROL SYSTEMS
Jan. 1983 240 p refs Symp. held in Lisbon, 12-14 Oct. 1982
In ENGLISH and FRENCH
(AD-A125687; ISBN-92-835-0324-4; AGARD-CP-321) Avail: NTIS HC A11/MF A01

Advances in optimal control theory, synthesis techniques and design methodology applicable to aircraft control are discussed. The rapidly developing technologies in computation, data distribution systems, computer aided design methods and data bases which permit application of theories and synthesis methods heretofore impractical are discussed. Aspects of these emerging technologies ranging from theory through applications including aircraft, missiles, space vehicles and unmanned vehicles are discussed. Automatic flight control, airborne/spaceborne computers, and air navigation are emphasized. For individual titles, see N83-22094 through N83-22111.

N83-22094# Systems Technology, Inc., Hawthorne, Calif.
PROGRESS AND PITFALLS IN ADVANCED FLIGHT CONTROL SYSTEMS
D. MCRUER *In* AGARD Advan. in Guidance and Control Systems 17 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

Unfavorable side effects of the conjunction of multiple-fail-operational fly-by-wire flight control and high-performance new aircraft technology are discussed. Greater flight control system (FCS) complexity and cost are obvious disadvantages but other unfavorable effects are more subtle. The first is associated with the flight control and flying qualities of unstable relaxed static stability aircraft. In solving the control problem an equivalent vehicle is created in which the key dynamic properties comprise a mix of FCS and airframe parameters. Unfortunately, the equivalent vehicle dynamics may no longer correspond to those of conventional aircraft. Instead, they are different in kind as well as degree. There are very few flying quality data that are appropriate for such systems and, not surprisingly, existing criteria are difficult or impossible to apply directly. Such data as do exist are summarized and implications for possible criteria developed. The second issue is the accumulation of lags and delays resulting when stick and flexible mode suppression filters, high-frequency actuation dynamics, and computational delays, are combined. These give rise to a net effective time lag or delay in the vehicle dynamics as seen by the pilot which, if excessive, can cause serious piloting problems. The third example focuses on some of the peculiarities associated with sampled, as contrasted with continuous, control. R.J.F.

N83-22095# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
DESIGNING IMPROVED TRACKING REGULATORS FOR PILOTING HIGHLY MANEUVERABLE AIRCRAFT [REALISATION DE REGULATEURS DE POURSOUTE AMELIORES POUR LE PILOTAGE DES AVIONS A GRANDE MASOEUVRABILITE]
O. L. MERCIER *In* AGARD Advan. in Guidance and Control Systems 13 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

The multivariable control of an highly maneuvering aircraft in an extended flight envelope is receiving a growing attention in recent years. From the control designer point of view, it bears close relationship to the servomechanism problem in the sense that a vector of output variables is regulated to track continuously set command variables. This tracking problem is further complicated by the fact that, in the range of considered maneuvers, the dynamic model is highly nonlinear, variable about the flight domain, and prone to severe modeling errors and variations. Yet, piloting objectives must be met while satisfying handling qualities specifications. In addition, tracking must be maintained under continuously acting external disturbances and low-frequency turbulence must be rejected. Important defects of classical methods are shown and an improved theory is presented and applied to the fighter control problem. Tolerance of model mismatch and nonlinearities is especially demonstrated in numerical simulations.
Author

N83-22096# Salford Univ. (England). Dept. of Aeronautical and Mechanical Engineering.
MICROPROCESSOR IMPLEMENTATION OF FAST-SAMPLING DIRECT DIGITAL FLIGHT-MODE CONTROLLERS
B. PORTER, A. BRADSHAW, A. GARIS, and M. A. WOODHEAD *In* AGARD Advan. in Guidance and Control Systems 8 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

Some general results are extended to allow for a computational time-delay of up to one sampling period by a simple modification of the control algorithms. The resulting control algorithms are simple to implement and provide tight non-interacting control. Their efficiency and effectiveness are demonstrated by the presentation of the results of a laboratory microprocessor implementation in which the controllers are required to effect fuselage pitch pointing and vertical translation maneuvers in the case of an analogue computer representation of the YF-16 aircraft. R.J.F.

N83-22097# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst fuer Dynamik der Flugsysteme
SYSTEMATIC COMPUTER AIDED CONTROL DESIGN
G. GRUEBEL and G. KREISSELMEIER *In* AGARD Advan. in Guidance and Control Systems 7 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

Computerized synthesis techniques of modern control theory are in widespread use, but a number of fundamental design problems still remain. They are the design specfications problem, the free design parameter problem, the plant complexity versus controller simplicity problem, and the dirty design environment problem. A design procedure which comes close to solving these design problems is recommended: it is an iterative design technique using a performance index vector which provides a systematic guidance for the designer to take care of multiple design objectives simultaneously and individually. As a design tool unconstrained

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

parameter optimization is used. A practical application is briefly reported: The design of a robust control loop for a fighter aircraft where 42 performance criteria of 9 different sorts have been considered simultaneously. R.J.F.

N83-22098# Rome Univ. (Italy). School of Aerospace Engineering.
DIGITAL IMPLEMENTATION OF A LASER ACTIVE FLIGHT CONTROL SYSTEM WITH PROCESSED DECOUPLED STATES
A. DANESI *In* AGARD Advan. in Guidance and Control Systems 14 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

The results of the state variable decoupling theory are applied to decouple the roll and yaw lateral motion as required to satisfy independently maneuvering and trajectory following specifications. The rudder channel gains, yielding the decoupling process and forcing the vehicle transient behaviour to reproduce the desired response, are computed and the resulting multi-input-multi-output autopilot feedback structure is described. The software aspects of the digital autopilot, including the laser package and microprocessors resolving the control laws, are presented and the system simulation results are shown for the evaluation of the system dynamical behaviour in response to a wind shear perturbation. R.J.F.

N83-22099# Technische Univ., Clausthal-Zellerfeld (West Germany). Lehrstuhl fuer Regeltechnik und Electronik.
IMAGE SUPPORTED NAVIGATION IN LOW ALTITUDES BASED ON THE DETECTION OF ROADS AND RIVERS
R. D. THERBURG *In* AGARD Advan. in Guidance and Control Systems 7 p (SEE N83-22093 12-01) Jan. 1983
Avail: NTIS HC A11/MF A01

If a flight navigation system has to operate independently of ground stations or satellites, it has to be updated by acquisition of ground data. Position-fixing by automated detection of rivers, roads, and other traffic routes in the visual image underneath the aircraft is discussed. These patterns, undistorted even if viewed from low altitudes, are detected by an electrooptical sensor, which correlates the image with a rotating slit. As this sampling pattern is matched to line-shaped image patterns, traffic routes are detected in highly structured background in spite of weak contrast. For position fixing data of detected traffic routes are fed to a micro computer on board, to be compared with stored map data of traffic routes. This approach forced the development of a suitable nonlinear filtering method, yielding an optimal estimation of the real position and thereby the position offset of a dead reckoning system. R.J.F.

N83-22100# RCA Government Systems Div., Cherry Hill, N.J.
DESIGN AND SIMULATION OF AN INTELLIGENT MISSILE SEEKER
J. HAYMAN *In* AGARD Advan. in Guidance and Control Systems 15 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

An intelligent tracking algorithm for an IR imaging missile seeker and a method of evaluating its performance in simulated flight is described. The missile is a fire-and-forget, shoulder-launched, anti-tank weapon that lofts to an altitude of approximately 150 meters and then homes toward the target using proportional guidance. A gyro stabilized seeker is precessed to the target by pointing commands. These pointing commands are developed from an imaging sensor by a new tracking algorithm that performs well in a highly cluttered background. Both the tracking algorithm design and its evaluation in missile flights were accomplished using a digital computer simulation called HUGGER. This program includes a 6 degree-of-freedom missile simulation, a detailed seeker model, a three-dimensional model of the target, a two-dimensional background model, and the intelligent tracking algorithm. Sensor images of the target as seen from the missile are formed on a 64 x 128 pixel infrared charge coupled device array. The algorithm utilizes three features within the image: intensity, spatial frequency, and internal gradients. A multithresholding technique is also described which enhances target discrimination. R.J.F.

N83-22101# Crouzet Aerospace and Systems, Valence (France).
ANEMOBAROMETRIC SYSTEMS FOR NEXT GENERATION AIRCRAFT [SYSTEMES ANEMOBAROMETRIQUES POUR AVIONS DE LA PROCHAINE GENERATION]
J. MANDLE *In* AGARD Advan. in Guidance and Control Systems 9 p (SEE N83-22093 12-01) Jan. 1983 refs In FRENCH
Avail: NTIS HC A11/MF A01

Major principles and significant results are presented for a general study of the vehicles for anemometry and barometry of the next generation aircraft. The evolution of equipment in the past is reviewed and recent trends are presented which represent two different concepts - integrated systems and specific systems. A survey conducted in 1980 among numerous organizations in France as well as in the United States shows that the second solution has more supporters. Transl. by A.R.H.

N83-22102# Smiths Industries Ltd., Bishops Cleeve (England). Aerospace and Defence Systems Div.
THE USE OF MULTIPLEX DATA BUSES IN A HIGH INTEGRITY SYSTEM
P. CROUCH and A. G. SEABRIDGE (British Aerospace Aircraft Group) *In* AGARD Advan. in Guidance and Control Systems 11 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

The utility systems of an aircraft were analyzed and shown to benefit considerably from integration into a connected system with shared processing resources. The MIL-STD-15538 data bus was selected as the most cost effective tool for integration, but raises problems connected with ensuring the safety of the aircraft. Careful design of the data bus components and controllers with particular attention being paid to built-in-test techniques and in the functional segregation of the interfaces, subsystems and computing facilities has allowed a sufficiently reliable system to be designed and this is now entering full scale development. R.J.F.

N83-22103# Singer-Kearfott, Wayne, N. J.
ADVANCED DESIGN AND PERFORMANCE OPTIMIZATION TECHNIQUES UTILIZED TO DEVELOP THE F-111 WEAPONS/NAVIGATION COMPUTER (WNC)
A. J. SHAPIRO *In* AGARD Advan. in Guidance and Control Systems 14 p (SEE N83-22093 12-01) Jan. 1983
Avail: NTIS HC A11/MF A01

A new weapons navigation computer (WNC)(AN/AYK-18) to provide the F-111 with an upgraded central computer to serve through the 1990's is discussed. The goals for this computer were increased computational capability, increased reliability, operability with existing (CP-2/CP-2 EX) and future (MIL-STD-1750) Instruction Set Architectures (ISA's), and form, fit and function compatibility with its AN/AK-6 predecessor. By the systematic application of design, performance and cost trade-offs, all essential goals were achieved. Computational capability improvement was achieved by using a 32-bit Central Processor Unit (CPU), memory and local bus and a 16-bit bus and architecture for the remainder of the computer. Reliability was improved by employing Kearfott's hollow card cooling concept and thereby keeping all components well below their critical temperatures. The ISA's for both AN/AYK-6 and AN/AYK-18 were embedded in microcode and selectable by software. The resultant WNC has an affordable production cost, can emulate the required ISA's, has a predicted reliability of over 3000 hours, a throughput of 462 KOPS, Built-In Test (BIT) to the card level and is interchangeable with the AN/AYK-6. R.J.F.

N83-22104# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
A MODULAR APPROACH TO HIGH RELIABILITY SOFTWARE GENERATION WITH APPLICATION TO NONLINEAR CONTROL
S. M. WRIGHT and J. S. WINTER *In* AGARD Advan. in Guidance and Control Systems 11 p (SEE N83-22093 12-01) Jan. 1983 refs
Avail: NTIS HC A11/MF A01

This paper describes an interlocking set of techniques covering control law and control system architecture design, documentation and validation. These address the problems experienced by the airframe manufacturer in proving the integrity of a digital control system (hardware and software) in such a way that the undoubted power and flexibility of digital techniques can be fully exploited

An idealized processor architecture and instruction set is presented and its application illustrated by reference to a set of nonlinear control laws. This shows how the control law coding and verification can be eliminated as a separate step in the design process. Finally the beneficial effect of the control law structure on the process of failure identification and subsequent failure management is described. Author

N83-22105# Calspan Advanced Technology Center, Buffalo, N.Y.

FLIGHT CONTROL SYSTEM DESIGN USING ROBUST OUTPUT OBSERVERS

E. G. RYNASKI *In* AGARD Advan. in Guidance and Control Systems 8 p (SEE N83-22093 12-01) Jan. 1983 refs

Avail: NTIS HC A11/MF A01

An investigation was made of the application of robust output observer theory to the design of flight control systems for advanced aircraft configurations. Observer theory constitutes a natural design tool because the resulting observers are in themselves unobservable and do not increase the order of the closed-loop response, thereby more closely satisfying flying qualities requirements. Examples are presented to show that the observer configuration is not unique in either the observer poles or the output sensors, and many different control system configurations using a variety of sensors can be designed to yield identical closed-loop dynamic behavior. In this way, considerable analytic and physical redundancy can be incorporated into nearly any flight control system. Author

N83-22106# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Dynamics Div.

ON VALIDATION OF MISSION-SOFTWARE BY CLOSED-LOOP TESTING IN REALTIME

H. NEUBAUER *In* AGARD Advan. in Guidance and Control Systems 15 p (SEE N83-22093 12-01) Jan. 1983

Avail: NTIS HC A11/MF A01

This contribution is intended to provide both some basic considerations on validation techniques for simulations and their application to a real-time digital computer simulation with hardware-in-the-loop (HWIL) Author

N83-22107# Dowty Electronics Ltd., London (England)

BUILDING IN INTEGRITY TO A HIGHER ORDER LANGUAGE

N. J. B. YOUNG *In* AGARD Advan. in Guidance and Control Systems 10 p (SEE N83-22093 12-01) Jan. 1983 refs

Avail: NTIS HC A11/MF A01

Despite potential advantages the use of High Order Languages (HOL's) in high integrity systems remains inadvisable. HOL compilers are complex and difficult to validate and even when correct may produce unexpected results. Methods are discussed for simplifying HOL's so that high visibility is maintained from HOL code through the process of translation down to machine code level. These methods can be applied to standard HOL's or a new HOL can be designed around them. The methods are particularly useful in embedded systems (such as engine controllers) of low cost relative to the facility to which they are applied and which require considerable modification during trials or in service. Author

N83-22108# Northrop Corp., Hawthorne, Calif. Flight Control Research Dept.

DEVELOPMENT AND APPLICATION OF DIGITAL CONTROL FOR TACTICAL AIRCRAFT FLUTTER SUPPRESSION

D. S. JOSHI, D. F. KESLER, and E. H. JOHNSON *In* AGARD Advan. in Guidance and Control Systems 14 p (SEE N83-22093 12-01) Jan. 1983 refs

(Contract F33615-80-C-3217)

Avail: NTIS HC A11/MF A01

Active control methods have been applied to synthesize and mechanize digital control laws for tactical aircraft flutter suppression. Several methods to digitize analog control laws have been compared. The State Space Method with Jordan Canonical Transformation offers a systematic and efficient digital flutter control design for multivariable systems. A transonic wind tunnel test conducted under a U.S. Air Force contract conclusively demonstrated the feasibility of digital implementation. Author

N83-22109*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

NASA/RAE COLLABORATION ON NONLINEAR CONTROL USING THE F-8C DIGITAL FLY-BY-WIRE AIRCRAFT

G. F. BUTLER, M. J. CORBIN, S. MEPHAM, J. F. STEWART, and R. R. LARSON *In* AGARD Advan. in Guidance and Control Systems 17 p (SEE N83-22093 12-01) Jan. 1983 refs

Avail: NTIS HC A11/MF A01 CSCL 01C

A cooperative advanced digital research experiment (CADRE) was established by the National Aeronautics and Space Administration (NASA) and the Royal Aircraft Establishment (RAE), in which nonlinear control algorithms developed by the RAE were tested on the F-8C digital fly-by-wire (DFBW) aircraft based at the Dryden Flight Research Facility. In the initial phase of the collaboration, some variable-gain algorithms, referred to collectively as variable integral control to optimize response (VICTOR) algorithms, were flight tested. With VICTOR, various measures available within the control system are used to vary gains and time-constants within the closed loop and thereby enhance the control capability of the system, while reducing the adverse effects of sensor noise on the control surfaces. A review of design procedures for VICTOR and results of preliminary flight tests are presented. the F-8C aircraft is operated in the remotely augmented vehicle (RAV) mode, with the control laws implemented as FORTRAN programs on a ground-based computer. Pilot commands and sensor information are telemetered to the ground, where the data are processed to form surface commands which are then telemetered to the ground, where the data are processed to form surface commands which are then telemetered back to the aircraft. The RAV mode represents a single-string (simplex) system and is therefore vulnerable to a hardover since comparison monitoring is not possible. Hence, extensive error checking is conducted on both the ground and airborne computers to prevent the development of potentially hazardous situations. Experience with the RAV monitoring and validation procedures is described. Author

N83-22110# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Aircraft Div.

FLIGHT TEST EXPERIENCE WITH A DIGITAL INTEGRATED GUIDANCE AND CONTROL SYSTEM IN A CCV FIGHTER AIRCRAFT

U. KORTE *In* AGARD Advan. in Guidance and Control Systems 11 p (SEE N83-22093 12-01) Jan. 1983 refs

Avail: NTIS HC A11/MF A01

A quad redundant digital FBW Control System for a highly unstable fighter aircraft has been developed and flight tested by MBB in a single seater F-104 G which had been modified as a CCV demonstrator. The CCV program was funded by the German MOD. From Dec. 1977 to Nov. 1981 a total of 118 flights has been conducted. During these flights the quadruplex system was successfully tested for five different configurations starting with the highly stable basic aircraft and ending up with the highly unstable canard configuration with a static instability up to 22% mean aerodynamic chord (MAC). Some of the results obtained regarding control system design, handling evaluation and redundancy management with the digital system will be presented. Author

N83-22111# Marconi Avionics Ltd., Rochester (England). Combat Aircraft Controls Div.

GROUND AND FLIGHT TESTING ON THE FLY-BY-WIRE JAGUAR EQUIPPED WITH A FULL TIME QUADRUPLEX DIGITAL INTEGRATED FLIGHT CONTROL SYSTEM

T. D. SMITH, C. J. YEO, and R. E. W. MARSHALL *In* AGARD Advan. in Guidance and Control Systems 20 p (SEE N83-22093 12-01) Jan. 1983 refs

Avail: NTIS HC A11/MF A01

A national (U.K.) research programme has been undertaken with the aim of the design, development and demonstration of a safe, practical full time fly-by-wire flight control system for a combat aircraft. Throughout the program, the flight control system was to be treated in all airworthiness aspects as though it were intended for production. The flight trials were to include flight assessment of an integral spin prevention system and aircraft configurations which are unstable in pitch. The first major objective of the program has been achieved, namely the generation of confidence in the airworthiness of such a system, by the successful completion of

the design, development, ground testing and initial flight test assessment of a fully representative system. Author

N83-22112# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SOFTWARE FOR AVIONICS
Jan. 1983 450 p refs Conf. held in the Hague-Kijkduin, Netherlands, 6-10 Sep. 1982 *In* ENGLISH and FRENCH
(AD-A127131; ISBN-92-835-03332-6; AGARD-CP-330) Avail: NTIS HC A19/MF A01

The predominant impacts of computer software in avionics are addressed including the following areas: software design, analysis techniques, improvement of structure and design, military standards, verification, and validation. For individual titles, see N83-22113 through N83-22152.

N83-22113# General Dynamics Corp., Fort Worth, Tex.
AVIONIC SOFTWARE DESIGN
D. E. SUNDSTROM *In* AGARD Software for Avionics 8 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Time, theory, and applications experience have lead us to an understanding of a very specific software product, the avionics operational flight program. The knowledge we now have permits us to identify a common software structure and design methodology. The structure reflects the characteristics of the avionics environment, and is applicable to mission processors, stores management processors, integrated cockpit control processors, and possibly others. We identified a number of characteristics of the avionics environment and related these characteristics to design requirements for a common software operating structure. The adoption of this structure supports a design methodology which has many desirable features, beginning with common naming conventions, an emphasis on data flow specification, and clearly identified design responsibilities. A discussion of the structure and the design methodology are provided. This structure and methodology was demonstrated in production of F-16 airplanes and is currently the development basis for multiple software programs in advanced F-16 versions. It represents a mature and transferable technology. Author

N83-22114# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Unternehmnsbereich.
SOFTWARE DEVELOPMENT: DESIGN AND REALITY
H. VONGROOTE and F. SCHWEGLER *In* AGARD Software for Avionics 10 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Experiences gained during the development of the Operational Flight Program of the MRCA Tornado were described. A short outline of the organisational structure and of the Avionic System is given, followed by the description of the different design and test stages. Then some general reasons are presented which caused major changes to the software specifications and which are believed to be true for any development of a new avionic system. A description of the purging process of the assembler program was discussed. Author

N83-22115# British Aerospace Dynamics Group, Stevenage (England).
MASCOT DEVELOPMENTS TO IMPROVE SOFTWARE STRUCTURE AND INTEGRITY
H. R. SIMPSON *In* AGARD Software for Avionics 14 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

The principal features of the Modular Approach to Software Construction Operation and Test (MASCOT) approach to design are described and some possible developments to give improved software structure and integrity are proposed. These developments are concerned with three areas of the MASCOT approach: subsystem structure, process synchronization, and data access control. The proposed developments are entirely consistent with existing MASCOT concepts and, with little difficulty, can be incorporated into the system building, run time executive and dynamic monitoring software. It is a powerful feature of MASCOT that the supporting software which underpins the method (sometimes called the MASCOT machine) is not excessively complex and so can be reasonably easily implemented and readily understood. The proposed developments preserve this feature. B.G.

N83-22116# Electronique Serge Dassault, St. Cloud (France).
TOWARDS A VERITABLE SUPERVISOR PROGRAM FOR AVIONICS SOFTWARE [VERS UN VERITABLE ATELIER DE LOGICIEL AVIONIQUE]
G. BRACON *In* AGARD Software for Avionics 14 p (SEE N83-22112 12-01) Jan. 1983 refs In FRENCH
Avail: NTIS HC A19/MF A01

Experience acquired in the development of equipment and avionics software for the Mirage FI and the Mirage 2000, led to the definition of a software overseer. The AIGLE supervisor program is oriented toward considering methodologies and assists in developing, maintaining, and following the project. It involves a group of complementary operational tools which use a central data base and can then divide the information. The integration of official service and the comfort of man machine dialog permits improved productivity. The essential characteristics of AIGLE is the automatic knowledge of quality control information and of project management. This permits validation of production processes, an indispensable element in software certification.
Transl. by A.R.H.

N83-22117# Marconi Avionics Ltd., Boreham Wood (England).
REQUIREMENTS DECOMPOSITION AND OTHER MYTHS
T. G. SWANN *In* AGARD Software for Avionics 8 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

A myth is a traditional fiction that reveals a greater truth. Procurement of large, innovative, systems is discussed - why do we never get what we want? The problems are often blamed on certain types of faults in the requirement specification and the design process. Requirements specification are discussed and it is seen that they are far more complex than we are asked to believe. It is argued that the description of design as Requirements Decomposition is more than a simplification: it is positively misleading. Similary the virtues of good specifications, such as completeness and formality, are not just prerequisites for success: they are unattainable ideals. It is concluded that many traditional maxims, though valuable, should not be taken too literally. They are, perhaps myths. Author

N83-22118# British Aerospace Aircraft Group, Warton (England).
PRACTICAL CONSIDERATIONS IN THE INTRODUCTION OF REQUIREMENTS ANALYSIS TECHNIQUE
C. P. PRICE and D. Y. FORSYTH *In* AGARD Software for Avionics 12 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

A wider use of requirements analysis techniques in the development of avionic systems is probable. They may be employed in the production of software requirements in particular or the development of higher level system requirements. Such approaches are said to consist of a methodology used in the production process, software tools to assist in analysis, and the existence of a specific target software design interface such as language and architecture. The predicted quality and productivity improvements will only be attained if the election of tools and techniques is tempered by practical considerations. The main issues any organization contemplating the use of requirements analysis techniques will have to consider are discussed. They include the scope of application, system or software, the special needs of users, attributes of the methodology, the level of automation and the means by which they can be introduced to a project. Semi-Automated Functional Requirements Analysis (SAFRA) is briefly described. In SAFRA, Controlled Requirements Expression (CORE) is the method of production embracing data collection, system analysis and notation. Storage and validation of the description is achieved using the Problems Statement Language and Problem Statement Analyser (PSL/PSA) including a system description language, database management system and a suite of apropriate reports. B.G.

N83-22119# Electronique Serge Dassault, St. Cloud (France).
D.L.A.O.: A SUPPORT SYSTEM FOR DEFINING AVIONICS SOFTWARE [D.L.A.O.: UN SYSTEME D'AIDE]
S. CHENUT-MARTIN and F. DOLADILLE *In* AGARD Software for Avionics 11 p (SEE N83-22112 12-01) Jan. 1983 refs In FRENCH
Avail: NTIS HC A19/MF A01

Major principles are described for a system for the computer aided design of software. This support system helps elaborate the specifications of real time software, particularly avionics programs. The steps followed in analyzing definition processes applied for onboard computers, as well as in analyzing user needs and existing systems are considered. The discreet solutions obtained are then developed with particular stress on simplicity of use and ease in constructing documents. The system should be integrated in a coherent ensemble of tools covering the different stages of the life cycle of the software. The problems posed by integration with a system for computer aided design are raised.
Transl. by A.R.H.

N83-22120# Marconi Avionics Ltd., Boreham Wood (England).
THE MENTOR APPROACH TO REQUIREMENTS SPECIFICATION
D. JORDAN and B. HAUXWELL *In* AGARD Software for Avionics 5 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Requirements specification methodologies and documentation systems which are available adopt a range of differing viewpoints on the system development problem. Each is oriented to enabling the user to specify efficiency some particular aspect of the target system, and each places a particular emphasis on certain features. The role of an automated documentation system should be to accommodate all information relevant to a system design, to check rigorously that information for consistency, and to make it visible in a range of reports which individually provide various emphasis on the information. Development of a integrated system mentor, is intended to assist in the gathering of information, definition of terms, and development of designs for avionics systems. The system has the following major features: a new specification method which guides the user in the decomposition of his problem by partitioning the behaviour of the target system among a number of operational capabilities; a specification language NATTER (A NATural TERminology) is intended for use by any personnel involved in the system development and is sufficiently flexible to accommodate all functional documentation for the target system; and an advanced algebraic analysis technique which enables the system to perform a powerful dynamic consistency analysis of the evolving specification, and provide valuable feedback to the development teams. B.G.

N83-22121# Mathematischer Beratungs- und Programmierungsdienst G.m.b.H. Dortmund (West Germany).
THE COMPUTER AIDED SPECIFICATION SYSTEM EASY
L. HIRSCHMANN and N. CHRISTENSEN *In* AGARD Software for Avionics 12 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Easy is a formalism which support the description of the specification in a simple semiformal manner and emphasises the use of data types. It is our view, that a specification should not only be precise, unambigious and complete, but is also a document which serves for the communication between people (software engineers). The term specification is used to describe the result of the system design phase i.e. for the description of the decomposition of the system into modules and the interaction between these modules. A specification written in Easy consists of packages which provide the encapsulation of logically related information, data and functions. Packages communicate by interfaces which consist of procedures, types and constants. Objects of the export-interface are resources implemented in the exporting package and are made available to other packages. Objects used from other packages are listed in the import-interface. Restrictions in the use of exported procedures must be mentioned in the description of the procedure or (preferably) in the paragraphs 'sequence' and 'error'. A software tool - Easy Tool - was developed to support the use of Easy. It checks specifications for syntactical and semantical correctness, consistency and completeness, supports the editing, stores and maintains specifications in a data base and generates several crossreference lists. Future versions of the tool will support the transition from specification to implementation to make sure the program matches the specification. B.G.

N83-22122# General Dynamics Corp., Fort Worth, Tex.
THE IMPACT OF STANDARDIZATION ON AVIONIC SOFTWARE
J. D. ENGELLAND *In* AGARD Software for Avionics 6 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

This era of avionic software gave rise to a number of serious problems. Several of the software standards being promulgated today are legacies of the problems encountered with these early digital systems. However, in spite of all problems the digital systems were clearly demonstrated to be better and more capable and the movement to digital systems accelerated. With the advent of the microprocessor, it became practical to distribute a processor into virtually every subsystem. As a result, it has become possible to implement nearly any logic or mathematical concept in the avionic system software (e.g., Kalman filters, digital maps, coupled fire/flight control). Avionic systems have, in fact, reached the point where software is no longer simply a part of the system, software is the system. B.G.

N83-22123# Ada Joint Program Office, Arlington, Va.
ADA STATUS AND OUTLOOK
J. F. KRAMER, JR. *In* AGARD Software for Avionics 6 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

The Ada programming language is discussed. Author

N83-22124# Ministry of Defence, Paris (France).
D-12 STANDARDIZING LTR FOR ONBOARD COMPUTERS: THE PRESENT AND THE FUTURE [STANDARDISATION DU LTR POUR CALCULATEURS EMBARQUES]
I. DEMONTCHEUIL *In* AGARD Software for Avionics 10 p (SEE N83-22112 12-01) Jan. 1983 In FRENCH
Avail: NTIS HC A19/MF A01

Numerous developments have taken place since the LTR language was standardized in France in 1974 for operational military applications, so the language is effectively used in more operational onboard problems systems and in development. The LTR V2 language meets the principal criteria, produces an effective code, covers specific needs, has facility for writing or modifying programs, and has an adequate production chain. Because of the progress of programming techniques, a strategy must be defined for the future. It is not possible to wait in hope that ADA can provide a solution since examination of its definition raises fears about its effective usage for onboard systems application. This is why a strategy offering the best guarantee was defined - renewing the LTR language to profit from technological improvements, while preserving the effectiveness of acquisition and the possibility of utilization. This language, called LTR V3 is presented along with its supervisor programming. Transl. by A.R.H.

N83-22125# Naval Weapons Center, China Lake, Calif.
OPERATIONAL FLIGHT PROGRAM DEVELOPMENT WITH A HIGHER ORDER LANGUAGE
R. E. WESTBROOK and L. L. CREWS *In* AGARD Software for Avionics 4 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

The problems and the future trends and solutions to many of the problems of developing Operational Flight Programs (OFP) for embedded computer systems are presented. Author

N83-22126# Marconi Avionics Ltd., Boreham Wood (England).
THE USE OF HIGH ORDER LANGUAGES ON MICROPROCESSORS
R. M. BOARDMAN *In* AGARD Software for Avionics 5 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

The use of high order languages on microprocessors is addressed. The special features of the software tools (compilers, loaders, etc.) and support environments which are highly desirable if the high order languages are to be used effectively are described. The impact of high order languages on programming and documentation techniques is discussed, and the implications for both Off Line and On Line Testing are considered. Microprocessors

which are embedded within larger systems and which are dedicated to specific tasks, for example display drivers or signal processing units are discussed. For the majority of systems these tasks are real time. For most avionics applications the microprocessors are fitted with the minimum amount of memory, usually a mixture of ROM and RAM, and have a minimum of interfaces with the outside world. These interfaces are frequently special purpose. The practical application of a High Order Language to this type of microprocessor based project is described in the forms of a Case Study. Author

N83-22127# Ferranti Computer Systems Ltd., Gwent (England).
SOFTWARE DESIGN AND DEVELOPMENT USING MASCOT
R. DIBBLE *In* AGARD Software for Avionics 15 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

The MASCOT methodology was developed to contain increasing software costs and ensure the production of reliable software. Ferranti programmers produced standard MASCOT products and developed several large real time application using MASCOT. Their experience are discussed. A basic feature of the methodology is modularity, which produces benefits at all stages of software development, although the degree of decomposition required by MASCOT is a problem for most projects. MASCOT identifies three types of modules (Activities, Channels and Pools) and represents the design in a diagrammatic form (the ACP diagram) which is regarded as a useful design tool and an effective representation of that design. Formal definition of data and its access mechanisms is an improvement over existing practices but whether it significantly eases the problems of multiprocessor design is disputed. Overall there is a price to be paid for the MASCOT method in terms of runtime overheads and we see how this problem was resolved by various projects. The advantages and disadvantages of MASCOT are discussed and related to avionic software requirements. The relevance of the design philosophy to the imminent arrival of Ada is considered. Author

N83-22128# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Aircraft Div.
SAFETY CRITICAL FAST-REAL-TIME SYSTEMS
B. GUESMANN, O. F. NIELSEN, and R. HANSON *In* AGARD Software for Avionics 6 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

The development of advanced military aircraft requires large embedded digital systems and digital test equipment for performance enhancement. Examples at MBB are CCV III, an eight computer test rig for evaluating next-generation fly-by-wire systems and cross software test systems (CSTS) for verifying safety critical airborne software. Typical cycle times of such systems range from 10 to 60 msec. Such systems impose restrictions on software design and development tools, especially on required high order language tools. Four languages, FORTRAN, PEARL, C and PASCAL were evaluated for use in the CCV III system and CSTS. Finally C was chosen to implement both systems with very satisfactory results. A comment will be given with respect to convert C programmed systems to ADA in the future. Author

N83-22129# Naval Postgraduate School, Monterey, Calif.
USABILITY OF MILITARY STANDARDS FOR THE MAINTENANCE OF EMBEDDED COMPUTER SOFTWARE
N. F. SCHNEIDEWIND *In* AGARD Software for Avionics 6 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Several military software standards were examined and evaluated with respect to their applicability and usability for maintaining embedded computer software. These standards included the following: Department of the Navy Tactical Digital System Documentation Standards, SECNAVINST 3560.1; MIL-STD 1979, Navy Military Standard for Weapon System Development; and Weapon Specification 8506. These standards were discussed from three standpoints: (1) the degree to which they support the use of newer software development technologies (e.g., requirements analysis methodologies) for improving software maintenance; (2) the effect of the microcomputer and its software development environment on the application of these standards; and (3) the extent to which these standards enhance traceability (tracing the various levels of related documentation). These aspects required a reevaluation of the applicability of software standards. A recommendation is made to use the A7-E Aircraft software redesign project as a model for improving (1) and (3) in the three standards. Item (2) was judged to be not relevant to the development of software standards. Author

N83-22130# Kongsberg Vapenfabrikk A/S (Norway).
SOFTWARE CONFIGURATION MANAGEMENT AT WORK
J. T. PEDERSEN *In* AGARD Software for Avionics 5 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Software configuration management is dicussed. Author

N83-22131# Marconi Avionics Ltd., Boreham Wood (England).
CONFIGURATION MANAGEMENT AND THE ADA PROGRAMMING SUPPORT ENVIRONMENT
K. J. PULFORD *In* AGARD Software for Avionics 10 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

It is the aim of software development environments to increase the efficiency with which software is produced. One such environment is the ADA programming support environment (APSE) initiated by the U.S. Department of Defence. These environments are a great benefit to programmers making some of their tasks much easier. They also offer great opportunities to monitor and control software development. This in its turn will affect the way that projects are organized and run, and it will affect project personnel jobs to varying extents. The way that projects will be affected by the adoption of an APSE is explored by considering the way that Configuration Management can be implemented in an APSE. Author

N83-22132*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SOFTWARE FAULT TOLERANCE FOR REAL-TIME AVIONICS SYSTEMS
T. ANDERSON (Newcastle upon Tyne Univ.) and J. C. KNIGHT *In* AGARD Software for Avionics 6 p (SEE N83-22112 12-01) Jan. 1983 refs
(Contract NAS1-14101; NAS1-14472)
Avail: NTIS HC A19/MF A01 CSCL 09B

Avionics systems have very high reliability requirements and are therefore prime candidates for the inclusion of fault tolerance techniques. In order to provide tolerance to software faults, some form of state restoration is usually advocated as a means of recovery. State restoration can be very expensive for systems which utilize concurrent processes. The concurrency present in most avionics systems and the further difficulties introduced by timing constraints imply that providing tolerance for software faults may be inordinately expensive or complex. A straightforward pragmatic approach to software fault tolerance which is believed to be applicable to many real-time avionics systems is proposed. A classification system for software errors is presented together with approaches to recovery and continued service for each error type. Author

N83-22133# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
ELECTRONIC WARFARE SOFTWARE
R. L. SHAW *In* AGARD Software for Avionics 5 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

A three year effort which looked at various software cost reduction techniques within the framework of electronic warfare (EW) processing requirements is summarized. An EM processing characterization was undertaken to provide a data base for the following investigations, which are also summarized: (1) The investigation of the compatibility of instruction sets, which are used or have a near term possibility of being used in EW systems, to the EW processing tasks; (2) The investigation of high order languages and software structuring efficiencies based upon bench marks which characterized major EW functions. M.G.

N83-22134# Marconi Avionics Ltd., Boreham Wood (England).
AN EIGHT POINT TESTING STRATEGY FOR REAL TIME SOFTWARE
R. E. WILSON and N. HIGSON *In* AGARD Software for Avionics 8 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

A strategy for testing real time modular software systems is described. The structure, objectives, and documentation considerations are addressed. The responsibilities of programming staff using such a strategy and the problems entailed in re-testing as result of errors detected at higher levels of testing are also considered. M.G.

N83-22135# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Sistemi Avionici ed Equipaggiamenti.
TORNADO FLIGHT CONTROL SOFTWARE VALIDATION: METHODOLOGY AND TOOLS
R. PELISSERO *In* AGARD Software for Avionics 13 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

Methods and tools adopted in the Tornado project to perform software confidence testing; investigation of failure effect, performance prediction, and assessment and read across between simulated and in flight behavior are described. The real time facility in use is based on an integrated hardware/software system that was ad-hoc designed to allow closed loop testing of the Tornado TF/AFDS subsystem with particular emphasis given to autopilot. The real equipments of interest are installed on an avionic rig and the flight conditions are obtained via a data flow to/from an external computing facility which performs both the acquisition/stimulation functions and the various simulations (aircraft, engine, sensors, etc.). The validity of the results achieved by the facility is confirmed by repetition of maneuvers performed during previous flights. In addition, other possible applications of such a facility are summarized. M.G.

N83-22136# Tracor, Inc., Warminster, Pa.
APPLICATIONS OF NETWORK MODELING AND ANALYSIS TO SYSTEM VALIDATION AND VERIFICATION
G. M. SUNDBERG *In* AGARD Software for Avionics 11 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

Network logic modeling and analysis (NLMA), a manual analytic process derived from network analysis and Boolean logic, is described. Its main purpose is to verify and validate complex systems or concepts at any stage of development. Specific examples are given which illustrate the application of the method at each phase of the software life cycle. M.G.

N83-22137# Electronique Serge Dassault, St. Cloud (France).
IDA: SOFTWARE TEST LANGUAGE AND RELATED TOOLS [IDA: LANGUAGE DE TEST DU LOGICIEL ET OUTILS ASSOCIES.]
G. LAMARCHE and P. TAILLIBERT *In* AGARD Software for Avionics 15 p (SEE N83-22112 12-01) Jan. 1983 refs In FRENCH
Avail: NTIS HC A19/MF A01

Results are described from a study conduct to define a group of methods which permit computerizing the test operation of real time software. The principal characteristics of the test language defined are presented. The different problems that can be encountered when using such a language are considered as well as the definition of a macrolanguage and a standard library of tools. A test tool particularly adapted to the case of a computer program behaving as a parallel processor is discussed.
Transl. by A.R.H.

N83-22138# Litton Technische Werke, Freiburg (West Germany).
SOFTWARE VERIFICATION OF A CIVIL AVIONIC AHR SYSTEM
M. KLEINSCHMIDT and N. SANDNER *In* AGARD Software for Avionics 9 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Requirements for software verification procedures to be used with highly integrated digital avionics software are defined. Verification tools are described along with their use in the testing of an attitude and heading reference system. M.G.

N83-22139# Aerospace Corp., Los Angeles, Calif. Information Sciences Research Office.
PROGRESS IN VERIFICATION OF MICROPROGRAMS
S. D. CROCKER *In* AGARD Software for Avionics 4 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Work on the development of a microcode verification system is described and a picture of how such a system might be used in the near future is given. Author

N83-22140# Naval Weapons Center, China Lake, Calif.
VALIDATION OF SOFTWARE FOR INTEGRATION OF MISSILES WITH AIRCRAFT SYSTEMS
J. R. MCMANIS *In* AGARD Software for Avionics 6 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

Critical aspects involved in the validation of avionics software developed to integrate missiles with attack aircraft systems are addressed. The situation covered is where the missile and the aircraft both have embedded computer systems, and that they have evolved to their current state in separate and totally independent development efforts. M.G.

N83-22141# Ferranti Computer Systems Ltd., Gwent (England).
IMPLEMENTING HIGH QUALITY SOFTWARE
E. J. DOWLING *In* AGARD Software for Avionics 14 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

Various factors affecting program implementation are discussed and some solutions are considered, in particular the range of tools that is available, and the way they can be applied. The traditional debug program is shown to be only one part of the whole tool set. Finally, the advantages and problem of ADA and its environment (APSE) are discussed. Author

N83-22142# Institut de Genie Logiciel, Paris (France).
THE QUALITY OF AVIONICS SOFTWARE: SPECIFICATION AND EVALUATION [LA QUALITE DES LOCICIELS AVIONIQUES: SPECIFICATION ET EVALUATION]
G. GERMAIN, M. GALINIER, and M. DELACROIS *In* AGARD Software for Avionics 15 p (SEE N83-22112 12-01) Jan. 1983 refs In FRENCH
Avail: NTIS HC A19/MF A01

While the IEEE glossary defines software quality as the ensemble of characteristics of a software product relative to its ability to satisfy given needs (such as those established in written specifications), the characteristics of quality which can be modelled and measured are not specified. A total approach to quality is described including the levels of decomposition of parameters. The identification and evaluation of internal and external parameters of avionics software are discussed. Transl. by A.R.H.

N83-22143# Marconi Avionics Ltd., Rochester (England). Flight Controls Div.
DISSIMILAR SOFTWARE IN HIGH INTEGRITY APPLICATIONS IN FLIGHT CONTROLS
D. J. MARTIN *In* AGARD Software for Avionics 13 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

The requirements of high integrity systems are defined and examples of failure surviving systems given. Having discussed the impact of digital processors on system design, various solutions are reviewed. Multiplex similar redundant systems are used widely in flight controls and some of their strengths and weaknesses are detailed. Software techniques applied to similar redundant systems are then briefly described. A dissimilar redundant solution, using two different microprocessors, is discussed and the impact of this architecture on software procedures is reported. Finally, a review of the strengths and weaknesses of the dissimilar architecture approach is given. M.G.

N83-22144# Marconi Avionics Ltd., Rochester (England).
THE MANAGEMENT OF A LARGE REAL-TIME MILITARY AVIONICS PROJECT
P. J. CARRINGTON, R. M. GISBEY, and K. P. J. MANNING *In* AGARD Software for Avionics 8 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

The AQS 901, an airborne submarine detection system installed in the Royal Australian Air Force Orion and the RAF Nimrod Long-Range Maritime Patrol Aircraft, is described. to counter the modern submarine threat, the development of sensor and processing systems to detect and locate the enemy submarine has a high priority. Expendable, sensitive underwater listening devices, called sonobuoys, pick up the faint but characteristics submarine sounds. These sonobuoy signals are transmitted on an radio frequency link to the aircraft where real-time analysis is performed by the AQS 901 Sonics Processor to extract the wanted signal from the noise, to present the data to the operator in the most easily assimilated form, and to provide a wide range of user options for display manipulation and data combination. The AQS 901 system consists of 22 units of special-purpose hardware and 150 K of CORAL software. The project started in 1973, the first flight trials took place in 1977, and the system went into service in 1980. The software is now in maintenance. R.J.F.

N83-22145# McDonnell Aircraft Co., St. Louis, Mo.
F/A-18 SOFTWARE DEVELOPMENT: A CASE STUDY
T. V. MCTIGUE *In* AGARD Software for Avionics 15 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A01/MF A01

A description of the successful avionics software development for the U.S. Navy/McDonnell Douglas F/A-18 Hornet Fighter/Attack Weapon System is given. The avionics computer subsystem consists of two central mission computers and a number of distributed processors embedded in various sensor and display subsystems. This distributed processing system is interconnected by and communicates over a MIL STANDARD 1553A serial 1 MHz command/response multiplex network. The avionics software architecture is discussed and the rationale is presented for the partitioning of the software tasks between the central mission computers and the distributed processors are also discussed. Finally, the design of the operational flight program for the central mission computers is described, including a discussion of the development process and support facilities which were used for the software integration and validation. R.J.F.

N83-22146# Bundesakademie fuer Wehrverwaltung und Wehrtechnik, Mannheim (West Germany).
A LIFE CYCLE MODEL FOR AVIONIC SYSTEMS
H. SCHAAFF *In* AGARD Software for Avionics 7 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

A life cycle model that puts emphasis on design activities of avionics system is given. The objective of the project management of an avionic system must be to bring forth the user requirements as completely, as correctly and as early as possible because this saves money and time. The life cycle model presented helps to achieve this especially by the introduction of the formal activity functional design and its distinct separation from the technical design. The presented model is valid for avionic systems, but not only for these. It is valid for military embedded computer systems in general. R.J.F.

N83-22147# Air Force Avionics Lab., Wright-Patterson AFB, Ohio.
AVIONICS SOFTWARE SUPPORT COST MODEL
D. V. FERENS *In* AGARD Software for Avionics 8 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

The development of the Avionics Software Support Cost Model (ASSCM) is discussed. ASSCM promises to represent a significant milestone in the area of software life cycle cost analysis. The use of historical data insures that ASSCM reflects actual costs of software support, as well as the policies and procedures used by USAF Air Logistics Centers to support software. The use of the Delphi survey results enables ASSCM to be useful for a wide variety of avionic software programs. The model was designed to be easy to use, especially during the conceptual or early design phase of a software program. Minimal input data is required. The model was developed in a modular format so that the model would be relatively easy to modify as new data becomes available or new application types are added. ASSCM can be useful to some degree for many U.S. and NATO software programs, especially on military avionics projects. The model may need some degree of modification for applications significantly different from those for which ASSCM was developed. R.J.F.

N83-22148# National Aerospace Lab., Amsterdam (Netherlands).
A SOFTWARE-COST DATABASE FOR AEROSPACE SOFTWARE DEVELOPMENT
G. J. DEKKER *In* AGARD Software for Avionics 8 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

A user-friendly method for the collection, storage and retrieval of software-cost data was developed, with emphasis on aerospace software projects. Data is and will be collected regarding 47 well-defined cost factors, divided in 8 classes. It is felt that the clear definition of these cost factors will be of main importance for the applicability of the collected data. When suitable data is available for completed projects, the impact of these factors on the software development cost can be estimated. This will lead to a more reliable cost estimation and cost management method. The cost estimation method that will be calibrated by means of the collected data, the implemented data collection and retrieval system, called a software-cost database, and the use of this system as management tool during running projects are described. R.J.F.

N83-22149# Ministry of Defence, London (England).
THE MILITARY USER VIEW OF SOFTWARE SUPPORT THROUGHOUT THE IN-SERVICE LIFE OF AVIONIC SYSTEMS
S. J. BARKER and B. HAMBLING *In* AGARD Software for Avionics 5 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

It is argued that software-based military avionic systems should be considered as vehicles requiring continuous software development throughout their operating life. The reasons for software change are discussed and emphasis is given to an increasing need to adapt avionic systems to match a changing hostile environment with both speed and safety. More thought should be given to basic system design to facilitate both hardware and software replacement by greater modularity and reduced hardware/software dependence. Some examples of current system inadequacies are given. The need to reduce the cost of software development is emphasized and the type of software support environment as envisaged in the current ADA/APSE development is seen as a significant step towards this end. R.J.F.

N83-22150# British Aerospace Aircraft Group, Woodford (England).
DESIGN OF A SOFTWARE MAINTENANCE FACILITY FOR THE RAF
J. WHAILEY and T. H. SCOTT-WILSON *In* AGARD Software for Avionics 10 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

In order to establish the size of the software maintenance team required for the airborne computing system, it is necessary to have some measurement of software reliability and the number of system requirement changes likely to affect the software configuration. The data available to date is largely empirical and further research is required to establish acceptable techniques. Various options were discussed in order to satisfy the requirement for a software maintenance facility for the Central Navigation System of Nimrod AEW Mk 3, the configuration finally chosen for the software testing rig consisting of a mixture of aircraft hardware and computer based simulations of the system dynamics. The effort required in maintenance could be reduced in future by the adoption of better software design techniques, the adoption of computer based management packages and improved software testing tools. R.J.F.

N83-22151# Naval Air Development Center, Warminster, Pa. Software and Computer Directorate.
A SOFTWARE ENGINEERING ENVIRONMENT (SEE) FOR WEAPON SYSTEM SOFTWARE
H. G. STUEBING *In* AGARD Software for Avionics 16 p (SEE N83-22112 12-01) Jan. 1983 refs
Avail: NTIS HC A19/MF A01

A Software Engineering Environment (SEE) was designed, developed, and used for the life-cycle support of weapon system software. This SEE consists of a software system that runs on a commercial multicomputer configuration. The approach features increased management visibility of the software development process, increased programmer productivity through automation, reducing the cost-of-change during maintenance, and the use of automated regression testing to improve software quality. These facilities were used for seven years to develop and maintain weapon system software for several projects. Accomplishments, refinements to the code and test functions, and a general approach to extend the capabilities into the requirements and design phases are described. Techniques are described that simultaneously allow different methodologies, programming languages, and target computers to be implemented on the same host computer. Also discussed is the implementation of a SEE in a distributed computer network. R.J.F.

N83-22152# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
ON AIRCRAFT TEST SOFTWARE FOR FIRST LINE MAINTENANCE
H. KLENK *In* AGARD Software for Avionics 8 p (SEE N83-22112 12-01) Jan. 1983
Avail: NTIS HC A19/MF A01

A method is presented to provide suitable flexibility and easy maintenance for a test software package, even when written in a lower level language. The method essentially consists of a decisive separation of the test software package into an executive part and a descriptive part for the avionic hardware. Because the executive part is independent of the special avionic equipment, hardware modifications result only in a change of the descriptive part of the software. These changes are easy to handle and suitable for future standardized methods using modern software development tools. The separation method was used to design and implement on-aircraft test software with good results. R.J.F.

N83-30357# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GROUND/FLIGHT TEST TECHNIQUES AND CORRELATION
Feb. 1983 535 p refs In ENGLISH; partly in FRENCH Symp. held at Cesme, Turkey, 11-14 Oct. 1982
(AD-A129433; ISBN-92-835-0328-7; AGARD-CP-339) Avail: NTIS HC A23/MF A01

Large advances in wind tunnel and flight test instrumentation and data processing have provided better confidence in the data and, consequently, improved comparison bases. Even larger advances were made in computational aerodynamics and this has provided the basis for an efficient design tool for transport aircraft. However, in spite of all these improvements there is still a problem in providing accurate and satisfactory performance predictions. Concern was also expressed that with the increasing sophistication of test and prediction techniques, engineers may lose "track" of the physics of prediction and comparison. For individual titles, see N83-30358 through N83-30384.

N83-30358# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
PROGRESS IN WIND TUNNEL TEST TECHNIQUES AND IN THE CORRECTIONS AND ANALYSIS OF THE RESULTS
T. W. BINION, JR. (AEDC), X. VAUCHERET, and X. BOUIS *In* AGARD Ground/Flight Test Tech. and Correlation 31 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

In response to the increased complexity and cost testing, wind tunnel operators are doing many things to improve test effectiveness. Several recent innovations designed to increase the amount of information obtained during a test, to reduce information unit cost, and to improve data quality are described. Author

N83-30359# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio.
AEROTHERMODYNAMIC FLIGHT ENVELOPE EXPANSION FOR A MANNED LIFTING REENTRY VEHICLE (SPACE SHUTTLE)
J. K. HODGE, D. R. AUDLEY, P. W. PHILLIPS (AFFTC), and E. K. HERTZLER (AFFTC) *In* AGARD Ground/Flight Test Tech. and Correlation 12 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

A systematic approach of integrating the best of ground tests, flight simulators, and flight tests was developed and used for aerothermodynamic flight envelope expansion for the Space Shuttle Orbiter. Equations and parameters were selected which were appropriate for the flight simulator at the Air Force Flight Test Center (AFFTC) and also for the reduction of flight data from imbedded thermocouples. Transient flight test maneuvers were designed using the simulator and suggested to the National Aeronautics and Space Administration (NASA) at the Johnson Space Center. Parameters were estimated from flight thermocouple data during the maneuvers by a new data reduction technique. The parameters were compared with simulator parameters which were based on ground test data and theory. The objective, however, was envelop expansion and not data comparison. Simulator parameters were appropriately and quickly updated before the next flight test. The new flight data reduction technique is also valuable in analyzing wind tunnel thermocouple data to reduce test time. Author

N83-30360# Air Force Flight Test Center, Edwards AFB, Calif.
PREDICTED AND FLIGHT TEST RESULTS OF THE PERFORMANCE AND STABILITY AND CONTROL OF THE SPACE SHUTTLE FROM REENTRY TO LANDING
P. W. KIRSTEN and D. F. RICHARDSON *In* AGARD Ground/Flight Test Tech. and Correlation 23 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

Aerodynamic performance and stability data obtained from the first three reentries of the Space Shuttle Orbiter is presented. Flight results are compared to predicted data from Mach 25 to Mach 0.4. Differences between flight and predicted data as well as probable causes for the discrepancies are given. Comparisons between simulator and flight results are also presented. Author

N83-30361# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
GROUND/FLIGHT CORRELATION ON THE ALPHA-JET EXPERIMENTAL AIRCRAFT WITH A TRANSONIC WING: A COMPARISON BETWEEN WIND TUNNEL AND FLIGHT RESULTS FOR AERODYNAMIC PERFORMANCE
D. JACOB, D. WELTE, and H. WONNENBERG *In* AGARD Ground/Flight Test Tech. and Correlation 14 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

Wind tunnel and flight results obtained in an experimental program with a transonic wing (TST) on an Alpha-Jet as test vehicle are compared. The comparison is concentrated on lift, drag and buffet data. In addition to the analysis of round and flight data for the TST flight data for the transonic wing and the standard wing are briefly compared. Author

N83-30362# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
GROUND/FLIGHT CORRELATION ON THE ALPHA-JET EXPERIMENTAL AIRCRAFT WITH A TRANSONIC WING: A COMPARISON OF THE WING PRESSURE DISTRIBUTION AND LOCAL WAKE SURVEY FROM ANALYTICAL, WIND TUNNEL AND FLIGHT RESULTS
H. BUERS (Dornier G.m.b.H.), V. SCHMITT, and J. LERAT *In* AGARD Ground/Flight Test Tech. and Correlation 20 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

Pressure Distributions at four sections of a transonic wing on a combat aircraft have been measured in different wind tunnels and in flight. The results are compared with each other and with theoretical data. In addition, wind tunnel and flight test wake results obtained from a rotating pitot-tube are presented. Author

N83-30363# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

FLIGHT AND WIND-TUNNEL CORRELATION OF BOUNDARY-LAYER TRANSITION ON THE AEDC TRANSITION CONE

D. F. FISHER and N. S. DOUGHERTY, JR. (Rockwell International) *In* AGARD Ground/Flight Test Tech. and Correlation 25 p (SEE N83-30357 19-01) Feb. 1983 refs

Avail: NTIS HC A23/MF A01 CSCL 01A

Transition and fluctuating surface pressure data were acquired on a 10 degree included angle cone, using the same instrumentation and technique over a wide range of Mach and Reynolds numbers in 23 wind tunnels and in flight. Transition was detected with a traversing pitot pressure probe in contact with the surface. The surface pressure fluctuations were measured with microphones set flush in the cone surface. Good correlation of end of transition Reynolds number Re (sub T) was obtained between data from the lower disturbance wind tunnels and flight up to a boundary layer edge Mach number, M (sub e) = 1.2. Above M (sub e) = 1.2, however, this correlation deteriorates, with the flight Re (sub T) being 25 to 30% higher than the wind tunnel Re (sub T) at M (sub e) = 1.6. The end of transition Reynolds number correlated within + or - 20% with the surface pressure fluctuations. Broad peaks in the power spectral density distributions indicated that Tollmien-Schlichting waves were the probable cause of transition in flight and in some of the wind tunnels. Author

N83-30364# Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).

EXPERIMENTAL INVESTIGATIONS OF TRANSPORT AIRCRAFT LOW SPEED ENGINE INTERFERENCE EFFECTS AND FLIGHT TEST CORRELATION

B. EWALD and W. BURGSMUELLER *In* AGARD Ground/Flight Test Tech. and Correlation 15 p (SEE N83-30357 19-01) Feb. 1983 refs

Avail: NTIS HC A23/MF A01

Engine airframe interference effects for wing mounted engine in transport aircraft development and flight testing were examined. The tendency to reduced engine numbers results in a large effect of the one engine out second segment climb on overall aircraft economy. Large development efforts are worthwhile to realize even small drag reductions in this condition. The most perfect engine simulator available, the turbine powered simulator (TPS), was used in the high speed regime only. The concept of low speed TPS testing was developed. The TPS is proven to be a reliable and valuable experimental tool also in low speed range, provided that sophisticated data acquisition and evaluation techniques are used for optimum accuracy and repeatability. Operating equipment and test methods are improved. Results and experience are described. E.A.K.

N83-30365# Canadair Ltd., Montreal (Quebec).

COMPARISON OF PREDICTION, WIND TUNNEL AND FLIGHT TEST DATA FOR THE CANADAIR CHALLENGER TURBOFAN AIRCRAFT

F. MAVRIPLIS *In* AGARD Ground/Flight Test Tech. and Correlation 14 p (SEE N83-30357 19-01) Feb. 1983 refs

Avail: NTIS HC A23/MF A01

Theoretical aerodynamic methods, wind tunnel test and flight test for the Challenger aircraft which features an advanced supercritical wing, a wide body and large aft mounted nacelles were presented. These results represent one of first applications of Jameson's isolated wing full potential flow transonic method to advanced wing design for an aircraft which is now in service. The techniques used to obtain wind tunnel force and pressure distribution data at high speed and CLmax data at low speed are described. A flight wing pressure survey which provided data for comparison with wind tunnel test results is described. Correlations of pressure distributions between theory and wind tunnel test indicate the capabilities and limitations of the isolated wing transonic code. Wing pressure and spanwise load distributions from flight test correlate well with corresponding data from wind tunnel tests. Flight test results on CLmax and buffet onset boundary correlate also well with predictions based on wind tunnel data. Reynolds Number and transition fixing for wind tunnel testing of supercritical wings to obtain good correlation with flight test are recommended. E.A.K.

N83-30366# British Aerospace Aircraft Group, Warton (England).

LESSONS FROM TORNADO AFTERBODY DEVELOPMENT

D. C. LEYLAND *In* AGARD Ground/Flight Test Tech. and Correlation 15 p (SEE N83-30357 19-01) Feb. 1983

Avail: NTIS HC A23/MF A01

The wind tunnel model test program for the Tornado aircraft design included the development of a new afterbody test rig, which showed the benefit of measuring airframe axial force separately from nozzle and allowed detailed configuration for minimum drag. Flight tests showed good agreement with drag prediction but handling characteristics under certain conditions were different from predictions derived from full model tests, as a consequence of relatively minor differences in afterbody representation. Flight and model investigations led to satisfactory configuration and to requirements for future model test programs. Flight and model test data were compared by arranging additional afterbody model tests of geometric changes made during the flight program. There was good agreement between results and, conclusions for the requirements for future model and flight testing. The introduction of high frequency response pressure instrumentation is proposed. E.A.K.

N83-30367# Avions Marcel Dassault, Saint-Cloud (France). Dept. Dynamique du Vol.

THE HIGH ANGLE OF ATTACK BEHAVIOR OF A COMBAT AIRCRAFT: CORRELATION BETWEEN PREDICTION AND FLIGHT [COMPORTEMENT A GRANDE INCIDENCE D'UN AVION DE COMBAT: CORRELATION ENTRE LES PREVISIONS ET LE VOL]

P. L. MATHE *In* AGARD Ground/Flight Test Tech. and Correlation 8 p (SEE N83-30357 19-01) Feb. 1983 In FRENCH

Avail: NTIS HC A23/MF A01

The Mirage 2000 aircraft is equipped with an entirely electronic flight control system. The aircraft is automatically protected from eventual loss of control by a flight control function which assures an automatic limitation of the angle of the aircraft to a value dependent on flight conditions; and by careful adaptation of the command and control functions of the aircraft's axes of roll and loop. This adaptation minimizes the slipping introduced by maneuvers at high angle of attack. The automatic limitation of the incidence and rigorous control of the transverse axes are keys to the protection of the aircraft against loss of control. Transl. by E.A.K.

N83-30368# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.

THE USE OF FREE-FLIGHT MODELS FOR THE PREDICTION OF DEPARTURE CONTROL

G. F. MOSS, A. J. ROSS, G. F. EDWARDS, and E. B. JEFFERIES *In* AGARD Ground/Flight Test Tech. and Correlation 17 p (SEE N83-30357 19-01) Feb. 1983 refs

Avail: NTIS HC A23/MF A01

The importance of prediction techniques for the flight-dynamic behavior of proposed aircraft projects and in particular the use of the free flight model technique are discussed. Such free flight models are able to carry onboard flight control systems and can be used to evaluate stability augmentation and departure prevention methods. Examples of flight records of free flight tests are presented and compared with theoretical predictions and corresponding full scale data. A research program using HIRM, a high incidence research model configuration, is described which has as its central objective the widening of understanding of the flight dynamics phenomena of combat aircraft at high angles of attack. E.A.K.

N83-30369# Saab-Scania, Linkoping (Sweden).

COMPARISON OF FLIGHT AND WIND TUNNEL BUFFETING MEASUREMENTS ON THE SAAB 105 AIRCRAFT

S. H. TEIGE, B. S. A. NILSSON, S. J. BOERSEN (NLR), and A. N. KRAAN (NLR) *In* AGARD Ground/Flight Test Tech. and Correlation 10 p (SEE N83-30357 19-01) Feb. 1983 refs

Avail: NTIS HC A23/MF A01

Buffet tests on a Saab 105 aircraft which were carried out in flight at high speed and wind tunnel measurements on a half model were performed at the same Mach numbers and almost the same Reynolds number are discussed. Buffet levels were derived from wind tunnel accelerometer signals using Jones'

method. It is concluded that with careful testing, this method may be used to predict flight buffet loads from wind tunnel measurements. E.A.K.

N83-30370# Royal Aircraft Establishment, Bedford (England). Aerodynamics Dept.
SOME MEASUREMENTS OF BUFFETING ON A FLUTTER MODEL OF A TYPICAL STRIKE AIRCRAFT
D. G. MABEY and B. E. CRIPPS *In* AGARD Ground/Flight Test Tech. and Correlation 16 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

Some buffeting measurements on a flutter model of the wing of a typical strike aircraft are described and the results are compared with flight experiments. New criteria for light, moderate and severe levels of buffeting are proposed, to supplement previously derived empirical criteria. The results confirm that buffet penetration in flight is not limited by the severity of buffeting, but by handling limits. The wing of this model has a rigid body freedom in the low frequency roll mode, which clearly indicates wing-rock after buffet onset. Measurements of the response in this mode indicated that the buffet excitation was bounded, and comparable with that in the first symmetric bending mode, even when the aerodynamic damping in the roll mode was falling rapidly. The rapid fall, after buffet onset, of the aerodynamic damping in this low frequency rigid body mode was accurately predicted from steady pressure measurements. In marked contrast the measured increase, after buffet onset, of the aerodynamic damping for the first symmetric bending mode could not predicted from steady pressure measurements. These observations have important implications for the prediction of buffeting in flight from measurements on models. M.G.

N83-30371# Technische Hogeschool, Delft (Netherlands). Dept. of Aerospace Engineering.
AERODYNAMIC MODEL IDENTIFICATION FROM DYNAMIC FLIGHT TEST DATA AND WIND TUNNEL EXPERIMENTS
J. A. MULDER, J. G. DENHOLLANDER, and H. BINKHORST *In* AGARD Ground/Flight Test Tech. and Correlation 21 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

Dynamic flight test techniques may be employed for the measurement of a variety of aircraft performance characteristics as well as for the measurement of stability and control characteristics in the form of for instance classical Stability and Control derivatives. The development of nonlinear aerodynamic models from dynamic flight test data is addressed. Several closely related characteristics of these models are discussed in detail such as goodness of fit to flight test data, the accuracy of model predictions and model complexity. Results are presented of a flight test program with the DHC-2 Beaver experimental aircraft equipped with a high accuracy instrumentation system. Different aerodynamic models are compared with results from windtunnel experiments. Author

N83-30372*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
HELICOPTER SIMULATION VALIDATION USING FLIGHT DATA
D. L. KEY (Army Research and Technology Labs.), R. S. HANSEN (Army Research and Technology Labs.), W. B. CLEVELAND, and W. Y. ABBOTT (Army Aviation Engineering Flight Activity) *In* AGARD Ground/Flight Test Tech. and Correlation 13 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01 CSCL 14B
See N83-13112. Author

N83-30373# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
CORRELATION ASPECTS OF ANALYTICAL, WIND TUNNEL AND FLIGHT TEST RESULTS FOR A HINGELESS ROTOR HELICOPTER
J. KALETKA and H. J. LANGER *In* AGARD Ground/Flight Test Tech. and Correlation 16 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

Two approaches to develop and verify mathematical descriptions of rotorcraft characteristics are discussed: (1) wind tunnel experiments with a model rotor, and (2) parameter identification from flight test data. A rotor test stand with a Mach scaled BO 105 model rotor was used for measurements in two different large wind tunnels. After addressing rotor scaling aspects, emphasis is placed on wind tunnel influences and their corrections to provide the transferability of the results to the full-scale rotor. Specific tests to determine flight mechanical static derivatives are described. BO 105 flight test data were used for the identification of mathematical models describing the dynamic behavior of the helicopter. After an introduction to system identification, the system excitation problem and the verification of results are addressed. Examples showing both identified derivatives and time histories of the helicopter and identified model responses are given. Finally, derivatives extracted from wind tunnel and flight tests are discussed. For comparison theoretically calculated values are also presented. M.G.

N83-30374# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugmechanik.
CORRELATION ASPECTS IN THE IDENTIFICATION OF DYNAMIC EFFECTS USING COMPLEMENTARY TECHNIQUES FLIGHT IN TURBULENCE: GUST ALLEVIATION
K. WELHELM and R. VERBRUGGE (Inst. de Mecanique des Fluides) *In* AGARD Ground/Flight Test Tech. and Correlation 22 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

An overview of a research program underway at DFVLR-Braunschweig (FRG) and IMF-Lille (France) is presented. The goals of this program are (1) the comparison of complementary techniques by correlating their results, and (2) the modeling of aerodynamic transient effects which must be considered for aircraft flying in turbulence situations in connection with a gust alleviation system. The following techniques are applied in the program: theoretical prediction, static wind tunnel measurements, forced oscillation balance measurements, semi-free flight model tests (dynamic simulation in wind tunnel), catapult free-flight model tests, full-scale flight tests and system identification methods. A brief description of the different facilities is given, advantages and special problems associated with the application of the different test techniques are shown. Test results are presented and compared. Two alternate approaches for modeling aerodynamic transient effects are presented. The influence of the modeling of these effects on the efficiency of an open-loop gust alleviation system is shown. Author

N83-30375# Institut de Mecanique des Fluides de Lille (France).
ASPECTS OF CORRELATION IN THE IDENTIFICATION OF DYNAMIC EFFECTS FROM COMPLIMENTARY TECHNIQUES: EVOLUTION AT HIGH ANGLES [ASPECTS DE LA CORRELATION DANS L'IDENTIFICATION D'EFFECTS DYNAMIQUES A PARTIR DE TECHNIQUES COMPLEMENTAIRES EVOLUTION AUX GRANDS ANGLES]
D. TRISTRANT *In* AGARD Ground/Flight Test Tech. and Correlation 21 p (SEE N83-30357 19-01) Feb. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A23/MF A01

Some experimental and analytical methods which contribute to the comprehension and prediction of aircraft behavior at high angles of attack and stall/spin are presented. A combat aircraft can start a spin departure around an horizontal trajectory which becomes vertical after several spin turns. The comparison between such a spin and that observed in vertical wind tunnel on free flight model is not easy, particularly if these movements are agitated. A representation of high angle motions, visually giving the principal characteristics of the phenomena independently of the trajectory is suggested. Such a repesentation allows the correlation of spin motions between the vertical wind tunnel and the full scale flight. One of the basic parameters which could modify the quality of the correlation of spin tests realized in Froud similitude is the Reynolds number. With a typical example concerning a light aircraft, the important influence of Reynolds number on spin equilibrium state and the test method which allows one to understand and correlate the phenomena are shown. With a typical example concerning a combat aircraft, some measurement results on a dynamic balance are examined which allow the evaluation of the aerodynamic force system at high angle of attack, the modeling

of aerodynamic effects and then spin simulations which can be compared with vertical wind tunnel results on free flight model.
Author

N83-30376# Army Aviation Research and Development Command, Moffett Field, Calif. Aeromechanics Lab.
DYNAMIC STRUCTURAL AEROELASTIC STABILITY TESTING OF THE XV-15 TILT ROTOR RESEARCH AIRCRAFT
L. G. SCHROERS *In* AGARD Ground/Flight Test Tech. and Correlation 18 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

Predicted aeroelastic characteristics are examined in light of the major parameters effecting rotor-pylon-wing stability. Flight test techniques used to obtain XV-15 aeroelastic stability are described. The flight test results are summarized and compared to the predicted values. In addition, a limited comparison of wind tunnel results, flight test results, and their correlation with predicted values is presented. M.G.

N83-30377# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Military Aircraft Div.
GROUND AND FLIGHT TEST TECHNIQUES USED FOR PROOF OF STRUCTURAL INTEGRITY OF THE TORNADO COMBAT AIRCRAFT
K. KNAUER and O. SENSBURG *In* AGARD Ground/Flight Test Tech. and Correlation 48 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

A short description of the Tornado program is given. The complex requirements for this all-weather combat aircraft resulted in an optimal concept including features like highly loaded swing wing in combination with a sophisticated high lift system; fly-by-wire and automatic terrain following; supersonic inlet; ant two three spool engines with integrated thrust reverser. To accommodate all the mentioned features in a minimum size/weight aircraft, it is necessary to give special attention to the structural aspects. A description of some typical examples for structural certification is presented: load and flutter models; structural component tests; design verification tests, especially for the wing suspension and pivot system; proof and ultimate load testing; and fatigue life assessment. Comparisons of selected predictions with ground and flight test results are presented for the important structural disciplines: stresses and deflections of important components; loads; and aeroelastics. Some examples of bad correlation between theory and test are discussed together with possible explanations. The merits and disadvantages of the most important theoretical methods are highlighted. R.J.F.

N83-30378# British Aerospace Aircraft Group, Warton (England). Aircraft Group.
COMPARISON OF FLIGHT LOADS MEASUREMENTS RESULTS ANJ PREDICTION FOR TORNADO
J. R. J. DOVEY and G. MORETTI *In* AGARD Ground/Flight Test Tech. and Correlation 19 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

An extensive program of flight loads measurements was made on Tornado MARCA aircraft to contribute to service clearance as required by the American Military specifications. A brief resume is presented of the purpose of flight load measurements, the overall program, the calibration of the load measurement devices, the data reduction facilities, the flying techniques and of the methods used for detailed analysis of the results. Comparisons are made between flight measurements and predictions for several aircraft components for specific maneuvers and for rates of change of load with change of aircraft parameters. The contribution of flight load measurements to the extension of the flight envelope in rapid roll maneuvers is discussed and the usefulness to the final Tornado flight clearance is also assessed. R.J.F.

N83-30379# Aeritalia S.p.A., Torino (Italy). Bruppo Velivoli da Combattimento.
CORRELATION PROBLEMS BETWEEN FLUTTER FLIGHT TEST DATA AND GROUND TESTS/CALCULATION RESULTS FOR A VARIABLE SWEEP WING AIRCRAFT
G. DEFERRARI, A. LOTZE (MBB), and R. PYRAH (British Aerospace Aircraft Group) *In* AGARD Ground/Flight Test Tech. and Correlation 17 p (SEE N83-30357 19-01) Feb. 1983 refs
Avail: NTIS HC A23/MF A01

It was shown that especially in connection with nonlinearities, either generated by structural, control system or aerodynamic transonic effects, flutter clearance can not be based exclusively on flight testing nor on conventional flutter calculations. Flutter flight testing is a useful and required tool for flight clearance purposes but approaching areas with low flutter margins, good correlation with analytical investigations confirmed by ground resonance tests is vitally necessary, to be able to explain the physical behavior of the flutter case and to avoid unsafe conditions during flutter flight testing. If correlation between flight test and analysis is poor, possible nonlinear effects must be incorporated into the analysis. Having proven good correlation with flight testing for special test conditions, the clearance according to the most critical case during whole service life and considering all possible amplitudes has to be provided by analysis if this condition can not be reached by flight testing. R.J.F.

N83-30380*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
REAL-TIME FLUTTER ANALYSIS OF AN ACTIVE FLUTTER-SUPPRESSION SYSTEM ON A REMOTELY PILOTED RESEARCH AIRCRAFT
G. B. GILYARD and J. W. EDWARDS *In* AGARD Ground/Flight Test Tech. and Correlation 15 p (SEE N83-30357 19-01) Feb 1983 refs
Avail: NTIS HC A23/MF A01 CSCL 01C

Flight-test results of the first three flights of an aeroelastic research wing are described. The flight flutter-test technique used to obtain real-time damping estimates from fast-frequency sweep data was obtained and the open-loop flutter boundary determined. Nyquist analyses of sweep maneuvers appear to provide additional valuable information about flutter suppression system operation, both in terms of phase-margin estimates and as a means of evaluating maneuver quality. An error in implementing the flutter-suppression system required in a one-half nominal gain configuration, which caused the wing to be unstable at lower Mach numbers than anticipated, and the vehicle experienced closed-loop flutter on its third flight. Real-time flutter-testing procedures were improved. R.J.F.

N83-30381# Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
FLIGHT FLUTTER TESTING WITH EMPHASIS ON THE TIP VANE METHOD
H. ZIMMEMANN and R. DESTUYNDER (ONERA) *In* AGARD Ground/Flight Test Tech. and Correlation 14 p (SEE N83-30357 19-01) Feb. 1983 refs Previously announced as A83-18435
Avail: NTIS HC A23/MF A01

A short summary of the most important flight excitation systems developed and used in the last twenty years is given. Special emphasis is put on the vane excitation system. This system was developed for the flight vibration tests of the A 310 intermediate-range transport aircraft. The general, functional, and safety requirements for this system are described. Also the preliminary tests, and the set-up and handling of such a system are reported. Because the vane excitation can be measured precisely, the tip vane method offers the advantage of representing aircraft response in terms of transfer functions rather than only autospectra. The transfer function so derived together with a multi-mode matching technique were then used to determine the frequencies and damping of the aircraft modes. The multi-mode matching technique is also described. The paper also reports some results obtained by flight vibration testing of the A 300 and A 310 aircraft. R.J.F.

N83-30382# Aeritalia S.p.A., Torino (Italy). Gruppo Velivoli da Combattimento.
A THEORETICAL/EXPERIMENTAL TECHNIQUE TO EVALUATE STORE SEPARATION CHARACTERISTICS
F. PORRATO and V. MO *In* AGARD Ground/Flight Test Tech. and Correlation 16 p (SEE N83-30357 19-01) Feb. 1983
Avail: NTIS HC A23/MF A01

The methodology developed in AERITALIA for a few years and currently adopted to clear the separation of external stores from the parent aircraft is discussed. The tools used in this process, i.e., mathematical models, wind tunnel testings, ground and flight trials, are presented and their advantages and disadvantages briefly discussed. Particularly, the role of the matching phase between data gathered by the different techniques mentioned above to increase the reliability on store separation predictions, and hence to clear the separation of stores from the parent aircraft, is presented and discussed with a brief assessment of the method used. R.J.F.

N83-30383# Societe Nationale Industrielle Aerospatiale, Paris (France).
HELICOPTER AIR INLETS: DESIGN PROCESS, WIND TUNNEL TESTING AND CORRELATIONS WITH FLIGHT DATA
F. TOULMAY *In* AGARD Ground/Flight Test Tech. and Correlation 23 p (SEE N83-30357 19-01) Feb. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A23/MF A01

Major inlet design problems of helicopter engines and ways of solving them through down-scaled models are discussed. Pressure loss, dynamic pressure recovery, pressure distortion, hot air re-ingestion, external drag, and constraints due to engine and/or aircraft architecture are among the topics discussed. Indications are given concerning the selection of model parameters, test procedure and real-time processing R.J.F.

N83-30384# Royal Aircraft Establishment, Farnborough (England)
SYNTHESIS OF RESPONSES TO AGARD-FMP QUESTIONAIRE ON "PREDICTION TECHNIQUES AND FLIGHT CORRELATION"
J. WILLIAMS *In* AGARD Ground/Flight Test Tech. and Correlation 30 p (SEE N83-30357 19-01) Feb 1983
Avail NTIS HC A23/MF A01

Correlation between flight results and wind tunnel, analytical prediction, free-flight model, and simulation methods, for performance, flying qualities, aeroelastic effects and subsystems such as store separation and inlets is discussed. The results of a survey of flight correlation and prediction techniques are given. R.J.F.

N83-34891# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ADVANCES IN SENSORS AND THEIR INTEGRATION INTO AIRCRAFT GUIDANCE AND CONTROL SYSTEMS
J. L. HOLLINGTON, ed. (Smiths Industries, Cheltenham, England) Loughton, England Jun. 1983 151 p refs
(AGARD-AG-272; ISBN-92-835-1451-3; AD-A132910) Avail: NTIS HC A08/MF A01

Advanced in electro-optic sensors and airborne radar, new types of inertial sensor, low cost fluidic sensors, the measurement of airspeed and windshear with an airborne laser, an application of analytical redundancy, and the integration of a new sensor on to an existing aircraft are topics of discussion. For individual titles, see N83-34892 through N83-34901.

N83-34892# Marconi Avionics Ltd., Basildon (England).
THE STATUS OF LLTV FOR AVIONIC APPLICATIONS
W. J. R. CLARK *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 10 p (SEE N83-34891 23-01) Jun. 1983
Avail: NTIS HC A08/MF A01

An historical review of the development of low light television (LLTV) cameras is presented the operating principles and salient characteristics of the two types of camera tube suitable for avionic applications are described. The natural environment in which such systems must operate and the fundamental and practical limitations to their performance are also described. The alternatives and applications experience based upon practical flight trials were compared. Author

N83-34893# Marconi Avionics Ltd., Basildon (England). Electro Optical Surveillance Div.
THERMAL IMAGING FOR AVIONIC APPLICATIONS
G. M. CUTHBERTSON *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 12 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01

The quality of visual images formed from thermal radiation is now a standard which permits thermal imagers to be widely used in military avionic systems. The physical principles underlying the technology and the natural environment in which it operates are outlined. The evolution of thermal imager designs and the way that the latest advances in detectors and circuit technology were implemented in the Class II U.K. Thermal Imager Common Module (TICM II) program are briefly traced. Author

N83-34894# Ferranti Ltd., Edinburgh (Scotland). Radar Systems Dept.
ADVANCES IN AIRBORNE RADAR. THE NEW CAPABILITIES
C. M. STEWART *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 16 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01

The power and speed of the minicomputer, microprocessor, and other signal processing subsystems have had a very significant effect on the operational capability now available from airborne radar. The mechanization of hitherto unrealizable processing strategies has encouraged the development of more sophisticated pulse compression and pulse Doppler radars and allowed them to achieve their full potential within the size and weight constraints of an aircraft installation. The new capabilities in each of the operational roles in which radar is used outlining the techniques employed are reviewed. Author

N83-34895#
INTRODUCTION TO OPTICAL RATE SENSORS
U. K. KROGMANN *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 35 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01

After dealing with the reasons of optical rate sensor penetration in the near future a short introduction to the physical function and basic design of passive and active optical rate sensors was given. Particularly the passive sensors are expected to yield a decisive breakthrough in the future since they seem to offer a more favorable cost versus performance potential as compared to the active ring laser gyro. The realization of the relatively simple physical principles of optical rate measurements as treated here involves new gyro technology problems which now refer to the electro-optics, laser physics and integrated optics rather than to the precision mechanics. Feasibility problems today regarding passive sensors should be alleviated in the future where the inertial field can benefit from developments within the optical communication field. As far as the active ring laser gyro is concerned it has obtained a high level of maturity being ready for mass production. However, it is still an expensive sensor. Author

N83-34896*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
INERTIAL REFERENCES BASED ON SINGLE MODE OPTICAL FIBER WAVEGUIDES
W. C. GOSS *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance Control Systems 8 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01

Recent developments in low loss single mode optical fiber waveguides, semiconductor waveguide lasers and waveguide optical and electro-optical components have made a new class of rotational inertial frame references possible. The subclasses of possible fiber waveguide gyro configurations are discussed and one approach which is under development is reviewed. Signal detection and processing, error sources, expected physical and performance characteristics, and present development status are discussed. Author

N83-34897*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
LOW COST FLUIDIC SENSORS
H. D. GARNER *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 10 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01 CSCL 01D

The gyroscopic inertial sensors used in general aviation autopilots and in stability augmentation systems probably contribute more than any other component to the initial cost and to the continuing maintenance costs of these installations. Several fluidic devices which were developed to replace the gyroscopes in the conventional "wing-leveler" type autopilots used in small, general aviation airplanes are described. These sensors are characterized by simplicity of design, ease of fabrication, and lack of wearing parts. A unique, fluidic, true airspeed sensor is also described. All these devices are adapted to fabrication by low cost plastic molding techniques, and their lack of wearing parts promises long, maintenance free service lives. Author

N83-34898# Royal Aircraft Establishment, Bedford (England).
AIRSPEED AND WIND SHEAR MEASUREMENTS WITH AN AIRBORNE CO2 CW LASER
A. A. WOODFIELD and J. M. VAUGHAN (Royal Signals and Radar Establishment) *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 18 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01

The Laser True Airspeed System (LATAS) installed on the RAE HS125 research aircraft is described. It has proved exceptionally reliable and rugged. Examples of results are presented including a climb to 43000 ft; flight through a severe thunderstorm wind shear (microburst); pressure error measurements; and signals observed in cloud, heavy rain and from solid objects such as the ground. Some thoughts on other potential applications such as using the sensor for an intelligent autothrottle, for measuring crossflow velocities; for measuring tire and ground speeds to save tire wear; and as a combined air data and ground velocity system for helicopters (including a facility to maintain a steady hover) are presented. Author

N83-34899# Royal Aircraft Establishment, Farnborough (England).
AUTOMATIC SPEECH RECOGNITION AS A COCKPIT INTERFACE
R. G. WHITE *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 16 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01

The future use of automatic speech recognition machines for the management of cockpit systems and for low bandwidth air-ground communications is discussed. After describing the principles of speech recognition, the benefits afforded to the aircrew are considered. These are balanced against the difficulties of operating in the cockpit environment. The effects that this maturing technology is likely to have on cockpit design and operating procedures are discussed. Techniques for training machines to recognize the aircrew's utterances are considered. The future for the avionic applications of automatic speech recognition is promising. A great deal of relevant research is being undertaken within NATO countries, including flight research programs planned for 1982. Author

N83-34900*# *National Aeronautics and Space Administration.* Dryden (Hugh L.) Flight Research Center, Edwards, Calif.
ANALYTIC REDUNDANCE MANAGEMENT FOR FLIGHT CONTROL SENSORS
J. C. DECKERT (Draper (Charles Stark) Lab.) and K. J. SZALAI *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 13 p (SEE N83-34891 23-01) Jun. 1983 refs
Avail: NTIS HC A08/MF A01 CSCL 01C

The formulation and flight test results of an algorithm to detect and isolate the first failure of any one of 12 duplex control sensor signals (24 in all) being monitored are reviewed. The technique uses like signal differences for fault detection while relying upon analytic redundancy relationships among unlike quantities to isolate the faulty sensor. The fault isolation logic utilizes the modified sequential probability ratio test, which explicitly accommodates the inevitable, irreducible low frequency errors present in the analytic redundancy residuals. In addition, the algorithm used sensor output selftest, which takes advantage of the duplex sensor structure by immediately removing a hard failed sensor from control calculations and analytic redundancy relationships while awaiting a definitive fault isolation decision via analytic redundancy. This study represents a proof of concept demonstration of a methodology that is applied to duplex or higher flight control sensor configurations and, in addition, can monitor the health of one simplex signal per analytic redundancy relationship. Author

N83-34901# British Aerospace Public Ltd. Co., Preston (England). Aircraft Group.
INTEGRATION OF A NEW SENSOR ON TO AN EXISTING AIRCRAFT
A. S. LEYLAND *In* AGARD Advan. in Sensors and their Integration into Aircraft Guidance and Control Systems 7 p (SEE N83-34891 23-01) Jun. 1983
Avail: NTIS HC A08/MF A01

Although all sensors have differencing requirements the principles described apply to every integration task. To demonstrate the technique, an assumption was made that a requirement exists to assist the crew in poor visability by fitting a low light sensor. The requirement and the aircraft system to which it is fitted are fictitious, although representative of current systems. The method used is Top Down Design, which takes the original requirement, breaks it down to various functions and processes and then recreates it into various line replaceable units, and software requirements, in a structured compatible format. Author

N84-11116# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AEROELASTIC CONSIDERATIONS IN THE PRELIMINARY DESIGN OF AIRCRAFT
Loughton, England Sep. 1983 322 p refs In ENGLISH and FRENCH Conf. held in London, 11-12 Apr. 1983
(AGARD-CP-354; ISBN-92-835-0338-4; AD-A133981) Avail: NTIS HC A14/MF A01

The latest trends in aeroelastic analysis, aeroelastic tailoring, structural optimization and flutter optimization are reviewed. The application of these techniques to aircraft design is discussed. For individual titles, see N84-11117 through N84-11135.

N84-11117# Lockheed-California Co., Burbank. Advanced Flutter and Dynamics Methods.
PRELIMINARY AEROELASTIC DESIGN OF STRUCTURES (PADS) METHODS DEVELOPMENT AND APPLICATION
N. A. RADOVCICH *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 29 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

Preliminary Aeroelastic Design of Structures (PADS) is a highly computerized design system for generating structural weight data which include aeroelastic effects for advanced aircraft configurations. These data can then be used to update the statistical and semianalytical weight data base during configuration tradeoff studies. Three aspects of PADS are discussed: the formulation of computer operating system technology and data management techniques which will permit the definition and execution of engineering processes in a user friendly environment, a definition of engineering processes for preliminary aeroelastic design of structures which may be used to design an aircraft for strength and stiffness in the elapsed time normally available for a conceptual design phase; and the presentation of results from the PADS validation effort, computer software as well as engineering processes, using a known airplane design data base. R.J.F.

N84-11118# Societe Nationale Industrielle Aerospatiale, Toulouse (France).
AEROSPATIAL'ES APPROACH TO THE STUDY OF FLUTTER AT THE DESIGN STAGE OF THE PROJECT [APPROCHE AEROSPATIALE DE L'ETUDE DU FLOTTEMENT AU NIVEAU DE L'AVANT-PROJET]
M. CURBILLON *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 32 p (SEE N84-11116 02-01) Sep. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A14/MF A01

Because of its importance from the point of view of safety and certification, the flutter behavior of a plane must be estimated as soon as possible in the study of a project. In fact, geometry, structural conception, and sizing could be strongly influenced by this phenomena. The problem is formulated in order to present the most important factors. The objectives of the flutter study at the design stage are defined. The approach of the simplified mathematical model, normal modes and flutter calculations are exposed. Examples from aerospatiale studies are included.
Author

N84-11119# Boeing Military Airplane Development, Seattle, Wash.
AEROELASTIC TAILORING OF HIGH-ASPECT-RATIO COMPOSITE WINGS IN THE TRANSONIC REGIME
C. J. BORLAND and D. W. GIMMESTAD *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 12 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

A procedure for coupling a rapid, accurate transonic aeroelastic analysis method, based on nonlinear small disturbance theory, with a simple design optimization method for high aspect ratio composite box beam type structures is described. A sample aeroelastically tailored preliminary design employing nonlinear transonic aerodynamics is presented. Currently available aeroelastic tailoring methods for composite aircraft structure employ linearized analysis of aeroelastic loads in the optimization cycle. For aircraft whose primary structural design conditions lie in the transonic regime, however, these loads may be considerably in error and may therefore lead to an other than optimum design. For aircraft with advanced technology or supercritical airfoil sections, the aerodynamic loading is extremely sensitive to changes in shock position and strength, which are affected in turn by small changes in geometry due to aeroelastic loading. R.J.F.

N84-11120# British Aerospace Aircraft Group, Weybridge (England).
AEROELASTIC DESIGN OF CIVIL TRANSPORTS AT THE PROJECT STAGE
R. E. J. BRAZIER, A. E. DUDMAN, and B. W. PAYNE *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 11 p (SEE N84-11116 02-01) Sep. 1983
Avail: NTIS HC A14/MF A01

The concepts of aeroelastic design of civil transports at the project stage are outlined. The formulation of the data and computing requirements are described, as well as the aeroelastic predictions to the project design. The design of a competitive civil transport aircraft must take account of aeroelastic effects and aeroelastic requirements at the project stage. The overall design will be decided by other considerations but the final tuning of the design, leading to structural/performance optimization has to include aeroelastic data on static distortion, dynamic loading and flutter requirements. In order to be able to produce these data at the project stage, where geometry and configuration changes need to be assessed rapidly, a system was developed by which quick and reliable predictions can be made. R.J.F.

N84-11121# Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost.
TRANSONIC FLUTTER CLEARANCE FOR A SUPERCRITICAL TRANSPORT AIRCRAFT IN THE PRELIMINARY STAGE
N. PRONK, H. WALGEMOED, and R. J. ZWAAN (NLR, Amsterdam) *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 13 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

Recently, design studies for a short haul transport with a supercritical wing were made. One of the aeroelastic questions to be answered already in the preliminary design phase of these wings was the question of flutter freedom in the foreseen flight envelope. A survey is given of the steps taken in the flutter clearance, especially those which were prompted by the transonic aspects. Aerodynamic investigations are discussed involving transonic wind tunnel tests on oscillating supercritical airfoils, transonic flutter tests on a supercritical wing model and the development of calculation methods. A flutter analysis method for these transonic conditions is verified on the wind tunnel model results and applied to the full scale design, showing the influence of the transonic aerodynamics. R.J.F.

N84-11122# Vereinigte Flugtechnische Werke G.m.b.H., Bremen (West Germany).
INFLUENCE OF MAIN DESIGN PARAMETERS ON FLUTTER BEHAVIOUR FOR AIRCRAFT CONFIGURATIONS WITH HEAVY CONCENTRATED MASSES
H. ZIMMERMAN and S. VOGEL *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 11 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

Heavy concentrated masses fitted elastically to the wing can induce flutter in an aircraft. This flutter case is well known for fighter aircraft with certain store configurations. For transport aircraft this flutter case becomes more and more important especially for wing engined aircraft with heavy engines, and modern transonic profiles. The structural and aerodynamic influence parameters for this flutter case are described for a particular project. A flutter speed inside the flight envelope caused by this type of flutter can only be prevented by taking account of aeroelastic criteria and their influence on the early design of the aircraft. For a frozen design this flutter case can only be prevented by penalizing the weight and drag properties of the aircraft. Because transonic aerodynamics also decreases the flutter speed (known as the transonic dip) for aircraft with modern transonic profiles this flutter case deserves special consideration
Author

N84-11123# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario).
AEROELASTIC DESIGN CONSIDERATIONS FOR TURBOPROP POWERPLANT INSTALLATIONS
J. J. GLASER *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 18 p (SEE N84-11116 02-01) Sep. 1983 refs Sponsored in part by Dept. of National Defence and National Research Council of Canada
Avail: NTIS HC A14/MF A01

Experience gained in designing turboprop powerplant suspension systems to minimize vibrations resulting from propeller unbalance is discussed. An overview is first given of turboprop suspension considerations including whirl flutter, vibration isolation and landing loads. This is followed by an outline of the design evolution of the DHC-7 suspension system proven sucessful in service. The design features of the DHC-8 system, currently under development, are also prepared. Recommendations pertinent to preliminary design and development are given. R.J.F.

N84-11124# Douglas Aircraft Co., Inc., Long Beach, Calif.
THE DEVELOPMENT OF FAST-FLOW (A PROGRAM FOR FLUTTER OPTIMIZATION TO SATISFY MULTIPLE FLUTTER REQUIREMENTS)
B. A. ROMMEL *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 17 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

FAST-FLOW is being developed as a production program for finite element flutter optimization. This program is the third step in an automated sequential structural design process that begins with an optimization for buckling and static strength. FAST-FLOW features a user selected design optimization procedures such as the feasible direction design search in CONMIN or a criteria optimizer to provide the structural resizing. Multiple flutter requirements resulting from variations in payload, fuel state, speed, and altitude are simultaneously satisfied FAST-FLOW tracks both flutter speed and hump mode damping factors in design space. Second order Taylor approximations of the flutter speeds and hump mode damping factors may be updated periodically during a fully automated design cycle. During an update, the model is resembled in modal form, modes are updated, and the location of the flutter

speeds and hump modes is reestablished. Then, the gradient and Hessian matrices used in the Taylor approximations for each requirement are updated. These design sensitivities are then used in a fast redesign cycle with the optimizer until the design converges or a new update is required. Program architectural considerations are presented and contrasted with standard structural analysis programs. The impact of finite element dynamics on standard production flutter analysis procedures is also discussed. Author

N84-11125# Royal Aircraft Establishment, Farnborough (England).
THE INITIAL DESIGN OF ACTIVE CONTROL SYSTEMS FOR A FLEXIBLE AIRCRAFT
I. W. KAYNES and D. E. FRY *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 17 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

Methods have been developed for designing active control systems to alleviate the symmetric loads due to vertical gusts on a flexible aircraft. Techniques for choosing sensor positions and system gains are demonstrated, with the interpretation of results being aided by graphical methods that allow easy assessment of conflicting objectives and system constraints. A relatively simple model shows that loads in continuous turbulence can be alleviated by at least 50%, with ailerons driven by feedback signals from accelerometers at the center of gravity and on the wing and with pitch stability augmented using the elevators. Maneuverable loads are also alleviated. The methods are shown to be useful for predicting the potential of active controls at an early stage of design definition. The possibility of slight degradations from a number of sources is assessed, including more complex representations of the aileron actuator and the sensors, aileron rate limitations and different choices of gust model. Author

N84-11126# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
AEROELASTIC DESIGN CONSIDERATIONS IN THE DEVELOPMENT OF HELICOPTERS
H. STREHLOW and B. ENENKL *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 25 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

There are a number of aeroelastic phenomena associated with the design of helicopters. The dynamic stability and response characteristics of rotary wing aircraft are dependent on parameters which have to be defined in the preliminary design phase. The type of rotor and its control determine largely the aeroelastic behavior of a helicopter. Of special interest are nowadays hingeless and bearingless rotor systems. Aeroelastic design considerations for these rotor types are discussed. Coupling effects due to geometric nonlinearities and blade root attachments with recone, droop, sweep and offsets are of great importance with respect to the aeroelastic stability and must be considered carefully in a preliminary phase. In addition, stability and vibration problems call for exact blade tuning possibilities, which in turn require an analytical understanding. Coupling between rotor and fuselage may have significant effects on aeroelastic stability and response. Design parameters related to this complex area are also discussed. Author

N84-11127# Westland Helicopters Ltd., Yeovil (England).
THE INFLUENCE OF AEROELASTIC STABILITY REQUIREMENTS ON HELICOPTER DESIGN
S. P. KING *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 12 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

The avoidance of aeroelastic and aeromechanical instabilities is a prime objective of aircraft design, and must be considered throughout the design cycle. Due to lack of data the analysis of instabilities during preliminary design is a difficult task, consequently simple models may be more useful than large and complex analyses. A number of potential instabilities are discussed; blade flutter; main rotor flap lag stability; tail rotor pitch flap lag and the complete aircraft problems of ground and air resonance. In each case a description of the mechanism involved in the instability is given and a simple analytic tool for its investigation is suggested. Author

N84-11128# Sikorsky Aircraft, Stratford, Conn
AEROELASTIC CONSIDERATIONS IN THE DESIGN OF HIGH SPEED ROTORS
W. L. MIAO and R. H. BLACKWELL *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 16 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

The high speed requirement dictates that the rotor design be simple and clean. Elimination of blade articulations as well as pitch bearings and lag dampers is emerging as a candidate technology for such a rotor. The resulting bearingless type rotor design has to deal with the question of rotor stability and the coupled rotor/airframe stability. The merits of the stiff inplane design versus the soft inplane design in light of the stability issues are discussed. The philosophy of introducing blade bending torsion couplings to improve stability characteristics is substantiated. As vibration potential increases with airspeed exponentially and may become a limiting factor to the speed achievable, reducing vibration should be an integral part of the aeroelastic considerations for high speed rotor. Parameters that can reduce vibrations are discussed generically. Sensitivities of vibration are shown for blade bending and torsion stiffnesses, mass distribution, frequency and mode shape. Author

N84-11129# Societe Nationale Industrielle Aerospatiale, Marignane (France).
ESTIMATED ANALYSIS OF THE AEROELASTIC BEHAVIOR OF TAIL ROTORS [ANALYSE PREVIONNELLE DU COMPORTEMENT AEROELASTIQUE DES ROTORS ARRIERE]
G. GENOUX and G. BLACHERE *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 22 p (SEE N84-11116 02-01) Sep. 1983 refs In FRENCH
Avail: NTIS HC A14/MF A01

A relatively precise knowledge of the aeroelastic behavior of helicopter rotors is necessary for their optimum sizing and maximum safety. In the case of tail rotors, behavior prediction is complex because of the dynamic environment, aerodynamics, and their particular operating conditions (passage range, important twisting action, regime...). Complete modeling of the behavior of the anti-torque rt rotor and of helicopter structure is difficult at the estimation stage. Despite inherent limitations at this step, the approach consists in creating an ensemble of specialized models adapted to the types of rotors studied, of reasonable shape, which permits an estimated knowledge of the most important problems. Certain methods used at Aerospatiale for the study and aeroelastic adjustment of tail rotors are described as well as their application to different concepts (articulated rotors, rotors made of composites, and "fenestrons". Transl. by A.R.H.

N84-11130# Politecnico di Milano (Italy). Dept. of Aerospace.
THE ROLE OF AEROELASTICITY IN THE PRELIMINARY DESIGN OF HELICOPTER ROTORS
V. GIAVOTTO, M. BORRI, A. RUSSO (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Varese, Italy), and A. CERIOTTI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Varese, Italy) *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 8 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

The design of a helicopter rotor is a complex process, in which aeroelastic aspects are involved practically at all stages. As the integration of the different models employed in the design needs to be rationalized, integrated computation system shall be developed, whereby aeroelasticity can be taken into account since the earliest stages. This paper shows the first significant results of a development activity of this kind carried out by AUGUSTA in cooperation with POLITECNICO of Milano. Author

N84-11131# Avions Marcel Dassault-Breguet Aviation Saint-Cloud (France).
AEROELASTICITY AND OPTIMIZATION AT THE DESIGN STAGE [AEROELASTICITE ET OPTIMISATION EN AVANT-PROJET]
C. PETIAU and D. BOUTIN *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 18 p (SEE N84-11116 02-01) Sep. 1983 refs In FRENCH
Avail: NTIS HC A14/MF A01

A procedure developed for static and dynamic structural analysis is completed in several weeks using a three view scheme of the

aircraft, laws of the relative mass of wing units, a summary definition of the internal architecture, a choice of materials, and construction technology. For each version studied, calculation at the design stage involves: (1) a first finite element analysis of rough planning with sampling and simplified loads; (2) analysis of problems of static aeroelasticity, computation of loads by accounting for aeroelasticity, and the automatic study of surrounding loads; (3) computation of flutter with a study of critical configurations with exterior loads removed; and (4) the automatic optimization of sampling, supplying the minimal weight of the structure that satisfies the constraints of static behavior, of aerodistortion limitations, and of the speed of velocity of flutter. A combat aircraft with wings made composite materials is analyzed. A.R.H.

N84-11132# British Aerospace Aircraft Group, Preston (England).
AEROELASTIC CONSIDERATIONS IN PRELIMINARY DESIGN OF A MILITARY COMBAT AIRCRAFT
M. ORMEROD and D. G. GIBSON *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 12 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

This report gives an outline of the aeroelastic considerations taken into account during the early stages of a modern combat aircraft design. It describes the manner in which the aerodynamic performance requirements are balanced against what can be achieved by structural optimization. At the same time, flutter characteristics are established in such a way that as many as possible of the design features that are potentially critical for flutter are identified. It is shown that these procedures can produce structure that achieves the selected performance targets and give adequate fundamental (bending/torsion) flutter speeds. However, there are significant secondary effects associated with items such as tip missiles, control surface actuation and underwing stores that have to be treated carefully if meaningful design advice is to be given before the design is frozen. Author

N84-11133# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Airplane Div.
PRELIMINARY DESIGN OF AIRCRAFT USING STRUCTURAL OPTIMIZATION METHODS
H. GOEDEL, G. SCHNEIDER, and H. HOERNLEIN *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 13 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

Weight minimized surfaces of a modern high performance aircraft have to fulfill statical, dynamical and aeroelastical requirements such as highly maneuverable aircraft, high control surface effectiveness, no flutter in the mission domain. To meet these requirements it is necessary to improve the optimization procedures and applicate them even in the preliminary design phase of an aircraft to become acquainted with the influence of the main design parameters. The presented paper deals with the activities at MBB in the field of structural optimization. The presented paper deals with the activities at MBB in the field of structural optimization. The theoretical background of the optimization will be described with special regard to the constraints such as stresses, deflections in conjunction with control surface effectivenesses, flutter speed and side limits. Flutter speed optimization is based on an optimality criterion including physical facts whereas for the other constraints mathematical programming procedures are used. By means of well known test examples, a vertical tail structure and a simplified wing structure the capabilities of the applied optimization program systems are shown and results are presented. Author

N84-11134# Rockwell International Corp., El Segundo, Calif.
A FLUTTER OPTIMIZATION PROGRAM FOR COMPLETE AIRCRAFT STRUCTURAL DESIGN
S. SIEGEL *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 17 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

A new computer program for flutter optimization has been developed and successfully used to accurately account for the interactive aerodynamic and structural effects of the complete aircraft. The program is both cost and time effective when compared with alternate available approaches and can be used from preliminary through advanced design stages. To insure that strength requirements are met, the optimization program starts with the strength design and automatically performs an iterative solution to raise the complete aircraft flutter speed. During each cycle of iteration, local areas of structure are stiffened by applying the criterion of constant strain energy density in the flutter mode to obtain near minimum weight solution. This program has successfully analyzed recent complete aircraft designs to provide adequate structure for flutter safety. Author

N84-11135# Politecnico di Milano (Italy). Ist. di Ingegneria Aerospaziale.
FAST FLUTTER CLEARANCE BY PARAMETER VARIATION
V. GIAVOTTO, P. MANTEGAZZA, T. MERLINI, L. DEOTTO (Aermacchi, Varese, Italy), M. LUCCHESINI (Aermacchi, Varese, Italy), and R. MANTELLI (Aermacchi, Varese, Italy) *In* AGARD Aeroelastic Considerations in the Preliminary Design of Aircraft 12 p (SEE N84-11116 02-01) Sep. 1983 refs
Avail: NTIS HC A14/MF A01

After a discussion regarding the main requirements of the study of flutter in the preliminary design, a unified computation system is proposed, which can effectively perform the various types of analysis required. This system was implemented and confirmed through the comparison with experimental results obtained with a wind tunnel model. The computation system used for the flutter analysis of a combat aircraft with external stores proved to be effective and adequately accurate even in the hardest situations, when the gradients of the critical speed with respect to design parameters are very high. Author

N84-12050# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SOME TRENDS IN AIRSHIP TECHNOLOGY DEVELOPMENTS
L. B. CREMA (Ist. di Tecnologia Aerospaziale, Rome) and A. CASTELLANI (Ist. di Tecnologia Aerospaziale, Rome) 1982 12 p refs Presented at the 56th Meeting of the Struct. and Mater. Panel, London, 10-15 Apr. 1983
(AGARD-R-717; ISBN-92-835-1458-0; AD-A133996) Avail: NTIS HC A02/MF A01

Recent advances in aerospace technology, and in particular the application of new materials and novel structures, have special relevance to the development of dirigibles. Significant reductions in structure weight, it is demonstrated, can be achieved through the use of, for example, carbon fiber composites. Corresponding improvements in operational performance are shown. Author

N84-12056# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
INTEGRATION OF FIRE CONTROL, FLIGHT CONTROL AND PROPULSION CONTROL SYSTEMS
Loughton, England Aug. 1983 194 p refs In ENGLISH and FRENCH Symp. held in Toulouse, 17-20 May 1983
(AGARD-CP-349; ISBN-92-835-0335-X; AD-A135166) Avail: NTIS HC A09/MF A01

The potential and problems of integrating mission critical and flight critical systems are examined. Fuel conservation, attack performance, combat survivability, and flight safety are addressed. For individual titles, see N84-12057 through N84-12071.

N84-12057# Federal Ministry for Defence, Bonn (West Germany)
INTEGRATION OF FIRE, FLIGHT AND PROPULSION CONTROL SYSTEMS: AN OVERVIEW, RETROSPECTIVE AND PROSPECTIVE
W. M. FRAEDRICH *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 12 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

A brief historical review of aviation control technology is presented and topics related to digital data processing are discussed in detail. Problems which may arise with a totally integrated system are demonstrated through the use of examples and strategies for avoiding such problems are suggested. M.G.

N84-12058# Air Force Armament Lab., Eglin AFB, Fla. Hypervelocity Missile Branch.
HYPERVELOCITY MISSILE: BASED ON THE CONCEPT OF AIRCRAFT/MISSILE INTEGRATION FOR MAXIMUM FIREPOWER
T. C. ADEN *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 14 p (SEE N84-12056 03-01) Aug. 1983
Avail: NTIS HC A09/MF A01

The conventional approach to weapons for the close air support/battlefield interdiction (CAS/BI) missions has not provided NATO forces with affordable, effective firepower of the order required to defeat armored thrusts. The conventional approach has led to weapons that are either too expensive for stockpile and training purposes or too expensive to go to war. It has also failed to provide NATO strike aircraft assigned to the CAS/BI missions with the ability to achieve a large number of kills per pass or kills per sortie. The hypervelocity missile concept integrates current and emerging flight control system (FCS) technology with a low cost, lightweight missile to provide NATO forces with a significant firepower improvement. The U.S. Air Force has completed a series of ground launched flight tests that have successfully resolved all technical issues critical to missile guidance, control and accuracy questions. This series of successful demonstrations permits immediate continuation into an air launch flight test environment to demonstrate the integration of the three critical elements -- the aircraft, the FCS, and the missile. Author

N84-12059# Norwegian Defence Research Establishment, Kjeller.
F-16 PENGUIN ANTI-SHIP MISSILE INTEGRATION
E. BRODERSEN *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 7 p (SEE N84-12056 03-01) Aug. 1983
Avail: NTIS HC A09/MF A01

Integration of the Norwegian Penguin Mk3 antiship missile for operation on the F-16 aircraft is discussed. Due to the inherent flexibility of both the aircraft and the missile system, no hardware changes are required on the aircraft. Software changes are designed such that the pilot can operate the weapon to its full performance by using existing cockpit controls and displays in a way quite similar to other air to ground missions. M.G.

N84-12060# Marconi Avionics Ltd., Rochester (England). Airborne Display Div.
INTEGRATION OF FIRE CONTROL, NAVIGATION SYSTEM AND HEAD UP DISPLAY
G. M. BARLING *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 18 p (SEE N84-12056 03-01) Aug. 1983
Avail: NTIS HC A09/MF A01

The inclusion of a sophisticated navigation function in a head up display/weapon aiming computer (HUD)/(WAC) is described together with integration of the resultant subsystem into an overall navigation/attack system. A growing trend in airborne systems computing is highlighted. Author

N84-12061# Northrop Corp., Hawthorne, Calif. Aircraft Div.
APPLICATION OF FLIGHT CONTROLS TECHNOLOGY TO ENGINE CONTROL SYSTEMS
R. J. SEEMANN and J. L. LOCKENOUR *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 26 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

A system design approach is outlined and some considerations for the design of electronically implemented control laws are discussed. A typical redundancy management concept, based on digital flight control techniques, for a quadruplex engine control system is described. This is followed by an analysis methodology to determine the probability of control system failure. Some implications that the use of probability theory has on the control system design requirements are discussed. M.G.

N84-12062# Societe Nationale d'Etudes et de Construction de *Moteurs d'Aviation, Moissy-Cramayel (France).*
THE RELATIONS BETWEEN THE NUMERICAL CONTROL OF THE ENGINE AND OTHER AIRCRAFT FUNCTIONS [LIENS ENTRE LA REGULATION NUMERIQUE DU MOTEUR ET LES AUTRES FONCTIONS DE L'AVION]
D. RAMBACH *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 9 p (SEE N84-12056 03-01) Aug. 1983 In FRENCH
Avail: NTIS HC A09/MF A01

Numerical control opens the door to a larger integration of the aircraft engine by means of dialog with the pilot and other aircraft systems, either to provide new functions or to improve actual services. The objectives aimed for cover better performance, a nontotal optimization, and a greater ease in piloting. To accomplish this, several systems must dialog. A number of structures permit this. A method is proposed for choosing a structure that preserves to each important system its autonomy in case of difficulty while always benefitting from the advantage of integration. The functions are analyzed and regrouped in a pyramid so as to respect a nonpropagation of engine trouble. The objective is to preserve a distinct and controllable organization in the integrated system. This nonoptimal organization gives priority to reliability on the one hand, and an unambiguous division of responsibilities on the other.
A.R.H.

N84-12063# British Aerospace Public Ltd. Co., Lancashire (England). Advanced Control Systems Group.
INTEGRATED POWERPLANT CONTROL SYSTEMS AND POTENTIAL PERFORMANCE BENEFITS
A. G. SEABRIDGE and R. A. EDWARDS *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 10 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

Three aspects of integration in which the powerplant control system was integrated with the aircraft systems were examined. It is shown that the powerplant control system can be progressively integrated into the aircraft systems architecture by a distributed computing system for utility systems management. It is shown that the powerplant control system is a candidate for further improvement as a result of the integration and the ready availability of off take load related data. Some of the advantages of integration with flight control are discussed. E.A.K.

N84-12064# Dowty and Smith Industries Controls Ltd., Cheltenham (England).
FULL AUTHORITY DIGITAL ELECTRONIC ENGINE CONTROLS AND THEIR INTEGRATION WITH FLIGHT CONTROL SYSTEMS IN VSTOL AIRCRAFT
E. S. ECCLES *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 10 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

The architecture and construction of the system applied to the Pegasus engine and aimed at the AV8B application are described. The system's architecture was determined by the requirements of a single engined VSTOL aircraft. It is essentially a dual-dual system. This architecture was chosen to provide reliable and positive detection of failure with rapid reaction and no degradation of performance. The likely extension of this system to the control of plenum chamber burning (PCB) is discussed. E.A.K.

N84-12065# Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
DESIGN AND DEVELOPMENT OF THE MULTIFUNCTION FLIGHT CONTROL REFERENCE SYSTEM
J. T. YOUNG, J. M. PERDZOCK, D. L. SEBRING (McDonnell Douglas Corp.), and L. EDINGER (Honeywell Inc.) *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 10 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

The multifunction flight control reference system (MFCRS) concept which uses a minimum number of inertial sensors in a survivable configuration to provide inertial data for flight control, navigation, weapon delivery, cockpit displays, and sensor stabilization is discussed. The MFCRS program was initiated to verify, through flight test, the key issues of redundancy management and flight control. A redundancy management system based on

parity equations was designed. It was shown which noise levels were higher than predicted. Additional filtering was required for MFCRS to prevent false alarms and high frequency actuator response. This filtering affected the flight control stability and performance and the flight control design was modified. It is found that integration of inertial data for fire control, flight control, and propulsion control will require close coupling and coordination between functional groups to resolve performance conflicts and compromises. E.A.K.

N84-12066# Ferranti Ltd., Edinburgh (Scotland).
SOME ASPECTS OF FLIGHT TRAJECTORY CONTROL IN FUTURE AVIONIC SYSTEMS FOR COMBAT AIRCRAFT
W. H. MCKINLAY *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 11 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

Some of the reasons for increased integration with the emphasis on flight profile control in combat aircraft, largely in the ground attack role are considered. Some of the reasons for further integration involving flight control are examined and the various phases of flight and particular problems are considered. It is suggested that future work will consist of developing particular capabilities, concentrating on the relationship between pilot and total system, learning how to control the design of such a closely coupled system and handling the important problems of testing, reliability, maintainability and the attainment of minimum economic configurations which will satisfy all these goals. The need for flexibility in any system which combines automation with a high degree of pilot participation is stressed. E.A.K.

N84-12067# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung.
A DIAGNOSIS SCHEME FOR SENSORS OF A FLIGHT CONTROL SYSTEM USING ANALYTIC REDUNDANCY
N. STUCKENBERG *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 12 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

A diagnosis 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. The feasibility of the presented concept is demonstrated. E.A.K.

N84-12068# Avions Marcel Dassault, Saint-Cloud (France).
EFFECTS OF INTEGRATED MAINTENANCE ON THE DEFINITIONS OF ONBOARD EQUIPMENTS [REPERCUSSIONS DE LA MAINTENANCE INTEGREE SUR LA DEFINITION DES EQUIPMENTS EMBARQUES]
M. COUTOIS *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 13 p (SEE N84-12056 03-01) Aug. 1983 In FRENCH
Avail: NTIS HC A09/MF A01

Equipments for the Mirage 2000 aircraft are related among themselves by a numeric bus centrally controlled by a single tactical (principal) computer. The integrated maintenance of these systems encompasses that realized during the functional operation of the weapon system and is based on permanent surveillance of the equipment operation and the recording of anomalies during flight. In addition, there is a maintenance realized during the particular operation of the weapon system which permits more in-depth tests of the equipment and verifies all information exchanges made by the numeric bus or by point-to-point analog or digital relations. During the maintenance operation, the weapon system no longer provides an operational function. The material and logic implications of the maintainability function accomplished by the equipments are described by distinguishing those arrangements used during functional operation and those used during maintenance. The software for integrated maintenance at the level of the principal computer which controls the numeric bus is described.
Transl. by A.R.H.

N84-12069# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (West Germany).
AN INTEGRATED AFCS FOR THE "PROFILE"-MODE
P. WUEST and W. ALLES *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 11 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

The structure of the integrated control system and the appropriate parameter design method using the AIRBUS A300 as an example is described. The structure of the system is characterized by: (1) a mixture of feedforward and feedback control thus allowing to separate the design of the command disturbance characteristics; and (2) decoupling speed and height loop. The control system design relies on the knowledge of aircraft and engine characteristics, both known to the FMC or similar devices. To ease the analytic parameter design, the relevant aircraft dynamic is simplified by the incorporation of well proven basic loops such as pitch attitude feedback and N1/EPR-control. Within the scope of this simplification eigenvalues of the entire system are prescribed. Energy-saving aspects by the reduction of throttle lever excursions is considered using this approach. E.A.K.

N84-12070# British Aerospace Aircraft Group, Brough (England). ACT Design Group
THE INTEGRATION OF FLIGHT AND ENGINE CONTROL FOR VSTOL AIRCRAFT
N. P. PATTINSON *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 7 p (SEE N84-12056 03-01) Aug. 1983 refs
Avail: NTIS HC A09/MF A01

A control philosophy appropriate to future jet VSTOL aircraft which leads naturally to the integration of flight and engine control system is discussed. The potential benefits of this class of system are stated and integration aspects, both in terms of control laws and at the hardware level, are considered. The areas surrounding this approach to VSTOL control which require deeper study are outlined. E.A.K.

N84-12071# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
A NONLINEAR CONTROL LAW FOR PILOTING AIRCRAFT IN THE AIR-TO-GROUND ATTACK PHASE [SUR UNE LOI DE COMMANDE NON-LINEAIRE POUR LE PILOTAGE DES AVIONS EN PHASE D'ATTAQUE AIR-SOL]
B. D. VU and O. L. MERCIER *In* AGARD Integration of Fire Control, Flight Control and Propulsion Control Systems 10 p (SEE N84-12056 03-01) Aug. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A09/MF A01

With focus on the control configured vehicle concept, a manual and non-conventional aircraft control law is presented which provides an improved target tracking in air-to-ground gunnery. The system architecture which integrates a weapon system, a fire control system and a flight control system is analyzed. In comparison to classical flight control systems, improvements come mainly from the elaborate processing of the pilot steering commands. The application of modern nonlinear control techniques to the design of the control law makes it otherwise well-suited for aircraft alignment maneuvers of large magnitude. The controllability of a linear version of the control law was demonstrated on a manned simulator. Author

N84-12072# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SPECIAL COURSE ON SUBSONIC/TRANSONIC AERODYNAMIC INTERFERENCE FOR AIRCRAFT
Loughton, England Jul. 1983 286 p refs In ENGLISH and FRENCH Course held in Rhode-Saint-Genese, Belgium, 2-6 May 1983 and in Dayton, Ohio, 16-20 May 1983
(AGARD-R-712; ISBN-92-835-0332-5; AD-A133675) Avail: NTIS HC A13/MF A01

The emphasis of the course was on the configuration optimization in the transonic regime where both military and commercial aircraft must maneuver in an agile but stable manner. The course material has been updated and was presented in a more structured fashion emphasizing the fluid dynamic interference mechanisms that are the keys to the optimization. In additon some aspects of subcritical interference were also covered including

those arising in the takeoff and landing phase of the flight with high lift devices deployed. Background material is given describing the computational and testing. The wide range of interference phenomena is covered arising in the optimization of both military and commercial aircraft starting from the simple airfoil and wing and extending to the complete configuration. For individual titles, see N84-12073 through N84-12086.

N84-12073# Boeing Co., Seattle, Wash.
SUBSONIC/TRANSONIC AERODYNAMIC INTERFERENCE FOR AIRCRAFT: INTRODUCTORY REMARKS
H. YOSHIHARA *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 5 p (SEE N84-12072 03-01) Jul. 1983
Avail: NTIS HC A13/MF A01

These introductory remarks provide examples of important subsonic and transonic fluid dynamic mechanisms that make up interference concepts used in aircraft optimization. The rationale for the lecture topic selection and the course outline are then given. Author

N84-12074# National Aerospace Lab., Amsterdam (Netherlands). Theoretical Aerodynamics Dept.
COMPUTATIONAL METHODS FOR SUBSONIC AND TRANSONIC AERODYNAMIC DESIGN
J. W. SLOOFF *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 40 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

An overview is provided of computational methods that can be used in solving the design problem of aerodynamics; i.e., the problem of finding the detailed shape of (parts of) configurations of which the gross geometric characteristics have already been determined in a preliminary, overall design process, and that, subject to certain constraints, have to meet given aerodynamic requirements. Attention is focussed on methods for solving the classical inverse problem of aerodynamics and on approaches using optimization techniques. Both methods limited to subsonic flow utilizing panel method technology as well as methods based on finite difference/volume formulations for compressible, transonic flow are covered. In conclusion a discussion is presented of the relative merits of the various computational approaches to the problem of aerodynamic design. Author

N84-12075# Boeing Co., Seattle, Wash.
SUBSONIC/TRANSONIC VISCOUS INTERACTIONS
H. YOSHIHARA *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 14 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

Significant viscous interactions arising at transonic cruise and maneuver conditions and low speed/high lift conditions are described for airfoils and swept wings. Consequences on the performance and stability of fighter and airlift aircraft are briefly sketched. Computational methods using the integral boundary layer/wake equations are then described in a narrative fashion. Author

N84-12076*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TRANSONIC AIRFOIL DEVELOPMENT
R. T. WHITCOMB *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 9 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01 CSCL 01A

This lecture consists of three parts, in which discussions are presented of the current state of development of transonic or supercritical airfoils designed for fully turbulent boundary layers on the surfaces, previous research on subcritical airfoils designed to achieve laminar boundary layers on all or parts of the surfaces, and current research on supercritical airfoils designed to achieve laminar boundary layers. In the first part the use of available two dimensional computer codes in the development of supercritical airfoils and the general trends in the design of such airfoils with turbulent boundary layers are discussed. The second part provides the necessary background on laminar boundary layer phenomena. The last part, which constitutes the major portion of the lecture, covers research by NASA on supercritical airfoils utilizing both decreasing pressure gradients and surface suction for stabilizing the laminar boundary layer. An investigation of the former has been recently conducted in fight using gloves on the wing panels of the U.S. Air Force F111 TACT airplane, research on the later is currently being conducted in a transonic wind tunnel which has been modified to greatly reduce the stream turbulence and noise levels in the tests section. Author

N84-12077# Boeing Commercial Airplane Co., Seattle, Wash. Aero Research and Development.
AERODYNAMIC DESIGN FOR OVERALL VEHICLE PERFORMANCE
I. H. RETTIE *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 10 p (SEE N84-12072 03-01) Jul. 1983
Avail: NTIS HC A13/MF A01

The process by which a wing is designed and integrated into an aircraft configuration is examined in detail. The way in which the characteristics of the design are matched to the size of the aircraft and to the critical segments of typical missions is described with some examples. High-speed computers are used routinely today to determine optimum dimensions for the vehicle. Their growing use in Computational Fluid Dynamics for aerodynamic design prior to wind tunnel testing is examined particularly as regards the capability this offers to tailor a single component such as the wing leading edge to obtain improvements in more than one flight regime by one modification to the aircraft. Author

N84-12078# National Aerospace Lab., Amsterdam (Netherlands).
APPLICATION OF COMPUTATIONAL PROCEDURES IN AERODYNAMIC DESIGN
J. W. SLOOFF *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 23 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

Examples are discussed on the application of computational methods in aerodynamic design problems involving interference. Amongst these are: subsonic wing-body, sting support, pylon-nacelle and pylon-store interference, high-lift devices, induced drag minimization through constrained optimization in the Trefftz-plane and transonic wing-fuselage design and analysis. In addition a discussion is given on the problem of optimal usage of aerodynamic soft-ware in analyses and design, requiring an integrated systems approach. Author

N84-12079*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TRANSONIC EMPIRICAL CONFIGURATION DESIGN PROCESS
R. T. WHITCOMB *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 9 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

This lecture describes some of the experimental research pertaining to transonic configuration development conducted by the Transonic Aerodynamics Branch of the NASA Langley Research Center. Discussions are presented of the following: use of florescent oil films for the study of surface boundary layer flows; the severe effect of wind tunnel wall interference on the measured configuration drag rise near the speed of sound as determined by a comparison between wind tunnel and free air results; the development of a near sonic transport configuration incorporating a supercritical wing and an indented fuselage, designed on the basis of the area rule with a modification to account for the presence of local supersonic flow above the wing; a device for improving the transonic pitch up of swept wings with very little added drag at the cruise condition; a means for reducing the large transonic aerodynamic interference between the wing, fuselage, nacele and pylon for a for a fuselage mounted nacelle having the inlet above the wing; and methods for reducing the transonic interference between flows over a winglet and the wing. Author

N84-12080# Aircraft Research Association Ltd., Bedford (England).
AERODYNAMIC INTERFERENCE: A GENERAL OVERVIEW
A. B. HAINES *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 52 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

A general survey is given of the sources of aerodynamic interference and of how adverse interference can be avoided and favorable interference exploited in the optimisation of the design of complete configurations for modern civil transport and military combat aircraft. The basic nature of wing-body interference is discussed at some length since these effects are at the root of much of what is to follow. There is considerable emphasis on means to reduce profile, vortex and transonic wave drag but it is also stressed that favorable interference concepts can be employed to improve lift for manoeuvere and to optimise stability and control characteristics at high incidence. R.J.F.

N84-12081# Messerschmitt-Boelkow-Blohm/Entwicklungspring Nord, Bremen (West Germany).
TRANSONIC CONFIGURATION DESIGN
G. KRENZ *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 26 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

General design aspects as well as specific criteria for a transonic wing lay-out are described and some special problems inherent in any transonic wing design are discussed on the basis of wind tunnel measurements. Aerodynamic wing concepts are considered, following two different design strategies by model tests in the transonic wind-tunnel. It was found that the shock development on the upper wing surface has a strong effect on both the design and off-design performance of the wing in terms of lift-drag. Potential flow methods used in transonic wing designs are discussed. R.J.F.

N84-12082# British Aerospace Aircraft Group, Preston (England).
TRANSONIC CONFIGURATION DESIGN (FIGHTER)
D. E. SHAW *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 21 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

Current design procedures with special reference to aerodynamic interference and the associated use of computational fluid dynamics are discussed. A number of illustrations of various interference phenomena that play a major part in the optimisation of a new design are given. Specifically, the examples given are: the detailed effects of twin fins versus single fin; the flap taileron effects on laterals; wing stores; the effects of vortices; and wind tunnel effects with vortices included. R.J.F.

N84-12083# Aircraft Research Association Ltd., Bedford (England).
EXTERNAL STORES INTERFERENCE
A. B. HAINES *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 20 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

External store installations are frequently a source of considerable adverse aerodynamic interference giving large increases in drag, reductions in usable lift and poor store release characteristics. This adverse interference can be greatly alleviated or even transformed into favorable interference. Some of the available evidence for a wide variety of arrangements is given. The nature of the interference, both adverse and favorable, is described, particular emphasis being placed on the major adverse interference in standard multiple carriers and in some underwing installations. The possible benefits of wing tip carriage and carefully arranged underfuselage arrays are noted. Throughout, stress is laid on the fact that dramatic improvements might be possible by adopting a radical approach to store carriage. R.J.F.

N84-12084# Boeing Commercial Airplane Co., Seattle, Wash. Aero Research and Development.
INTERFERENCE PROBLEMS IN AIRCRAFT DESIGN
I. H. RETTIE *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 10 p (SEE N84-12072 03-01) Jul. 1983
Avail: NTIS HC A13/MF A01

The nature of aerodynamic interference among the components of an aircraft is examined. Some of the flow mechanisms involved are studied with the help of theoretical flow models with the objective of identifying design guidelines for the avoidance of performance or other penalties. The possible achievement of favorable interference in some cases is also discussed. Emphasis is placed upon the growing capability of computational methods which allow the designer to explore interference effects during the early phase of a design prior to wind tunnel tests. Author

N84-12085# Messerschmitt-Boelkow-Blohm/Entwicklungspring Nord, Bremen (West Germany).
ENGINE/AIRFRAME INTERFERENCE
G. KRENZ *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 17 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

A short review about typical aircraft representatives with different types of engine housing is given. The reasons why current commercial transport aircraft designed for the transonic flight regime prefer conventional engine locations under the wing are given. On first sight type of configuration rarely changed over the past 25 years. However, the strength of flow interference was increased considerably due to the rapid progress in engine as well as wing technology. On the engine side mainly the enlarged massflow and fan diameter contribute to the stronger interaction, while the wing tends to thicker leading to higher loaded designs with supercritical flow in the transonic flight regime. The increasing effects of wing/engine interference were studied in several transonic wind-tunnels. Results including those of varying engine distances from the transonic wing are presented. R.J.F.

N84-12086# British Aerospace Aircraft Group, Preston (England).
ENGINE-AIRFRAME INTERFERENCE EFFECTS
A. VINT *In* AGARD Spec. Course on Subsonic/Transonic Aerodyn. Interference for Aircraft 21 p (SEE N84-12072 03-01) Jul. 1983 refs
Avail: NTIS HC A13/MF A01

The various types of interference between a turbo-jet or turbo-fan engine and the airframe as applicable to military aircraft are described in detail. Examples of the effects on overall aircraft aerodynamics are given, including, where possible, simple means for their evaluation. It is shown that the interference may give either significant benefits or penalties and that relatively minor geometric changes can have profound effects. Above all it is shown that the effects of all aspects of engine airframe interference must be known early in the design process so tht pitfalls can be avoided or beneficial effects included in the initial aircraft design. R.J.F.

N84-15034# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ADVANCED CONCEPTS FOR AVIONICS/WEAPON SYSTEM DESIGN, DEVELOPMENT AND INTEGRATION
Loughton Oct. 1983 484 p refs In ENGLISH and FRENCH Symp. held in Ottawa, 18-22 Apr. 1983
(AGARD-CP-343; ISBN-92-835-0337-6; AD-A138600) Avail: NTIS HC A21/MF A01

New design and development strategies are considered to achieve the technical and performance benefits expected of highly advanced and integrated avionics/weapons system in an economic and timely manner. The applicable design and development concepts being considered are as follows: design of the overall system to satisfy the operational requirements; parallel design and development activities in relevant disciplines; retention of design and application flexibility and growth in subsystems by means of appropriate data processing and subsystem inter/intracommunications structure; planning of logistic support elements including reliability, maintainability and supportability as well as life cycle cost considerations; and comprehensive integrated

ground testing prior to airborne evaluation of the weapons systems. For individual titles, see N84-15035 through N84-15075.

N84-15035# General Dynamics Corp., Fort Worth, Tex. Avionic Systems Dept.
SYSTEM ARCHITECTURE: KEY TO FUTURE AVIONICS CAPABILITIES
G. R. ENGLAND *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 6 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

Modern aircraft still rely, as old World War II aircraft, upon the pilot or crew for integration of information from diverse discrete subsystems, sensors and weapons. During this long period of technology time, each generation of systems has generally become more complex and increased the quantity and rate of information to the crew. In many weapon system implementations these two factors have resulted in increased problems in the areas of system availability, affordability, supportability and operability. Although the F-16 has broken this trend it is still evident that new system architectures will be needed as mission requirements in the future create added system demands. Traditional avionic design, support and operability approaches will be unable to cope. The size reduction and performance improvements resulting from large scale and high speed integrated circuits will make it possible to restructure the way avionics systems are designed. For example, standard modules for multiuse applications are possible. These modules become the building blocks for a new type of system architecture. Advanced data switching communication techniques provides the necessary data transfer rates to support sensor fusion, cockpit automation, and fault tolerant processing. Generic signal processors make shared functions realizable. Author

N84-15036# Westinghouse Electric Corp., Baltimore, Md. Defense and Electronics Center.
TACTICAL REQUIREMENTS IMPACT ON AVIONICS/WEAPON SYSTEM DESIGN
T. E. SPINK and J. F. PATTON *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 15 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

The complexity of tactical weapon delivery was greatly increased by the advent of new weapons, the enormity of enemy defenses and the awesome capability of new digital technology. However, careful assessment of the tactical requirements becomes even more important if a truly effective marriage of airframe, avionics and weapons is to be achieved. A review of a typical tactical mission requirement, battlefield interdiction, establishes a base for derivation of functional requirements on which an integrated attack system architecture is designed. The result is a need for a multisensor, multimode capability functionally integrated to achieve the flexibility required by the mission. Author

N84-15037# Northrop Corp., Hawthorne, Calif. Aircraft Div.
OPERATIONAL READINESS AND ITS IMPACT ON FIGHTER AVIONICS SYSTEM DESIGN
J. F. IRWIN *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 11 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

Operational Readiness (OR) is a widely used term that covers various aspects of availability, maintainability, reliability and testability. Just as the development of avionic systems require the establishment of system engineering, software design and interface management guidelines, the same requirement exists for the world of operational readiness. These OR guidelines include the following controllable elements: design for testability (DFT), operational fault tolerance, system diagnostic reconfiguration, post flight data extraction/analysis, and integrated test and maintenance. Design and Acquisition of systems and prime electronic equipment must account for early consideration of testability and automatic test design requirements. Testability factors influence all phases of design, integration, deployment and support of electronic equipment and will adversely impact weapon system availability and ultimate return on investment if improperly specified and implemented. The major goals of fault tolerant systems are increased weapon systems availability, mission survivability, and an affordable life cycle cost. Widespread acceptance of operational readiness objectives will probably be predicated on the demonstrated life cycle cost of those initial aircraft containing fault tolerant systems. A managerial and technical roadmap for accomplishing the desired operational readiness goals in the next generation fighter is provided. The contribution of the various attributes (including testability, avionic architecture, fault tolerant designs, BIT, standardization and operational readiness control) is provided. Author

N84-15038# Naval Weapons Center, China Lake, Calif. Weapons and Tactics Analysis Center.
AVIONICS CONCEPT EVALUATION AT THE FORCE LEVEL
M. CARTWRIGHT and T. HAVEN *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 7 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The development of new avionics systems should be guided and supported by force level analysis. Evaluation at the force level is necessary in order to assure that a concept, as it is conceived and developed, will indeed provide a significant increase in capability when the resulting weapon system is used in an operational environment. The Weapons and Tactics Analysis Center (WEPTAC) at the Naval Weapons Center is a war gaming facility for doing force level analysis. It is used to evaluate weapon systems and tactics as they would be employed in realistic scenarios involving opposing forces. It provides a valuable tool, therefore, for the evaluation of avionics concepts. The importance of force level analysis in avionics system development, describes the WEPTAC facility, and gives an example of the use of WEPTAC to evaluate an avionics concept is discussed. Author

N84-15039# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
A FUTURE SYSTEM DESIGN TECHNIQUE BASED ON FUNCTIONAL DECOMPOSITION, SUPPORTED BY QUANTIFIABLE DESIGN AIMS, AND GUIDELINES FOR MINIMUM MAINTENANCE COSTS
D. OLDFIELD and L. T. J. SALMON *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 6 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

The increasing cost and complexity of modern fast jet aircraft, coupled with the long development period which takes place while technology is changing rapidly, make it necessary to consider a new approach to system design. Such an approach should be based on a structured top down procedure, in which the rather general requirement can be changed into a detailed documented design in a controlled manner. One important aspect of design is cost, and in particular cost effectiveness and life cycle cost. At least some of the design aims are based on cost effectiveness reasoning, and it is necessary to have an appreciation of the background to this. Reliability dependent maintenance costs amount to much more than the original purchase price, and hence it is essential to be aware of the possible cost drivers, and include maintenance aspects in the design approach from the beginning. Author

N84-15040# Electronique Serge Dassault, St. Cloud (France).
TOWARDS A MODULARITY OF SOFTWARE CONCEIVED FOR THE REQUIREMENT OF THE USER [VERS UNE MODULARITE DU LOGICIEL CONCUE POUR LES BESOINS DE L'UTILISATEUR]
P. CATEL *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 14 p (SEE N84-15034 06-01) Oct. 1983 In FRENCH
Avail: NTIS HC A21/MF A01

Background data on software for the main computer of an avionics system is reviewed and the step taken at Dassault in the search for modularity of software that is adapted to user needs is examined. This step evolved in two phases. The first phase concerned the median size (up to 64 K words) and permitted definition of a software structure and rules for cutting. The second phase appeared on the occasion of starting a new application, of more important volume, before becoming the base for an important family of applications. A study, led conjointly with the program specifier (the master work of the system), permitted different improvements, both on the plan of the structure as well as the methods for cutting, so as to obtain a perfect recovery of the entities of the software. This was concretized by the use of new

tools and by extensions of the virtual machine of the computer used. A.R.H.

N84-15041# *Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).* Military Aircraft Div.
INCREASING SIGNIFICANCE OF ELECTROMAGNETIC EFFECTS IN MODERN AIRCRAFT DEVELOPMENT
D. JSEGER *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 18 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

Due to the use of new materials, the enlargement of the electromagnetic environment, the increasing susceptibility of electronic components and the rising dependence on satisfactorily functioning electronics, greater attention must be paid to electromagnetic effects in modern aircraft development. The increase in the scope of problems in comparison with the past and the possibilities which can be recommended for their solution are presented. Author

N84-15042# Naval Air Development Center, Warminster, Pa.
AVIONICS/CREW STATION INTEGRATION
W. G. MULLEY *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 9 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

Advanced development concepts aimed at increasing the aircraft instrumentation performance for multiplatform applications of 1990's weapons systems are discussed. The objectives of these three areas are as follows: the system integration objectives are to produce a system architecture easily adaptable to many platforms; technology objectives are to determine the state of the art for displays, electronics, and controls; and the human factors objectives are to determine the proper human machine interfaces so that the ultimate crew station will be capable of providing the pilot with the proper display and controls performance to satisfy the diverse requirements of a fighter, attack, ASW, fixed wing, rotary wing, and V/STOL platforms in both a one man crew or two man crew matrix. All data/control interface among units of this crew station system and other platform subsystems are via digital data buses and video multiplex buses. No individual discrete signal, data, or control lines are needed. The six interfaces necessary to ensure the optimum development of this crew station, the predicted platform mission improvements, and the requisite life cycle cost considerations are discussed. This concept serves as a basis for planning the integation of the necessary hardware and software features in current and future weapons systems. Author

N84-15043# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
COMBINED VISUALIZATION [LE COMBINE DE VISUALISATION]
B. SIMON *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct. 1983 In FRENCH
Avail: NTIS HC A21/MF A01

Combined visualization corresponds to a mechanical ensemble uniquely regrouping a head up display and a head down display. The head up imagery is collimated and the head down imagery is either collimated or focalized on a fixed plane. Such a system permits a diversity of uses: (1) extending the visual field downward when the head down visualization is collimated; (2) reducing the head up symbology by a better division on the entire screen when the head down visualization is collimated; and (3) when the head down visualization is focalized at a fixed distance, it can be associated with another head down screen. A.R.H.

N84-15044# Bundesamt fuer Wehrtechnik und Beschaffung, Koblenz (West Germany).
GUIDELINES AND CRITERIA FOR THE FUNCTIONAL INTEGRATION OF AVIONIC SYSTEMS WITH CREW MEMBERS IN COMMAND
F. W. BROECKER *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 12 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

Significant technical hardware advances were made during the past few years in digital-micro-technology that have caused problems of how to handle and how to use their great potential for the best benefit of designing a distinctly better system and working environment for the crew member in order to make him a real functional member of the system. Such a good approximation to a real functional integration of technical means and human beings seems to be the only promising way for a distinct improvement of weapon system effectiveness. Although the human member of the airborne system has not made at all comparable performance advances, he is increasingly used in a Superman role, required to integrate and monitor most of the subsystem, and thereby to compensate for the shortcomings and discrepancies of the total weapon system. Last but not least the primary job is to perform a mission in hostile environment. Author

N84-15045# Naval Weapons Center, China Lake, Calif.
NAVY'S ADVANCED AIRCRAFT ARMAMENT SYSTEM PROGRAM CONCEPT OBJECTIVES
T. M. LEESE and J. F. HANEY *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 17 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The Advanced Aircraft Armament System (AAAS) was originally chartered to improve armament equipment performance, support, and interoperability. Because of funding constraints the AAAS Program was increasingly directed to development of air armament interface standards and technology, while advanced concept development of suspension release and stores management equipment was de-emphasized. The current program concentrates on supporting the Joint Navy/Air Force Aircraft Armament Interface Program whose task is development of MIL-STD-1760 (Aircraft Electrical Interconnection System) and associated guidelines for successful application. Since the advanced concepts which were to be originally developed are a more appropriate subject, the context of the discussion is the program prior to the redirection. The Fleet needs and deficiencies which provided the requirements for the concept effort are briefly outlined, the objectives and goals are detailed, and the approach to achieve mission flexibility and performance improvements at reduced ownership costs is discussed. A key aspect of the approach is development of generic designs which capitalize on cost and growth advantages of standards while allowing incorporation of advancing technology. Author

N84-15046# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
CONNECTING AIRCRAFT AND EXTERNAL LOADS [LIASONS AVION-CHARGES EXTREMES]
C. CONNAN and M. SALUAN *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 13 p (SEE N84-15034 06-01) Oct. 1983 In FRENCH
Avail: NTIS HC A21/MF A01

The evolution and complexity of so-called simple external loads (bombs) and the more important number of parameters demanded by complex loads (missiles, especially nacelles) makes the digitization of most material indispensable. The only other information left to connect is that pertaining to safety and large bandpass information. This information can be communicated as a function of the aircraft loads. For safety purposes, information authorizing the firing of weapons is not entirely digitized and is electrically segregated from other signals. The stanag 3837 project proposes a standardization of the electrical connections of external loads; however, it imposes the type of digital connection of the aircraft which is not necessary for interoperability: all securities are processed by doubling the numerical connection without any special connection. Architecture in existing aircraft or aircraft being developed or to be developed is discussed. Transl. by A.R.H.

N84-15047# Northrop Corp., Hawthorne, Calif. Aircraft Div.
TOWARDS THE FUNCTIONAL PARTITIONING OF HIGHLY INTEGRATED, FAULT TOLERANT AVIONICS SIGNAL PROCESSORS
J. A. REY *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 12 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

Avionics systems for new interdiction fighter aircraft require a high degree of integration, translated into automation for crew operations, of such formerly diverse subsystems of penetration, target acquisition, weapon delivery, threat detection and suppression and flight/propulsion control. Also coupled into this is the infusion of VHSIC/VSLIC. All this implies the need for a fault tolerant system to ensure flight safety and high operational ability. Some of the partitioning (configuration) issues involved in the integration process are discussed. Specifically, the issues involved with the functional partitioning into "generic" high speed signal processors and how this partitioning will cross some of the traditional interfaces between such things as flight control systems and avionics systems and subsystems within the avionic suite are addressed. Of special interest is the partitioning for sensor blending/data fusion/hi-speed data buses as pertains to terrain following/terrain avoidance function and how the critical path computations are made fault tolerant and/or allow for graceful degradation so that flight/mission safety is assured. Also discussed are the methods for computing reliability values based on these new configurations so that fault tolerant evaluations methods, such as the Markov process, may more realistically be computed.
Author

N84-15048# McDonnell Aircraft Co., St. Louis, Mo.
ADVANCED F/A-18 AVIONICS
R. C. DRUMMOND and J. L. LOOPER *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 13 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The F/A-18 Hornet is a single seat, twin engine aircraft designed to fulfill fighter and light attack roles for the United States Navy and Marine Corps, and is being purchased by Canada, Australia and Spain. It has a very capable multimission weapon system, integrated so a single pilot can perform both fighter and attack missions. The challenge of multimission capability is to provide the necessary weapon system elements for effective air-to-air and air-to-surface weapons delivery without requiring a major flight line change each time the aircraft is reconfigured with armament. The answers for the multimission Hornet are digital technology and extensive system integration. High reliability, large scale integrated circuits and microprocessors are employed throughout the digital avionics suite. Integration among avionic subsystems is accomplished over the MIL-STD-1553A dual digital multiplex bus under control of two mission computers. The Hornet has significant growth potential in addition to its present capabilities. Growth capacity includes spare computer memory, electrical power, cooling air and physical space.
Author

N84-15049# Royal Aircraft Establishment, Farnborough (England).
DEF STAN 00-18: A FAMILY OF COMPATIBLE DIGITAL INTERFACE STANDARDS
D. R. BRACKNELL and A. A. CALLAWAY *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 5 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

Four data transmission standards published as parts of DEF STAN 00-18 are described. They constitute a compatible family of standards for avionic data transmission to meet the majority of current system requirements, and serve to focus both component and system development resources within the UK, to the benefit of both MOD and Industry. The guide to the use of the standards, future plans, and new options for standarization are discussed.
M.G.

N84-15050# British Aerospace Aircraft Group, Brough (England). Avionics Development Engineering Dept.
TECHNIQUES FOR INTERBUS COMMUNICATION IN A MULTIBUS AVIONIC SYSTEM
W. H. HALL *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

While studying the design of total aircraft systems using MIL-STD-1533 Data Buses the need for interbus communication protocols in multibus architectures was established. Two types of interbus communication were identified as necessary; cyclic message transfer and acryclic message transfers. Cyclic messages are handled by assigning specific subaddresses in the bus controller remote terminals which receive and pass on these messages to the appropriate destination on a cyclic basis as preprogrammed in the relevant bus controllers. Acyclic messages are handled by a special protocol based on the use of the service request bit in the status word, the transmit vector word mode code, a specially formulated vector word, special data words which are used as interbus transmit and interbus receive command words, together with the use of reserved subaddresses, one for each bus on the network. This protocol is explained in detail together with the measures taken in the subsystem to remote terminal interface to ensure orderly transmission of data and effective error recovery with lost or corrupt messages.
Author

N84-15051# General Dynamics Corp., Fort Worth, Tex.
A VIDEO BUS FOR WEAPON SYSTEM INTEGRATION
P. L. CURRIER and W. E. MILES *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 9 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

Military standard 1760, which defines the mechanical and electrical characteristics of the connector interface for new weapons, is described. As a joint Air Force/Navy standard, all new weapons will be required to be designed such that all command, control, and communication with those stores will occur through these pre-defined connector pins. Once an aircraft is built to meet the connector requirements, then any new weapon can be added by only changing the weapon delivery software. The problems an airframe manufacturer faces in adopting the standard are highlighted and the solution of one of these problems, viz, the video requirements of the standard, is examined.
M.G.

N84-15052# Air Force Avionics Lab., Wright-Patterson AFB, Ohio.
NETWORK COMMUNICATIONS FOR A DISTRIBUTED AVIONICS SYSTEM
J. C. OSTGAARD and D. A. ZANN *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct 1983 refs
Avail: NTIS HC A21/MF A01

Due to the postulated 1990's threat environment advanced avionics architectures are experiencing demands for increased performance which have led, in part, to increased processing requirements and system complexity. As more processors are added to the control environment of sophisticated military aircraft, the choice of processor interconnection topology and methodology assumes greater importance. This choice profoundly influences information throughput, reliability, survivability and integrity throughout the weapon system. The ability to rapidly exchange/transfer information among processors and devices is critical if one is to develop a reliable, effective, communication system. Basic communication techniques which could serve as candidates in satisfying the network communication requirements of an advanced avionics architecture are addressed. Features of each technique are examined to ascertain the performance of these multi-access protocols in terms of developed system-driven criteria.
Author

N84-15053# McDonnell Aircraft Co., St. Louis, Mo.
AVIONICS FAULT TREE ANALYZER
M. E. HARRIS *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 15 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

McDonnell Douglas' F/A-18 aircraft allows use of a man-portable, microprocessor controlled, ground based test set to isolate avionic failures to the electronic card or shop replaceable assembly (SRA). Through a single existing connector on the aircraft, this Avionics Fault Tree Analyzer (AFTA) communicates, exercises, interrogates, and diagnoses the avionic subsystems. There are many instances when the AFTA not only isolates faults in the electronics but also in the aircraft wiring. Largely due to the truly distributive processing architecture of the aircraft and the modular design of the avionics, fault detection and isolation well beyond the weapon replaceable assembly (WRA) is achieved within milliseconds. Avionics as sophisticated as the flight control system, RADAR, and the stores management system are supported quickly and efficiently with electronics card replacement without intermediate level ground support facilities. The AFTA is currently a ground based device; however, the AFTA function will be incorporated in future aircraft. M.G.

N84-15054# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
FIRST LEVEL INTEGRATED MAINTENANCE IN WEAPONS SYSTEMS [MAINTENANCE PREMIER ECHELON INTEGREE DANS LES SYSTEMES D'ARMES]
M. E. L. COURTOIS *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct. 1983 In FRENCH
Avail: NTIS HC A21/MF A01

The localization of replaceable entities in breakdown and the validation of functional chains are the two objectives of first level integrated maintenance that must be performed using only devices onboard modern combat aircraft. Integrated maintenance in a weapon system meets these imperatives by profiting from the technical evaluation of the equipment, the architecture of the weapon system, and the digital bus for the exchange of multiplexed information such as that used on the mirage 2000 aircraft. The principles of integrated maintenance, both on the ground and in-flight, are discussed. Transl. by A.R.H.

N84-15055# Concordia Univ., Montreal (Quebec).
COMPUTER GRAPHICS TECHNIQUES FOR AIRCRAFT EMC ANALYSIS AND DESIGN
S. J. KUBINA (Defence Research Estab.) and P. BHARTIA *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 9 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

A comprehensive computer-aided system for the prediction of the potential interaction between avionics systems, with special emphasis on antenna-to-antenna coupling, is described. The methodology is applicable throughout the life cycle of an avionic/weapon system, including system upgrades and retrofits. As soon as aircraft geometry and preliminary systems information becomes available, the computer codes can be used to selectively display proposed antenna locations, emitter/receptor response characteristics, electromagnetic interference (EMI) margins and the actual ray-optical paths of maximum antenna-antenna coupling for each potential interacting antenna set. Antennas can be interactively relocated by track-ball (or joystick) and the analysis repeated at will for optimization or installation design study purposes. The codes can significantly simplify the task of the designer/analyst in effectively identifying critical interactions among an overwhelming large set of potential ones. In addition, it is an excellent design, development and analysis tool which simultaneously identifies both numerically and pictorially the EMI interdependencies among subsystems. M.G.

N84-15056# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany). Avionics Dept.
THE LOCK-ON-BEFORE-LAUNCH WEAPON DELIVERY AND DISPLAY/CONTROL CONSIDERATION
K. BOECKING *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 15 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

Investigations to provide basic test data to assess different methods of target acquisition and missile seeker aiming and lock-on are described. In addition, the pilot workload with different controls and displays was assessed and methods of reduction derived. Further different weapon information and weapon-video-display-systems and their advantages and disadvantages were investigated. The accuracy and speed of weapon aiming were especially evaluated. M.G.

N84-15057# British Aerospace Public Ltd. Co., Preston (England).
CASCADE: A DESIGN ENVIRONMENT FOR FUTURE AVIONIC SYSTEMS
A. O. WARD *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 18 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

The design and development environment for software has grown from the basic needs of assembler to the wider requirements of higher order languages. The use of the latter has also witnessed a growing, but disparate, use of tools associated with the design process. Language standardization has presented the opportunity to produce powerful software development environments. Integrity and cost requirements will dictate the introduction of formal verification techniques to all levels of design and implementation. The use of VLSI/VHSIC technology and beyond will allow the designer to specify components and hence the design environment should be integrated with relevant CAD tools. These prospects are discussed and illustrated using a model of a Comprehensive Avionic System Computing Analysis and Design Environment, (CASCADE). Those features of CASCADE which exist today are described and its progress is charted in the medium and long term. Author

N84-15058# British Aerospace Public Ltd. Co., Preston (England). Aircraft Group.
A PRACTICAL APPROACH TO THE DESIGN OF A NEW AVIONIC SYSTEM
P. A. DUKE *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 11 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

A program to design, construct and demonstrate an advanced avionic system for the next generation of tactical combat aircraft is described. The program has the prime objective of reducing the development risks associated with the rapid advance of technology. A number of factors contribute to this risk, notably the dramatic increase in system capability made possible by the general availability of LSI and VLSI circuitry. Traditionally independent systems can be linked using a data bus to provide a fully integrated system with the pilots needs foremost in mind. The system is based on a multi bus architecture recognizing the differing integrity requirements of different parts of the system. The avionic systems are linked to an advanced cockpit, with the objective of reducing pilot workload. The cockpit makes use of multi-purpose displays and an integrated approach to system control. A display of the out of cockpit scene is provided to allow the 'pilot' to operate the controls in a realistic manner and so provide representative input to the avionic system. The development is based on an evolutionary approach through a series of readily identifiable intermediate stages. Configuration control, procurement and management techniques are being developed in parallel with the avionic system itself. M.G.

N84-15059# General Dynamics Corp., Fort Worth, Tex.
INTEGRATION OF ICNIA INTO ADVANCED HIGH PERFORMANCE FIGHTER AIRCRAFT
E. R. CONRAD *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 8 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The incorporation of an integrated communications, navigation and identification avionics (ICNIA) system into modern high performance fighter aircraft is examined. To illustrate ICNIA interface with aircraft two types of avionics suites are considered. The first is an aircraft without an avionics multiplex interface, representing the older aircraft in service today. The second is an aircraft avionics suite with a dual multiplex bus interface such as is being designed today. M.G.

N84-15060# Operational Research and Analysis Establishment, Ottawa (Ontario). Directorate of Air Operational Research.
COMPUTER AIDED CONSTRUCTION OF GROUND ATTACK MISSION PROFILES OVER EUROPEAN TERRAIN
D. W. MASON *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 13 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

The optimization of an air-to-ground weapon inventory must investigate the trade-off between the effectiveness of the weapons and the vulnerability of the delivery aircraft to opposing ground defences while flying the mission profile required by the weapon. A computerized technique for constructing air-to-ground mission profiles in relation to actual terrain is described. The aim was to develop a profile construction system that permits the user to accurately but concisely direct the construction process. The technique relies on computer graphics to assist the user in creating realistic attack profiles. The system employs a data base of digitized central European terrain to produce perspective terrain image snapshots at key positions in the profile. Post analysis of the exposure history of a given profile will allow a reasonable assessment of the comparative survivability of an aircraft having to deliver weapon type A versus its survivability when delivering weapon type B. Although designed for use in weapon mix determinations for the Canadian Forces, this analysis tool may have useful applications in both aircraft design and air-to-ground weapon design for low level ground attack missions. M.G.

N84-15061# General Dynamics Corp., Fort Worth, Tex.
COLOR DISPLAY TECHNOLOGY IN ADVANCED FIGHTER COCKPITS
K. E. GROSGEBAUER, W. J. WILDMAN, and J. A. DAVIS *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 8 p (SEE N84-15034 06-01) Oct 1983 refs
Avail: NTIS HC A21/MF A01

Over the past four years, the use of color-display technology in military aircraft has received a significant amount of attention; to date, the question of how to use color effectively has not been answered. With high-quality color cathode ray tubes (CRTs) now being manufactured in the United States, Japan, France, and England, additional questions concerning the display performance requirements need to be answered prior to their introduction into the fighter cockpit. Weapon systems of today and those planned for the near term demand more effort from the pilot. A judicious application of color displays is considered to be one of the perequisites to overcome this additional workload. The selection process being applied to available color display technology, the flight simulator evaluations and some of the uses of color displays are discussed. As a result of simulator evaluations, future work will be directed toward optimizing color CRT technology and the use of color displays in the cockpit of advanced fighter/attack aircraft. Author

N84-15062# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Sistemi Avionici ed Equipaggiamenti.
CRITICAL FACTORS AND OPERATIONAL RESEARCH IN TACTICAL FIGHTER AVIONIC SYSTEM DEVELOPMENT
L. BERADI *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 13 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

The problem to design and to develop a complex system as a multiobjective optimization problem is considered. The avionic system of a tactical fighter is illustrated; assumptions and objectives of the project are listed. An approach to the problem that uses operations research tool and techniques, multiobjectives and marginal substitution rate functions is described. The method applied to the design and development of a tactical fighter avionic system is outlined. The expected characteristics, and the impact of implanned events on the system development are pointed out. Possible critical factors in the development process are emphasized by computation of the Marginal Substitution Rates. The operational mission software development for the avionic system is shown with attention to critical factors individuation. E.A.K.

N84-15063# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
AFTI/F-16: AN INTEGRATED SYSTEM APPROACH TO COMBAT AUTOMATION
F. R. SWORTZEL and W. S. BENNETT, II (General Dynamics) *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 15 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The Advanced Fighter Technology Integration, AFTI/F-16 Program which was developed and flight validating advanced technologies which improve fighter lethality and survivability is discussed. The capability is achieved by the integration of mission task tailored, digital flight controls with a director type fire control system and advanced target sensor/trackers into an automated maneuvering attack system. The core technology in the AFTI/F-16 approach to this integrated system capability is the digital flight control system (DFCS). Integrated with the onboard avionics system, the DFCS provides capabilities for maximum exploitation of flight/fire/weapon control and other subsystem integration. Task automation as applied to the fighter mission is evaluated with AFTI/F-16's automated maneuvering attack system (AMAS). Radar and FLIR/Laser sensor/trackers provide precise targeting information in AMAS for both air to air and air to surface attack. The pilot/vehicle interface through multifunction displays, wide field of view HUD, predictive HUD symbology and hands on controllers are considered. Voice command is anticipated to be a key interface feature. The AMAS is expected to allow accurate weapon delivery from low altitudes (below 100m) while achieving increased survivability through maneuverability, the low altitude environment and standoff delivery. E.A.K.

N84-15064# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
CONCEPT OF A FIGHTER AIRCRAFT WEAPON DELIVERY SYSTEM
R. L. RODE *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 7 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

Modern fighter aircraft which carry besides various types of bombs more and more intelligent weapons, are discussed. The development of a stores and missile management system must consider the requirement from the operational/tactical considerations and the optimal usage of advanced electronic equipment together with a growth and adaption capability in both areas. On the basis of existing weapon delivery systems some possible trends in weapon development and weapon control systems develcpment are discussed. The integration problems of a complete aircraft weapon delivery system from the planning stage via equipment and subsystem development to rig and on aircraft testing up to first flight test experiences are also outlined. E.A.K.

N84-15065# Elektronik-System G.m.b.H., Munich (West Germany).
CADAS: A COMPUTER AIDED DESIGN TOOL FOR AVIONIC SYSTEMS
M. BURFORD, R. COPE, and H. SCHNEEWE'SS *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

The development of CADAS - a computer aided design tool for avionic systems is outlined. Prior to outlining the basic concepts behind CADAS, an overview of present methods for validating software is presented. These concepts illustrate how certain key elements, such as the events language, the automatic generation and inclusion of models etc. were implemented. The objectives still to be achieved are presented. The need of such a general tool as a basic component of the programming support environment for embedded software is presented. E.A.K.

N84-15066# Boeing Military Airplane Development, Wichita, Kans.
DESIGN AND VERIFICATION OF ELECTROMAGNETIC COMPATIBILITY IN AIRBORNE WEAPONS SYSTEMS
W. R. JOHNSON *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 6 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

To achieve electromagnetic compatibility (EMC) among the electric, electronic and electromechanical systems in a complex airborne weapons system, the coordination of many engineering disciplines is required from concept to delivery. Often the primary objectives of structural, mechanical and electrical design are in direct conflict with good EMC practices. Interaction of the EMC organization requires a flexible management structure with hard line reporting within the EMC organization and soft line ties to the supported organizations. The major milestones required to achieve an electromagnetically compatible system are: (1) planning for EMC control; (2) analysis to highlight potential problem areas; (3) engineering evaluation tests to prove design concepts; (4) qualification testing of subsystems/equipments; (5) safety of flight testing on airplane to assure flight safety; and (6) system level EMC testing where safety margin demonstrations may be required. The steps required to accomplish the milestones and to assure that the weapon system will have a high probability of passing the final system level electromagnetic compatibility demonstration are discussed. E.A.K.

N84-15067*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
DESIGN, DEVELOPMENT AND FLIGHT TEST OF A DEMONSTRATION ADVANCED AVIONICS SYSTEM
D. G. DENERY, G. P. CALLAS, G. H. HARDY, and W. NEDELL *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01 CSCL 01D

The design of integrated avionics suitable for general aviation was examined. The program emphasizes the use of data busing, distributed microprocessors, shared electronic displays and data entry devices, and improved functional capability. Design considerations includes cost, reliability, maintainability, and modularity. A demonstration advanced avionics system (DAAS) was designed, built, and flight tested in a Cessna 402, twin engine, general aviation aircraft. The DAAS, and the system architecture are described. E.A.K.

N84-15068# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
METHODS FOR DEVELOPING THE NAVIGATION AND WEAPON SYSTEMS OF THE MIRAGE 2000 [METHODES DE DEVELOPPEMENT DU SYSTEME DE NAVIGATION ET D'ARMEMENT DU MIRAGE 2000]
D. BONCORPS *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct. 1983 In FRENCH
Avail: NTIS HC A21/MF A01

The definition, completion, and mass production of a weapon system as complex as that of the Mirage 2000 aircraft poses numerous problems that are solved by direct collaboration among the French Official Service, the industry, and the user (French Air Force). This collaboration was concretized by the establishment of an industrial coordination body that is charged by Technical Services with establishing work dossiers which are then examined at different levels by all the interested parties. The association of recent work methods with sophisticated methods of development permits the definition of a complex system that conforms with the demands of users, with the least delay and at minimum cost. A.R.H.

N84-15069# Naval Air Development Center, Warminster, Pa.
CREW STATION EVALUATION IN A DYNAMIC FLIGHT SIMULATION FACILITY
J. EYTH, JR. *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 10 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The unique capabilities and design of the dynamic flight simulator and crew station evaluation facility as they pertain to avionics systems development and validation are described. This capability for preflight man in the loop evaluation of aircraft systems/subsystems during early phases of development diminishes the problems surfacing during flight tests and will ultimately reduce the cost and time required for operational deployment. E.A.K.

N84-15070# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany) Military Aircraft Div.
CONCEPTS FOR AVIONIC AND WEAPON INTEGRATION FACILITIES
F. KAESTNER *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 8 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The Tornado avionic and weapon integration facility is presented. The increased test capabilities are pointed out. Requirements for future integration concepts and the according ground test facilities are given. E.A.K.

N84-15071# British Aerospace Public Ltd. Co., Preston (England).
HARDWARE-IN-THE-LOOP SIMULATION TECHNIQUES USED IN THE DEVELOPMENT OF THE SEA HARRIER AVIONIC SYSTEM
M. MANSELL, W. J. QUINN, and C. J. SMITH *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 17 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The use of simulation utilizing airborne hardware in the loop during the development of avionic systems is described. Each new weapon system, however, produces a different set of problems that usually requires a change of technique to satisfy the test requirements for the system. The Sea Harrier avionic system and the techniques used by British Aerospace in the development of this system are described. The special to type interfaces required to drive the forward looking radar, navigation system automatic flight control and HUD/weapon aiming computer are described. E.A.K.

N84-15072# Northrop Corp., Hawthorne, Calif. Aircraft Div.
SIMULATION REQUIREMENTS TO SUPPORT THE DEVELOPMENT OF A FAULT TOLERANT AVIONIC SYSTEM
J. SHAW *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 11 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

The simulation package which was designed to support the development of fault tolerant avionic systems is presented. The Executive Support System, ESS, package which is presently used as a development, test and verification tool for F-5G and F-18L avionics models is described. The ESS provides an avionics system designer with a mechanism for developing and testing several avionic core configurations and develop avionic simulation and application modules. E.A.K.

N84-15073# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Aircraft Div.
SOFTWARE TESTING OF SAFETY CRITICAL SYSTEMS
J. STOCKER *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 9 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

Safety critical systems must be thoroughly tested. Powerful test facilities and test concepts are very important. The methods used for testing the software of the Tornado Autopilot and flight director system (AFDS) are outlined and existing test systems are reviewed followed by a presentation of a new test facility i.e., the AFDS Cross Software Test System (AFDS-CSTS). E.A.K.

N84-15074# Dowty Electronics Ltd., London (England).
AUTOMATING THE TESTING OF SOFTWARE
N. J. B. YOUNG *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 13 p (SEE N84-15034 06-01) Oct. 1983 refs
Avail: NTIS HC A21/MF A01

Continuing growth in the number of high integrity software based systems which cause a corresponding growth in the problems of software validation are discussed. A variety of validation techniques were examined but the problem of how to apply these in a practically useful, cost efficient, automated form is not resolved. Some available techniques against a concept of automatability are outlined and directions in which they can be improved for usefulness rather than for academic interest are identified. The symbolic execution techniques is presented. It is found that a reduction in routine testing costs by a factor of two to three, and other benefits, can be achieved in many cases. E.A.K.

N84-15075# British Aerospace Public Ltd. Co., Preston (England). Aircraft Group.
A DYNAMIC APPROACH TO MILITARY AVIONICS SYSTEMS TESTING
R. A. C. SMITH *In* AGARD Advanced Concepts for Avionics/Weapon System Design, Develop. and Integration 9 p (SEE N84-15034 06-01) Oct. 1983
Avail: NTIS HC A21/MF A01

Avionic systems development testing is outlined. The preflight ground test philosophy is based on the construction of an avionics systems development rig. The rig testing techniques were changed as the avionics systems increased in complexity and influence throughout the aircraft. The techniques presently employed are made possible due to two main factors: (1) the adoption of an integrated approach towards the use of and interaction between the avionics rig and other development facilities; (2) an increase in the use of computing for the data acquisition and simulation tasks. This has resulted in a shift in emphasis from static to dynamic system testing and the avionics development rig for the Tornado F Mk 2 is capable of simulating flight. It is possible to exercise the avionics systems throughout the aircraft mission envelope on the rig before flight testing begins. The dynamic testing technique and its advantages form the basis for the Torndao F Mk 2 avionics rig facility and its operation. E.A.K.

N84-15076# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
FLIGHT MECHANICS AND SYSTEM DESIGN LESSONS FROM OPERATIONAL EXPERIENCE
Loughton Oct. 1983 344 p refs In ENGLISH and FRENCH Symp. held in Athens, 10-13 May 1983
(AGARD-CP-347; ISBN-92-835-0342-2; AD-A137607) Avail: NTIS HC A15/MF A01

Lessons in design and safety learned from operational experience, incidents, and accidents are discussed. Flight data recording systems, adverse flight conditions, survivability after failure, and the man-machine interface are specifically addressed. For individual titles, see N84-15077 through N84-15102.

N84-15077# Army Safety Center, Fort Rucker, Ala.
INVESTIGATION, REPORTING AND ANALYSIS OF US ARMY AIRCRAFT ACCIDENT
M. J. REEDER, G. D. LINDSEY, and D. S. RICKETSON, JR. *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 6 p (SEE N84-15076 06-01) Oct. 1983
Avail: NTIS HC A15/MF A01

Each year aircraft accidents result in large losses of US Army equipment and personnel resources. These losses are described in terms of aircraft and cause factors involved. Also presented is the system-oriented approach used in the investigation, reporting and analysis of these accidents. The results include identification of lessons learned with respect to cost, type aircraft, flight tasks, cause factors and system inadequacies which produced the cause factors. Author

N84-15078# National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.
THE USE OF FLIGHT RECORDERS IN THE INVESTIGATION OF AIRCRAFT MISHAPS
B. CAIGER *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 9 p (SEE N84-15076 06-01) Oct. 1983
Avail: NTIS HC A15/MF A01

Some problems encountered in the recovery of information from flight recorders for the investigation of aircraft mishaps are described. Techniques for rapid dissemination of the information to investigators are illustrated. Future developments in the design of voice and data recorders are discussed. Author

N84-15079# Civil Aviation Authority, Redhill (England). Airworthiness Div.
THE CIVIL AIRCRAFT AIRWORTHINESS DATA RECORDING PROGRAMME
H. D. RUBEN *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 18 p (SEE N84-15076 06-01) Oct. 1983
Avail: NTIS HC A15/MF A01

The idea of operational flight data recording started with the continuous recording of just two parameters velocity V and normal acceleration. The value of information gained from these simple recorders encouraged improved recorders and their development is traced up to the high capacity digital recorders available today. The data recording program operated jointly by the CAA and the participating airlines has grown considerably over the 20 years of its existence. Its present organization and activities are described, and a number of examples of the analyses performed on the data are given to illustrate the wide range of areas in which the data is useful. Author

N84-15080# Flight Safety Foundation, Inc., Arlington, Va.
TWO DECADES OF AIR CARRIER JET OPERATION
E. C. WOOD and G. P. BATES *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 7 p (SEE N84-15076 06-01) Oct. 1983 refs
Avail: NTIS HC A15/MF A01

The accident record of the world fleet of air carrier jet aircraft from 1960 to 1981 is examined. Comparisons of total accidents, fatal accidents, and hull losses for this time period are reviewed against numbers of departures and hours flown. It is shown that there is a close correlation between fatal accidents and hull losses and that there has been a general stabilizing of the accident rate in the past decade of two to four accidents (hull losses) per million departures with the probability that, if no changes are introduced, this rate will remain essentially unchanged. Phases of operations where accidents have occurred are also examined, showing that over 50 percent of the fatal accidents have occurred during 14 percent of the operational exposure time spent in initial approach, final approach, and landing. Of this 50 percent, nearly 40 percent have occurred in the initial and final approach phases. The data indicate that airframe systems and powerplants, as well as maintenance air traffic control and weather factors have reached a high level of reliability and that the human factor is still the prevalent factor in the existing accident rates. Operator error has remained at over 70 percent. Since it is reasonably predictable that future accidents will occur in or near a major airport and will probably involve post crash fire, safety measures in this area are also discussed. M.G.

N84-15081*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

INCIDENT REPORTING: ITS ROLE IN AVIATION SAFETY AND THE ACQUISITION OF HUMAN ERROR DATA

W. D. REYNARD *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 8 p (SEE N84-15076 06-01) Oct. 1983

Avail: NTIS HC A15/MF A01

The rationale for aviation incident reporting systems is presented and contrasted to some of the shortcomings of accident investigation procedures. The history of the United State's Aviation Safety Reporting System (ASRS) is outlined and the program's character explained. The planning elements that resulted in the ASRS program's voluntary, confidential, and non-punitive design are discussed. Immunity, from enforcement action and misuse of the volunteered data, is explained and evaluated. Report generation techniques and the ASRS data analysis process are described; in addition, examples of the ASRS program's output and accomplishments are detailed. Finally, the value of incident reporting for the acquisition of safety information, particularly human error data, is explored. M.G.

N84-15082# Air France, Paris. Service Securite et Analyse des Vols.

THE ANALYSIS OF RECORDS OF PARAMETERS: AN INDISPENSABLE TOOL IN OVERSIGHT AND IN OPERATIONS CONTROL [L'ANALYSE DES ENREGISTREMENTS DE PARAMETRES OUTIL INDISPENSABLE A LA SURVEILLANCE ET AU CONTROLE DE L'EXPLOITATION]

J. GAUTHIER *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 7 p (SEE N84-15076 06-01) Oct. 1983 In FRENCH

Avail: NTIS HC A15/MF A01

The systematic analysis of flight by reading records of flight parameters has been practiced at Air France for nearly 10 years. The fundamental concepts of this policy are discussed as well as the means, methods, and philosophy which led to the establishment of the protocol. The rigorous application of this protocol resulted in the effective adherence and participation of the crew. Operating principles are described for the Commission of Flight Analysis, which is responsible for examining the most significant dossiers as well as for anonymous communication which is designed to gather from the crew any complementary information that is useful to the Commission. Some principle results obtained because of systematic flight analysis are included. Transl. by A.R.H.

N84-15083# Aeritalia S.p.A., Torino (Italy). Gruppo Velivoli da Combattimento.

FLIGHT PARAMETERS RECORDING FOR SAFETY MONITORING AND INVESTIGATIONS

E. BERTOLINA *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 11 p (SEE N84-15076 06-01) Oct. 1983

Avail: NTIS HC A15/MF A01

A system for monitoring aircraft structural and engine parameters is discussed. The system adopts, as basic philosophy, an on board recording facility on each individual aircraft of all relevant flight and aircraft parameters and ground equipment performing two levels of analysis: (1) trouble shooting for structure, engine and systems limits exceedances or malfunctions after each flight during the normal turn around time giving a GO/NO GO indication for the next flight, and (2) a detailed calculation of fatigue loading experienced during each flight and the consequent residual life evaluation for the critical items, thus allowing the detailed monitoring of the usage of each aircraft. M.G.

N84-15084# Army Aviation Engineering Flight Activity, Edwards AFB, Calif. Flight Test Directorate.

ROTORCRAFT ICING TECHNOLOGY: AN UPDATE

R. WARD and H. W. CHAMBERS (Army Aviation Research and Development Command, St. Louis, Mo.) *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 15 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

Inflight icing tests for rotary wing aircraft are discussed. Topics specifically addressed include: (1) flight testing of pneumatic deice boots installed on a UH-1H helicopter in artificial icing conditions behind the Canadian NRC Ottawa Spray Rig; (2) artificial and natural icing tests of the unprotected CH-47C and UH-60A helicopter rotor systems; (3) evaluation of ice shapes on a UH-1H rotor system and hover performance degradation caused by rotor icing, and (4) current and planned improvements to the US Army JCH-47C Helicopter Icing Spray System (HISS). M.G.

N84-15085# Centre d'Essais en Vol, Istres (France). Service Essais.

AIRCRAFT OPERATIONS FROM AIRFIELDS WITH SPECIAL UNCONVENTIONAL CHARACTERISTICS

G. ROBERT *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 17 p (SEE N84-15076 06-01) Oct. 1983 refs In FRENCH

Avail: NTIS HC A15/MF A01

Studies conducted by the General Directorate of Civil Aviation, assisted by the De Havilland Aircraft Company and users, resulted in the definition of procedures which assure a significant level of safety with regards to engine trouble at takeoff on the short runways used by TPP2 multimotor aircraft. Since authorization of use of these runways according to these procedures is very recent, it is premature to draw definitive conclusions on operational results. At present, the waiver granted concerns only the DHC6-300 aircraft, however, the recommendations formulated would be applicable to other types of aircraft providing complementary data is used concerning the minimal control of ground speed and performance of rolling at takeoff with engine trouble. Transl. by A.R.H.

N84-15086# Office National d'Etudes et de Recherches Aerospatiales, Paris (France). Dept. de Physique Generale.

A SYSTEMATIC CHARACTERIZATION OF THE EFFECTS OF ATMOSPHERIC ELECTRICITY ON THE OPERATIONAL CONDITIONS OF AIRCRAFT

J. TAILLET *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 14 p (SEE N84-15076 06-01) Oct. 1983 In FRENCH; ENGLISH summary Original language document was announced as A83-48180

Avail: NTIS HC A15/MF A01

The effects of lightning and atmospheric static electricity on composite structures and digital controls is discussed. Flight trials were performed with instrumented aircraft to characterize and quantify the aircraft atmospheric electricity interactions, and to develop a data base that could eventually be used to ameliorate the effects of electromagnetic pulses. Static electricity can be coupled with the airframe by solid precipitation or by passage of the aircraft near an electrically charged cloud. Parasitic radioelectric signals gather on communications and navigation antennas, and are manifested in sparks, surface streamers, and coronal discharges. Coating with antistatic compounds and metallization can prevent the buildup of static charges. Lightning, however, can set off aircraft fuel, burst the radome, or kill the engines. Protective measures which include isolating and/or hardening the circuitry, reducing the collector loops surface for magnetic flux with twisted wires, and by replacing conductor data wiring by optoelectronic devices such as optic fibers, are outlined. E.A.K.

N84-15087# Royal Aircraft Establishment, Bedford (England)

WORLDWIDE EXPERIENCE OF WIND SHEAR DURING 1981-1982

A. A. WOODFIELD and J. F. WOODS *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 32 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

Large changes of wind and downdraughts (Wind Shears) which have caused several major aircraft accidents are discussed. Wind shear data from over 9000 landings at 71 airports around the world during 1981 and 1982 were analyzed by discrete gust methods. Time histories of wind velocities and aircraft reactions are presented for 9 of the more interesting events identified. These were selected from 86 examples of large wind shears where the three components of wind velocity were calculated. An example of a severe downburst in the vicinity of a thunderstorm is presented. Statistics on the probabilities of encountering wind shears with particular patterns of headwind speed changes were calculated from the 9000 landings. Effects at different airports, height bands, shear lengths, and patterns are compared. Suggestions are made for Design Cases of shear that could be used for testing autopilots and wind shear measuring systems. Criteria for the severity of single ramp changes in headwind are presented. E.A.K.

N84-15088# Technische Univ., Brunswick (West Germany). Inst. for Flight Mechanics.

INFLUENCE OF WINDSHEAR ON FLIGHT SAFETY

G. SCHAENZER *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 19 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

Physical background characteristics of wind shear phenomena including adequate flight safety procedures to overcome the problems were analyzed. Wind shear during takeoff and landing may restrict flight safety. In some situations hazards may be caused by limited flight performance. In most cases wind shear accidents and incidents result from misunderstanding of the wind shear phenomenon by the pilot. A considerable number of wind shear accidents are interpreted wrongly as pilot error. Numerous investigations were made to solve the wind shear problem, however, failed because of failure to understand the physical phenomena. The problem is shown that some of the correct safety procedures in wind shear contradict the pilot's feeling of how to control an aircraft. E.A.K.

N84-15089# Ministry of Defence, London (England). Defence Science.

SOME COMMENTS ON THE HAZARDS ASSOCIATED WITH MANOEUVRING FLIGHT IN SEVERE TURBULENCE AT HIGH SPEED AND LOW ALTITUDE

J. BURNHAM *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 12 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

The results of calculations made following several accidents and incidents during service training are described to show risks associated with severe turbulence during high speed maneuvering flight at low altitude. It does not imply that the phenomena are necessarily the cause of any particular accident or incident. Two dangers are considered: a combination of gust and maneuver loads may be sufficiently high to cause structural failure, or that this combination may result in a stall or other departure from controlled flight from which recovery is impossible due to the proximity of the ground. High speed low level flight by military combat aircraft are examined. Such aircraft are capable of achieving and sustaining high maneuvering accelerations. This capability is used in terrain following, in maneuvering to take advantage of terrain screening. The existence of a possible problem area which appears to have received little attention in the past is indicated. E.A.K.

N84-15090# Army Research and Technology Labs., Fort Eustis, Va. Safety and Survivability Technical Area.

ARMY HELICOPTER CRASHWORTHINESS

C. H. CARPER, L. T. BURROWS, and K. F. SMITH *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 17 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

The evolution of crash survival design criteria, its influence on the formulation of a US army military standard for rotary wing aircraft crashworthiness, and its application to current and new generation army helicopters are discussed. The need for a total system's approach in design for crashworthiness and the necessity for considering crashworthiness early in the design phase of a new aviation weapon systems development effort is emphasized. The actual application of crashworthiness to army helicopters with statistics that show dramatic reductions in fatalities and injuries with implementation of a crashworthy fuel system are presented. Crash testing, human tolerance definition, improved energy absorbers, crew restraint systems, and crash impact characteristics of composite helicopter structures are discussed. Applicability of the work within Army helicopter crashworthiness to commercial/civil helicopters and the cost effectiveness of helicopter design to be more crash survivable are discussed. E.A.K.

N84-15091# Naval Air Test Center, Patuxent River, Md. Strike Aircraft Test Directorate.

THE IMPACT OF THE F/A-18 AIRCRAFT DIGITAL FLIGHT CONTROL SYSTEM AND DISPLAYS ON FLIGHT TESTING AND SAFETY

B. T. KNEELAND, W. G. MCNAMARA, and C. L. WHITE *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 14 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

The development of the digital fly by wire flight control system (FCS) in the F/A-18 aircraft is reviewed. A general description of the FCS and an overview of the significant changes that were incorporated to improve handling qualities and to correct anomalies that were discovered during the full scale development (FSD) program are presented. The interface of the FCS with the total avionics package of the F/A-18 via the 1553 multiplex bus and the impact of this interface on specific flight testing and FCS development is also highlighted. The impact of the flight control laws on high Angle of Attack (AOA) handling qualities, and the changes made is presented. The specialized displays and controls that are implemented in the F/A-18 to assist the pilot and enhance flight testing and safety are discussed. E.A.K.

N84-15092# General Dynamics Corp., Fort Worth, Tex. Flight Control Systems.

LESSONS LEARNED IN THE DEVELOPMENT OF THE F-16 FLIGHT CONTROL SYSTEM

C. S. DROSTE *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 9 p (SEE N84-15076 06-01) Oct. 1983

Avail: NTIS HC A15/MF A01

Examples of several external factors which manifested themselves in the development of the F-16 and how the F-16 flight control system evolved to minimize their effect are discussed. External factors are pilot interface, ground maintenance, structural resonance, environmental conditions, indirect electrical hazards and other system failures. One of the most significant evolutions to aid in the isolation and resolution of problems is the time sequenced data provided by the F-16 maintenance memory. E.A.K.

N84-15093# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France). Dept. Equipements Dassault.

THE MIRAGE 2000: FLY BY WIRE CONTROL AND SAFETY [MIRAGE 2000: CDVE ET SECURITE]

J. LADEL and J. BASTIDON *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 9 p (SEE N84-15076 06-01) Oct. 1983 In FRENCH

Avail: NTIS HC A15/MF A01

The Mirage 2000 aircraft was built to provide the best efficiency in combat. To this end it uses electric flight control which permits a reasonable application of the generalized automatic control of the aircraft. Research on the safe operation of the piloting system led to a level of safety that is clearly superior to that observed on any previous aircraft. These performance and safety objectives were the subjects of theoretical and practical validations both in the laboratory and in flight in order to justify an a operational use of electric flight control. Transl. by A.R.H.

N84-15094# *Messerschmitt-Boelkow-Blohm G.m.b.H., Munich* (West Germany). Aircraft Div.

TORNADO AUTOPILOT MEASURES TO ENSURE SURVIVABILITY AFTER FAILURES

W. SCHMIDT and U. BUTTER *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 8 p (SEE N84-15076 06-01) Oct. 1983

Avail: NTIS HC A15/MF A01

Measures applied to the autopilot of the TORNADO to ensure survivability of the aircraft after failures during automatic low level flying are presented. Apart from redundant equipment, these measures include hardware and software limiters to minimize the effect of failures upon the aircraft, hardware and software monitors to detect and isolate failures, emergency procedures to initiate recovery maneuvers, as well as efficient testing of software. Author

N84-15095# Marconi Avionics Ltd., Rochester (England). Combat Aircraft Controls Div.

CERTIFICATION EXPERIENCE OF THE JAGUAR FLY-BY-WIRE DEMONSTRATOR AIRCRAFT INTEGRATED FLIGHT CONTROL SYSTEM

K. S. SNELLING *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 19 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

The digital Integrated Flight Control System (IFCS) is developed for the Jaguar Fly-By-Wire (FBW) demonstrator program, identifying the specification requirements, resultant architecture, implementation and the incorporated self test capability. The redundancy management aspect of the IFCS are described together with the techniques for providing the pilot with relevant information to determine the IFCS redundancy status. Particular emphasis is given to the software definition and preparation procedures, and the comprehensive integrity appraisal leading to flight clearance of the system. Following the extensive rig proving of the system, the early phases of flight test were very successfully carried out using the fixed gain control laws. During this period a major software update was commenced to incorporate the scheduled gain control laws and to enhance the self test capability. The software segregation introduced at this stage is described, together with the experience obtained in rectifying the system. Flight testing of the scheduled control laws is continuing, and the minor problems encountered are mentioned. A further software revision to include the control laws for the statically unstable aircraft is well advanced, and the benefits of software segregation identified during this revision are described. Author

N84-15096# Centre d'Essais en Vol, Bretigny-sur-Orge (France).

THE MAN-MACHINE INTERFACE IN NEW GENERATION COMMERCIAL AIRCRAFT [L'INTERFACE HOMME - MACHINE DANS LES AVIONS COMMERCIAUX DE LA NOUVELLE GENERATION]

R. GALAN *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 11 p (SEE N84-15076 06-01) Oct. 1983 In FRENCH

Avail: NTIS HC A15/MF A01

The history of the man machine interface from the very beginning of aviation is reviewed and various trends for the last decade of this century are examined. A simple glance reveals that the style of relations between aircraft and their crews evolved in a profound way and that a spectacular leap has taken place over 80 yeas. Centralization, new generation instruments, cathode tubes, systems for flight management, display devices, and push button technology are explored. Transl. by A.R.H.

N84-15097# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Military Aircraft Div.

NEW FLIGHT DECK DESIGN IN THE LIGHT OF THE OPERATIONAL CAPABILITIES

R. SEIFERT and K. BRAUSER *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 13 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

The classification of human errors (H.E.) by category and conditions of occurence is presented. According to the conditions and causes of H.E. occurence different means of preventing H.E.'s by ergonomic design, by manning, selection and training are considered. In flight deck design, besides conventional ergonomic design, two strategies are proposed: (1) provision of sufficient feedback to allow the pilot to detect and correct unintentional performance errors before they affect system performance, and (2) introduction of "fail safe and fail ops ergonomic design" by means of H.E. detection and correction functions designed into the man-machine interface intelligence. The last generations of aircraft are compared regarding their task and system complexity. The increased complexity formed the need, and the advances in electronics provided the means for the new integrated flight deck, based on a cockpit data management system that includes "error monitoring capabilities". Finally the pilot's cockpit requirements of fire/flight control and post-stall-manoeuvring modes are discussed, requiring increased automation, information feedback loops and a "reconfiguration" of the pilot's task load. Author

N84-15098# British Aerospace Public Ltd. Co., Godalming (England).

MODERN FLIGHT INSTRUMENT DISPLAYS AS A MAJOR MILITARY AVIATION FLIGHT SAFETY WEAKNESS

J. F. FARLEY *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 3 p (SEE N84-15076 06-01) Oct. 1983

Avail: NTIS HC A15/MF A01

Consideration of the major causes of flying accidents over which the airframe and engine manufacturers can exert a powerful influence shows the following list: structural failure, engine failure, flying control failure, instrument failure, and pilot error. With the first three of these causes, Structural, Engine and Flying Control failures, while mistakes do occur, the manufacturers have a reasonable record, there is no evidence of complacency, and in addition there is a large well established, government controlled, national bureaucracy offering valuable checks and advice on testing and airworthiness certification. Pilot error in different, but appropriate ways, also attracts much effort aimed at its reduction. Most importantly, so far as the purposes of this paper are concerned, the accident trends related to the first three causes, as well as those due to pilot error, do not appear to have changed fundamentally during the last decade. The same cannot be said of instrument display related accidents. Since the advent of Head Up and computed displays in general, and the operator's real need to expand the non-visual maneuver envelope, there has been a marked increase in display related accidents/incidents in both operational and development flying. This note suggests that attempts at curing the problem have been based on a false assumption that has ignored the reality of the piloting task in modern high performance jet aircraft. Proposals are offered to improve the situation by both engineering and organizational changes. Author

N84-15099# Vliegbasis Volkel (Netherlands).

PHYSIOLOGICAL AND PSYCHOLOGICAL ASPECTS OF THE PILOTING OF MODERN HIGH-PERFORMANCE COMBAT AIRCRAFT

J. C. F. AGHINA *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 3 p (SEE N84-15076 06-01) Oct. 1983

Avail: NTIS HC A15/MF A01

Since 1978 the Royal Netherlands Air Force has gained a lot of experience in handling a totally new aircraft, the F-16, which differs in many aspects from its predecessors. Not only the pilots, but the technicians too, had to adapt themselves to the new aircraft and they learned how to handle entirely new systems. The F-16 is a modern high performance fighter, like the F-4 and the F-15, and has caused problems for the pilots in comparison with former types, the F-104 and the NF-5. The extreme mobility of the aircraft produces not only a high gravity factor as such, but also a rapid G onset rate, by which a number of gravity depending physiological problems have arisen in a very obvious way. Furthermore, as a result of many technological innovations applied, i.e., aircraft's electronics, the pilot's task has also changed considerably, in particular with respect to the amount of information to be processed. The question arises of whether new approaches should be introduced into the selection, the physiological standards, the training, the supervision and the coaching of the operational pilots. Author

N84-15100# Royal Aircraft Establishment, Farnborough (England).

INCREASED AIRCRAFT SURVIVABILITY USING DIRECT VOICE INPUT

R. G. WHITE and P. BECKETT (British Aerospace PLC) *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 13 p (SEE N84-15076 06-01) Oct. 1983 refs

Avail: NTIS HC A15/MF A01

Direct Voice Input, a conventional keyboard and a touch-sensing display were compared as methods of en-route data entry during a simulated ground attack sortie. It was shown that when using Direct Voice Input the pilot looked inside the cockpit less frequently and for shorter periods and, when flying at very low level, was able to control height more accurately then when using either of the tactile systems. Contrary to expectation, the total entry times for a sequence of data and the times between entry of individual instructions and digits were long using Direct Voice Input than

with either the keyboard or the touch-sensing display. This was attributed to the characteristics and performance of the isolated word recognizer used in the DVI system. A further simulator trial is planned, which will use a connected speech recognizer with a higher recognition performance. Author

N84-15101# Airbus Industrie, Blagnac (France). Flight Div.
CERTIFICATION EXPERIENCE WITH METHODS FOR MINIMUM CREW DEMONSTRATION
J. J. SPEYER and A. FORT *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 31 p (SEE N84-15076 06-01) Oct. 1983 refs
Avail: NTIS HC A15/MF A01

AIRBUS INDUSTRIE's human factors involvement in flight test and certification with the double objective of checking functional effectiveness of the man-machine system and human welfare in its utilization process is discussed. The crew complement question prompted the consideration of workload for which Airworthiness Regulations provide a set of design-related, operational and human factors parameters. The rule on Minimum Flight Crew, FAA's FAR 25. 1523 and its Appendix D became effective in 1965 after an industry-wide consultation that included flight deck unions. This effectively coincided with the advent of the first two man crew commercial jet aircraft. The regulation called for an analysis and evaluation of the workload imposed upon the crewmembers of a particular type of aircraft by its cockpit environment. This concern for workload stems from theory and experience that beyond some unacceptable threshold of workload a pilot's or a crew's performance will be degraded to unsafe levels and that the ability to cope with unexpected emergencies may be seriously impaired without the assistance of an extra crewmember. With the advent of today's new technology aircraft the crew complement question stirred such a controversy among US and European pilot unions tha the President of the United States himself set up a Task Force on aircraft crew complement. Author

N84-15102*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
PILOT HUMAN FACTORS IN STALL/SPIN ACCIDENTS OF SUPERSONIC FIGHTER AIRCRAFT
S. B. ANDERSON, E. K. ENEVOLDSON (NASA Dryden Flight Research Facility), and L. T. NGUYEN (NASA Langley Research Center) *In* AGARD Flight Mech. and System Design Lessons from Operational Experience 10 p (SEE N84-15076 06-01) Oct. 1983 refs Document previously announced as N83-26856
Avail: NTIS HC A15/MF A01

A study has been made of pilot human factors related to stall/spin accidents of supersonic fighter aircraft. The military specifications for flight at high angles of attack are examined. Several pilot human factors problems related to stall/spin are discussed. These problems include: (1) unsatisfactory nonvisual warning cues; (2) the inability of the pilot to quickly determine if the aircraft is spinning out of control, or to recognize the type of spin; (3) the inability of the pilot to decide on and implement the correct spin recovery technique; (4) the inability of the pilot to move, caused by high angular rotation; and (5) the tendency of pilots to wait too long in deciding to abandon the irrecoverable aircraft. Psycho-physiological phenomena influencin pilot's behavior in stall/spin situations include: (1) channelization of sensor inputs, (2) limitations in precisely controlling several muscular inputs, (3) inaccurate judgment of elapsed time, and (4) disorientation of vestibulo-ocular inputs. Results are given of pilot responses to all these problems in the F14A, F16/AB, and F/A-18A aircraft. The use of departure spin resistance and automatic spin prevention systems incorporated on recent supersonic fighters are discussed. These systems should help to improve the stall/spin accident record with some compromise in maneuverability. Author

N84-23564# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
WIND TUNNELS AND TESTING TECHNIQUES
Loughton, England Feb. 1984 514 p refs In ENGLISH and FRENCH Symp. held at Cesme, Turkey, 26-29 Sep. 1983 (AGARD-CP-348; ISBN-92-835-0348-1; AD-A143674) Avail NTIS HC A22/MF A01

The design and operation of cryogenic wind tunnels and transonic facilities are discussed as well as associated fluid motion problems. Testing techniques are considered with emphasis on support interference, inlet/engine/ afterbodies, store separation, half models, aeroacoustic measurements, and wind tunnel-flight data comparisons. For individual titles, see N84-23565 through N84-23601.

N84-23565*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
OPERATIONAL EXPERIENCE WITH THE NATIONAL TRANSONIC FACILITY
L. W. MCKINNEY *In* AGARD Wind Tunnels and Testing Tech. 8 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01 CSCL 01B

Construction of the National Transonic Facility was completed in September 1982. The checkout of all systems required about one year. The facility operated to the design point of 120 million Reynolds number based on a 0.25 meter chord at a Mach number of 1.0. Performance of all systems was basically as expected. Setup for the detailed aerodynamic calibration begins late in 1983, and the calibration is expected to be complete by the last quarter of 1984. Author

N84-23566# National Aerospace Lab., Amsterdam (Netherlands).
THE EUROPEAN TRANSONIC WINDTUNNEL (ETW) Status Report
R. J. NORTH, F. MAURER, J. PRIEUR, J. A. SCHIMANSKI, and J. A. TIZARD *In* AGARD Wind Tunnels and Testing Tech. 12 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01

The status of the preliminary design phase of the European Transonic Windtunnel project is described. The latest version of the proposed tunnel is given together with some details of its estimated performance. Some features of the tunnel which were revised following the first preliminary design proposals are discussed and the results of an investigation into the expected future use of the tunnel are summarized. An aerodynamic circuit test-rig is described along with some of the results obtained. Information on the pilot tunnel is included as well as reference to the supporting program on cryogenic technology. Author

N84-23567# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Aerothermodynamique.
THE T2 CRYOGENIC WIND TUNNEL WITH SELF-ADAPTABLE WALLS AT ONERA/CERT [LA SOUFFLERIE CRYOGENIQUE A PAROIS AUTO-ADAPTABLES T2 DE LONERA/CERT]
A. MIGNOSI and J. B. DOR *In* AGARD Wind Tunnels and Testing Tech. 12 p (SEE N84-23564 14-01) Feb. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A22/MF A01

The transonic induction driven wind-tunnel T2 at the ONERA Toulouse Research Center is equipped with a 0.4 x 0.4 sq m test section, and is a pressurized closed circuit wind-tunnel, operating at ambient temperature with runs of 30 to 60 seconds. The wind-tunnel was adapted for cryogenic operation using liquid nitrogen as a coolant and an internal thermal insulation. The main characteristics of the wind-tunnel at low temperature and of the constituents used to perform airfoil tests with adaptive walls are described. The flow qualities are analyzed through an evaluation of the thermal gradients, pressure and thermal fluctuations studies, and the operating limit at very low temperature. The effects of various parameters able to influence test results are examined, such as boundary layer transition and differences between wall temperature and adiabatic wall recovery temperature. A.R.H.

N84-23568# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Porz (West Germany).
THE CRYOGENIC WIND TUNNEL COLOGNE
G. VIEHWEGER *In* AGARD Wind Tunnels and Testing Tech. 8 p (SEE N84-23564 14-01) Feb. 1984
Avail: NTIS HC A22/MF A01

The modification of a low-speed wind tunnel to cryogenic operation is discussed. The tunnel with a test section of 2.4 m x 2.4 m should be operational in the middle of 1984. The technical concept of the tunnel is examined and some of the most important components are described. Author

N84-23569# Institut Aerotechnique de Saint-Cyr, Saint-Cyr-l'Ecole (France).
PRODUCING A CRYOGENIC GUST IN AN EIFFEL TYPE ATMOSPHERIC WIND TUNNEL WITH SHORT GUST [PRODUCTION DUNE RAFALE CRYOGENIQUE DANS UNE SOUFFLERIE DE TYPE EIFFEL ATMOSPHERIQUE A RAFALE COURTE]
D. CHAUVET and C. DUJARRIC (Serice Technique des Programmes Aeronautiques, Paris) *In* AGARD Wind Tunnels and Testing Tech. 17 p (SEE N84-23564 14-01) Feb. 1984 refs In FRENCH
Avail: NTIS HC A22/MF A01

Demonstrations of the feasibility of an Eiffel-type cryogenic atmospheric wind tunnel with short gusts and of the economy of operation of such a concept requires prior resolution of certain specific technical problems found in this type wind tunnel. The technique for generating cryogenic gaseous flow by atomizing liquid nitrogen in air at the level of the plenum chamber is described as well as the chronological feeding out of a cryogenic gust. Theoretical and experimental studies are developed for optimizing the evaporation of liquid nitrogen in the plenum chamber of a wind tunnel. The results of measuring the grain size of drops of liquid nitrogen are compared with a computation model which correctly represents the real behavior of the aerosol.
Transl. by A.R.H.

N84-23570# Calspan Field Services, Inc., Arnold AFS, Tenn. Propulsion Wind Tunnel Facility.
A REVIEW AND AN UPDATE OF THE FDP SPECIALISTS MEETING (LONDON) ON WALL INTERFERENCE IN WIND TUNNELS
T. W. BINION, JR. and E. M. KRAFT *In* AGARD Wind Tunnels and Testing Tech. 12 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01

The work reported at the Fluid Dynamics Prediction London Specialists meeting on wall interference in wind tunnels is reviewed. While there are many outstanding issues still to be resolved, a final solution to the wind tunnel interference problem does appear achievable. Wall interference research has taken on renewed interest in recent years pushed by more stingent accuracy requirements for vehicle performance predictions. The reseach is directed toward increased prediction accuracy, particularly for ventilated tunnels operating at transonic conditions, development of interference assessment techniques from model and/or tunnel boundary measurement and interference avoidance via various adaptive wall schemes. In addition, since wall interference cannot be separated readily from the effects of other inherent tunnel and test properties such as wall boundary layers, noise, turbulence, model fidelity, etc., some research is being conducted to quantify the effect of other phenomena in order to verify the wall interference effects once they are identified. R.J.F.

N84-23571# Technische Univ., Berlin (West Germany). Inst. fuer Luft- und Raumfahrt.
A SHORT NOTE ON RECENT ADVANCES IN THE ADAPTIVE WALL TECHNIQUE FOR 3D-MODEL TESTS AT THE TU-BERLIN
U. GANZER *In* AGARD Wind Tunnels and Testing Tech. 2 p (SEE N84-23564 14-01) Feb. 1984 refs Sponsored in part by the German Minister of Research and Technology (BMFT) and The German Research Association (DFG)
Avail: NTIS HC A22/MF A01

In the test section with eight flexible walls the first successful wall adaptations were carried out for a lifting wing body configuration at transonic speeds. The adaptive wall technique is an iterative procedure in which the boundary conditions at the test section walls are adjusted to the conditions of an unlimited flow field. In the TU-Berlin test section eight flexible walls are individually shaped such that a (nearly) streamlined three dimensional wall configuration is formed. The starting configuration was the aerodynamically plane wall, i.e. the one which leads to constant Mach number along the empty test section (without model but with quadrant). The model in the test section creates a pressure distribution along each wall different from C sub P = 0. The wall shape can be used as a boundary condition for an external flow field calculation e.g. with a three dimensional panel method. The pressure distribution calculated this way can then be compared with the measured pressure distribution. Only if the measured and calculated pressures are the same the test section flow may be considered free of wall interference. The test results given demonstrate in principle the feasibility of the adaptive wall technique for three dimensional model tests. R.J.F.

N84-23572# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
TURBULENT DIFFUSER FLOW STUDIES RELATED TO THE DESIGN OF THE ETW DIFFUSER
H. W. STOCK *In* AGARD Wind Tunnels and Testing Tech. 9 p (SEE N84-23564 14-01) Feb. 1984 refs Sponsored in part by Technical Group ETW, Amsterdam
Avail: NTIS HC A22/MF A01

A computational method based on the boundary layer concept is used for calculating turbulent flows in diffusers with circular cross sections. That newly developed method is shown to produce reasonable agreement with a critical experiment for which existing methods fail. In a parametric study, varying Reynolds- and Mach number for different diffuser inlet conditions, turbulent flows in the diffuser are considered to describe the efficiency of the diffuser and the danger of flow separation. The Reynolds number range investigated was such, to cover flow situations from the 1:7.2 scale test diffuser under non cryogenic conditions to the full scale diffuser applying cryogenic conditions. In supplement some geometry modifications are studied to see whether the efficiency of the diffuser can possibly be augmented. Author

N84-23573# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
DISTURBANCES FROM VENTILATED TUNNEL WALLS IN AEROFOIL TESTING
M. C. P. FIRMIN and P. H. COOK *In* AGARD Wind Tunnels and Testing Tech. 15 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01

Evidence is presented which indicates that inflow through the slots of a slotted walled wind tunnel, when testing an aerofoil at conditions similar to those found in flight on wings, can penetrate into the tunnel flow to an extent which makes the determination of suitable homogeneous boundary conditions very difficult. The measurements show that the flow field generated by a lifting aerofoil causes low energy air from the plenum chamber to be drawn into the wind tunnel through the slots in the region of the upper surface of the aerofoil and that this air spreads into the working section downstream of the aerofoil. Suggestions are made for avoiding the difficulty in any future design of wind tunnel. Author

N84-23574# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
GROUND/FLIGHT TEST TECHNIQUES AND CORRELATION
P. POISSON-QUINTON *In* AGARD Wind Tunnels and Testing Tech. 14 p (SEE N84-23564 14-01) Feb. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A22/MF A01

Wind-tunnel usefulness and shortcomings during the development of a new Aircraft Project are discussed, taking into account progress on wind tunnel validity and cost/effectiveness, on the increasing role of the computer in the loop, and on the competition between computational fluid dynamics and wind-tunnel approaches for aerodynamic characteristics prediction. Lastly, the new role of the wind-tunnel in the Aircraft is advocated. R.J.F.

N84-23575*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
HIGH REYNOLDS NUMBER TESTS OF THE CAST 10-2/DOA2 TRANSONIC AIRFOIL AT AMBIENT AND CRYOGENIC TEMPERATURE CONDITIONS
E. STANEWSKY (DFVLR, Goettingen, West Germany), F. DEMURIE (DFVLR, Goettingen, West Germany), E. J. RAY, and C. B. JOHNSON *In* Agard Wind Tunnels and Testing Tech. 13 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01 CSCL 01A

The transonic airfoil CAST 10-2/DOA2 was investigated in several major transonic wind tunnels at Reynolds numbers ranging from Re = 1 million six hundred thousand to forty five million at ambient and cryogenic temperature conditions. The main objective was to study the degree and extent of the effects of Reynolds on

both the airfoil aerodynamic characteristics and the interference effects of various model-wind-tunnel systems. the initial analysis of the 10-2 airfoil results revealed appreciable real Reynolds number effects on this airfoil and, moreover, showed that wall interference, can be significantly affected by changes in Reynolds number thus appearing as true Reynolds number effects. R.J.F.

N84-23576# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Berlin (West Germany). Abteilung Turbulenzforschung.

DEFINITION, SOURCES AND LOWEST POSSIBLE LEVELS OF WIND-TUNNEL TURBULENCE

U. MICHEL and E. FROEBEL *In* AGARD Wind Tunnels and Testing Tech. 12 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

Wind tunnel turbulence is defined to include the fluctuations of all flow quantities in an empty tunnel test section. It can be separated into three modes, vorticity, entropy, and pressure. The pressure model is discussed in more detail. It is shown that contributions from the free shear layers of open test sections or the boundary layers of closed test sections are accompanied by much higher velocity fluctuations than plane sound waves. The lowest possible velocity fluctuation level in an open test section is determined by the pressure field generated by the free shear layer. The German-Dutch Wind Tunnel (DNW) is shown to reach this level. It is assumed that the lowest possible turbulence level in a closed test section is determined by the pressure field that is generated by the boundary layers in the test section. A spectral energy distribution and a Reynolds number scaling law for this contribution are derived. Author

N84-23577*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

AN EVALUATION OF FACTORS AFFECTING THE FLOW QUALITY IN WIND TUNNELS

F. K. OWEN (Complere Inc., Palo Alto, Calif.), P. C. STAINBACK, and W. D. HARVEY *In* AGARD Wind Tunnels and Testing Tech. 22 p (SEE N84-23564 14-01) Feb. 1984 refs

(Contract NAS1-16643; NAS2-10859; NAS2-11080)

Avail: NTIS HC A22/MF A01 CSCL 20D

Tests were conducted in a number of NASA wind tunnels to measure disturbance levels and spectra in their respective settling chambers, test sections, and diffusers to determine the sources of these disturbances. Results indicate that properly designed and located second minimum in transonic tunnels prevent fluctuation originating at struts and in diffusers from propagating upstream into the test section. The installation in or upstream of the settling chamber of carefully selected screens, honeycomb, and acoustic baffles could further reduce test section turbulence levels and scales without significant pressure losses. The performance of these modifications is strongly influenced by tunnel geometry and their influence on the mean flow around the circuit. Author

N84-23578# Dornier-Werke G.m.b.H., Munich (West Germany). Theoretical Aerodynamics.

PREDICTION OF CONDENSATION ONSET AND GROWTH IN THE EUROPEAN TRANSONIC WIND TUNNEL (ETW)

B. WAGNER and M. DOKER (DFVLR, Goettingen, West Germany) *In* AGARD Wind Tunnels and Testing Tech. 11 p (SEE N84-23564 14-01) Feb. 1984 refs Sponsored in part by the German Ministry of Research and Technology, and by the Technical Group ETW, Amsterdam

Avail: NTIS HC A22/MF A01

Experimental and theoretical investigations were carried out to allow reliable prediction of condensation onset and growth in cryogenic wind tunnels. The idea of streamline duplication was used in the experiments in order to simulate European Transonic Wind Tunnel (ETW) streamlines in an experimental facility of small cross section but with real ETW length scale. Classical nucleation theory was used for developing computer programs which can predict condensation processes in one dimensional flow including real gas effects. Experiments and calculations show satisfactory agreement and confirm the possibility of an operating range extension for the ETW. The results provide some new data with respect to those cases where the condensate consists of solid particles. Author

N84-23579# Douglas Aircraft Co., Inc., Long Beach, Calif. Aerodynamics Subdiv.

NONADIABATIC MODEL WALL EFFECTS ON TRANSONIC AIRFOIL PERFORMANCE IN A CRYOGENIC WIND TUNNEL

F. T. LYNCH, M. F. FANCHER, D. R. PATEL, and G. R. INGER (West Virginia Univ., Morgantown) *In* AGARD Wind Tunnels and Testing Tech. 11 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

The need to match the aircraft surface thermal conditions that exist at in-flight conditions when testing models in a cryogenic wind tunnel is addressed. Effects of non-representative heat transfer are reviewed for such basic viscous characteristics as the effect on boundary-layer transition location, the effects on turbulent boundary-layer integral parameters and skin friction, the effect on the transonic turbulent boundary-layer/shock-wave interaction, and the effects on separation onset and the extent of separated flow regions. A complementary experimental and computational investigation was conducted in order to help quantify the impact that nonadiabatic model wall conditions would have on the measured aerodynamic characteristics of transport (and other) airplane configurations tested in a cryogenic wind tunnel, and to help establish the allowable deviation from adiabatic wall conditions that can be tolerated if reliable results are to be obtained. Test results are presented which illustrate the large impact of moderate amounts of heat transfer on the lift and drag characteristics for both free-transition flow in the absence of any shock waves, and for typical cruise conditions with moderate strength shocks on the airfoil. In addition, test results are shown which illustrate a very large effect of heat transfer on buffer onset conditions and conditions near maximum lift. M.G.

N84-23580# National Aeronautical Establishment, Ottawa (Ontario).

PREDICTION OF RESONANCE FREQUENCIES FOR VENTILATED WALL WIND TUNNELS

M. MOKRY *In* AGARD Wind Tunnels and Testing Tech. 10 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

Based on the reflection and refraction of plane acoustic waves at an interface between the moving stream and the stagnant plenum air, a simple theory is developed for the prediction of transverse resonance in the two-dimensional test section with ventilated walls. The intensity and the frequency of resonance are determined from the modulus and the argument of the wall reflection coefficient respectively. In contrast to the eigenvalue method, the present technique is capable of predicting partial resonance, occurring in perforated walls and also in slotted walls at Mach numbers below 0.6.18, for which the resonant waves are partly reflected and partly transmitted at the wall. The reverse transmission of waves from the plenum into the test section is found to be inconsistent with the postulated resonance condition. M.G.

N84-23581# Lockheed Missiles and Space Co., Sunnyvale, Calif.

PRACTICAL SOLUTIONS TO SIMULATION DIFFICULTIES IN SUBSCALE WIND TUNNEL TESTS

L. E. ERICSSON and J. P. REDING *In* AGARD Wind Tunnels and Testing Tech. 12 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

Reynolds number scaling and support interference are the two main problems encountered in wind tunnel tests with subscale models. In the past, when the designer was striving to maintain attached flow over the vehicle, neither problem was very difficult to solve. The use of boundary layer trips often could solve the scaling problem and only the clumsiest of model support design would cause any interference beyond the easily corrected base drag effect. However, when the aerodynamics are dominated by separated flow effects, which often is the case for present day high performance aircraft and missiles, both problems become formidable. Practical means through which the test engineer can resolve these difficulties are described. Author

N84-23582# National Aeronautical Establishment, Ottawa (Ontario). Unsteady Aerodynamics Lab.

RECENT DEVELOPMENTS AND FUTURE DIRECTIONS IN DYNAMIC STABILITY RESEARCH AT NAE, OTTAWA

K. J. ORLIK-RUECKEMANN, E. S. HANFF, and M. E. BEYERS *In* AGARD Wind Tunnels and Testing Tech. 6 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

A review is presented of recent developments in the field of dynamic stability research in the Unsteady Aerodynamics Laboratory of the NAE. The developments include design and construction of several new oscillatory apparatuses, conceptual studies of some additional ones and thoughts about the future direction of the activities in this field. A method to account for sting oscillation effects on direct derivatives measured in a pitch oscillation experiment is briefly described, and some representative oscillatory results recently obtained on the so called Standard Dynamics Model are discussed. Author

N84-23583# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Abt. Technische Akustik.

PROPELLER AND ROTOR NOISE TESTING IN AEROACOUSTIC WIND TUNNELS

H. H. HELLER, W. R. SPLETTSTOESSER, R. F. NEUBAUER, F. R. GROSCHE, M. K. KALLERGIS, and K. J. SCHULTZ *In* AGARD Wind Tunnels and Testing Tech. 18 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

The availability of newly constructed low-noise aeroacoustic facilities - such as the German-Dutch-Windtunnel/DNW and the French CEPRA 19 Anechoic Open Jet Windtunnel - provides excellent experimental possibilities for conducting high-quality acoustic source-studies on aerospace-vehicle noise generators. This paper discusses recent and ongoing model-scale research on basic phenomena and applied problems pertaining to the generation and radiation of propeller and helicopter rotor noise. The importance and potential of aeroacoustic wind tunnel experiments in special facilities will be stressed, and illustrated mostly by examples of DFVLR and US-Army/DFVLR research projects. Emphasis is also put on the fruitful interrelationship of model-, wind-tunnel and full-scale flight testing. Author

N84-23584# Middle East Technical Univ., Ankara (Turkey). Dept. of Mechanical Engineering.

AEROACOUSTIC NOISE MEASUREMENTS IN WIND TUNNEL

H. N. ALEMDAROGLU *In* AGARD Wind Tunnels and Testing Tech. 14 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

The paper describes the general characteristics of the lowspeed Acoustic Research Wind Tunnel constructed in the Aerodynamics Laboratory of E.N.S.M.A (poitiers/France) and presents the results of the preliminary experiments conducted in this wind tunnel. The wind tunnel is of open test section, open circuit and blower type. It has a test section of 30x30 sq cm and a mean velocity of 42 m/s. Aerodynamic measurements revealed a maximum turbulence intensity of less than 1%. The open test section is completely enclosed within a acoustically lined semi-anechoic chamber of dimensions 3.3x4/2.8 sq cm. Acoustic calibration of the wind tunnel is done by using both white noise and pure tone noise sources and it was observed that the tunnel can be considered to be anechoic above 100 Hz for white noise tests. Preliminary measurements of aerodynamic noise are performed by using both smooth and artificially roughened circular cylinders placed in the open test section of the wind tunnel. An aeroacoustic coherence function is deviced in order to classify the subsonic flow at moderate Reynolds numbers 5.05x10 to the 4th power Re sub d around a circular cylinder in its different flow regimes; subcritical, transcritical and supercritical. The method uses simultaneous measurements of the power spectra of the far field acoustic pressure and of the turbulent longitudinal velocity fluctuations in the wake of the cylinder as well as their cross spectra density functions CSD and especially the coherence function between the two signals. The values of the coherent function corresponding to the critical Strouhal frequencies are intense in the subcritical regime, decrease sharply in the transcritical domain and then increase and stabilize in the supercritical regime. Author

N84-23585# Aeronautica Macchi S.p.A., Varese (Italy).

USE OF A SMALL SCALE WIND TUNNEL AND MODEL SHOP AT AERONAUTICA MACCHI AS AN INDUSTRIAL TOOL

R. MARAZZI, D. MALARA, M. LUCCHESINI, S. COMORETTO, and F. PACORI *In* AGARD Wind Tunnels and Testing Tech. 15 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

The paper describes some facilities and capabilities which are currently available at the Aerodynamic Test Department of Aeronautica Macchi. Special wind tunnel testing techniques allow the use of a small scale wind tunnel to obtain useful data for the development of aircraft configurations; model work-shop capabilities permit the manufacture of specialized wind tunnel models for detailed analysis of problem areas. The topics covered are: (1) updating of the rotary balance facility for the measurement of dynamic derivatives due to roll in the full range of model attitudes; (2) assessment of Reynolds number effects on high lift devices of modern design; (3) design and manufacture of an afterbody model; and (4) manufacture and testing of flutter models. B.W.

N84-23586# Arnold Engineering Development Center, Arnold Air Force Station, Tenn.

FLUID DYNAMIC ASPECTS OF TURBINE ENGINE TESTING

J. G. MITCHELL *In* AGARD Wind Tunnels and Testing Tech. 19 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

Turbine engine testing in ground test facilities cannot rely upon the simulation parameters that are common to aerodynamic testing in wind tunnels. The interfaces between the internal fluid dynamics of the engine and the external aerodynamics of the flight vehicle are sometimes simulated in wind tunnels and sometimes duplicated in engine test facilities. The choice is primarily dictated by test facility capability and finances available for test models. This paper will discuss some of the testing techniques which have been used and denote research efforts which are directed toward extension of test procedures and facility capability. In particular, applicable material from the recent AGARD Propulsion and Energetics Panel Symposium on Turbine Engine Testing will be summarized and amplified. Some emphasis will be placed upon airframe-inlet-engine testing and the development of testing capabilities for this purpose. Author

N84-23587# Societe Nationale Industrielle Aerospatiale, Toulouse (France). Div. Avions.

THE 310 AIRBUS TEST IN THE ONERA WIND TUNNEL: FLIGHT-WIND TUNNEL COMPARISON [AIRBUS A310 ESSAIS DANS LA SOUFFLERIE F1 DE L'ONERA COMPARAISON VOL-SOUFFLERIE]

M. SAIZ and C. QUEMARD (ONERA, Paris) *In* AGARD Wind Tunnels and Testing Tech. 23 p (SEE N84-23564 14-01) Feb. 1984 refs In FRENCH; ENGLISH summary

Avail: NTIS HC A22/MF A01

Methods used to obtain measurements on the 1/14 scale model of the A 310 in the F1 wind tunnel are described. The use of three types of mounts permitted a critical analysis of the results and assured their validity. Direct comparison of the measurements obtained with performances deduced from flight are remarkable. Transl. by A.R.H.

N84-23588# National Aerospace Lab., Amsterdam (Netherlands).

HALF-MODEL TESTING IN THE NLR HIGH SPEED WIND TUNNEL HST: ITS TECHNIQUE AND APPLICATION

S. J. BOERSEN and A. ELSENAAR *In* AGARD Wind Tunnels and Testing Tech. 15 p (SEE N84-23564 14-01) Feb. 1984 refs

Avail: NTIS HC A22/MF A01

The half model test technique which is based on a systematic comparison of half model test results with the corresponding full model data was evaluated. It is shown that the most important problems with this technique originate from half model mounting and wall interference effects. The effects are determined empirically by use of the full model test results as a reference. It is shown that the pressure distribution on the wing and the off design boundaries are well represented in the half-model tests. Some typical applications of this technique, in which half model test results are used on a relative basis, are presented. E.A.K.

N84-23589# Calspan Field Services, Inc., Arnold AFS, Tenn.
TEST TECHNIQUES FOR JET EFFECTS ON FIGHTER AIRCRAFT
E. A. PRICE, JR. and W. L. PETERS *In* AGARD Wind Tunnels and Testing Tech. 17 p (SEE N84-23564 14-01) Feb. 1984 refs Sponsored by AEDC
Avail: NTIS HC A22/MF A01

Efforts to improve test techniques for jet effects on fighter type aircraft are described. Defining the levels of aerodynamic interference on aircraft afterbodies from three types of model support systems, a prediction technique for hot jet effects on afterbody drag, and a hot versus cold jet experiment on target type thrust reversers is summarized. Support system interference from a strut, sting, and wingtip support on the afterbody axial force of the same jet effects model are compared over the Mach number range from 0.6 to 1.5. A technique for predicting hot jet effects on afterbody drag from ambient temperature jet data is presented and evaluated at Mach numbers 0.6, 0.9, and 1.2. Two distinctly different flow regimes characterized by flow attached to or detached from the surface of the afterbody are shown. Significant differences were found in the conditions for flow attachment for the hot and cold jet flows. E.A.K

N84-23590*# General Dynamics/Convair, San Diego, Calif.
DESIGN OF ADVANCED TECHNOLOGY MANEUVERING AIRCRAFT MODELS FOR THE NATIONAL TRANSONIC FACILITY
S. A. GRIFFIN, A. A. MCCLAIN, and A. P. MADSEN (General Dynamics, Fort Worth, Tex.) *In* AGARD Wind Tunnels and Testing Tech. 15 p (SEE N84-23564 14-01) Feb. 1984 refs Sponsored by NASA. Langley Research Center
Avail: NTIS HC A22/MF A01 CSCL 01A

The need for a large High-Reynolds-Number Transonic Wind Tunnel which will provide a tool to study phenomena sensitive to Reynolds number is discussed. The National Transonic Facility (NTF), is in the calibration phase and the desired capability. Its usefulness, however, will be influenced by the ability of industry to develop model systems capable of withstanding the severe operating environment of the facility so necessary to achieve full scale Reynolds number, without degradation of accuracy, and at reasonable cost. The feasibility of designing models of advanced aerodynamic technology maneuvering aircraft and to achieve full scale Reynolds number for each configuration in the NTF are determined. It is concluded that the facility does not offer the potential for making tunnel to full scale data correlations for this type of aircraft configuration. E.A.K.

N84-23591# Aeritalia S.p.A., Torino (Italy). Gruppo Velivoli da Combattimento.
DESIGN OF A WIND TUNNEL AFTERBODY MODEL FOR THE DEVELOPMENT OF A TRANSONIC COMBAT AIRCRAFT
G. BERTOLONE and E. FARINAZZO *In* AGARD Wind Tunnels and Testing Tech. 15 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01

A single engine combat aircraft, complete afterbody model was designed and tested in transonic wind tunnel for integration of the experimental results obtained from the unpowered models. The model was designed with potential capability to investigate the tailplane effectiveness and the effects of the secondary jet outlets, tail fairings, excrescences, and aerials. The general arrangement of the model are described. The necessity of an accurate sealing between the fixed and the weighed parts with the minimum mechanical interference to obtain reliable results in terms of afterbody drag is stressed. E.A.K.

N84-23592# Calspan Field Services, Inc., Arnold AFS, Tenn.
TRANSONIC NOZZLE-AFTERBODY FLOW FIELD MEASUREMENTS USING A LASER DOPPLER VELOCIMETER
F. L. HELTSLEY, B. J. WALKER (Army Missile Command, Redstone Arsenal, Ala.), and R. H. NICHOLS (AEDC) *In* AGARD Wind Tunnels and Testing Tech. 14 p (SEE N84-23564 14-01) Feb. 1984 refs Sponsored by AEDC
Avail: NTIS HC A22/MF A01

Nonintrusive laser Doppler velocimeter (LDV) flow field measurements for several nozzle afterbody configurations with cold nitrogen exhaust jets is described. Information about the test facility and instrumentation is presented. The test articles including one with a 15 deg. boattail afterbody and two having blunt bases are described. The two color, two component LDV optical package and data acquisition system used for the flow field measurements are discussed. The effects of particle dynamics upon the LDV measurement uncertainty are reviewed. Fluorescent seeding was used in conjunction with multiple techniques to gain a more complete understanding of the complex flow interactions in the model base region. Test results are summarized and selected data are presented. E.A.K.

N84-23593# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Hauptabt. Windkanaele.
THE NEW CALIBRATION TANK FOR ENGINE SIMULATORS AT DFVLR GOETTINGEN
B. BINDER, E. MELZER, and R. WULF *In* AGARD Wind Tunnels and Testing Tech. 9 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01

Interference effects between engine and airframe in wind tunnel tests the knowledge of the characteristics of model engines is necessary, especially if Turbine Powered Simulators (TPS) are used. The calibration tank which was built for the determination of TPS characteristics is described. Results of calibration measurements are presented for the six component balance and for the sonic nozzles to determine the mass flow. E.A.K.

N84-23594# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NEW TPS CALIBRATION BENCH, AND EJECTOR TESTS
J. P. BECLE, J. COSTE, and J. LEYNAERT *In* AGARD Wind Tunnels and Testing Tech. 12 p (SEE N84-23564 14-01) Feb. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A22/MF A01

The new calibration bench for large turbopowered simulator (TPS), adapted to the airplane models in wind tunnels, is described. This bench uses an existing wind tunnel wall balance equipped with two compressed air supply devices, which is installed in a depressurized tank. The depressurization is obtained by the jet effect of the TPS acting as an ejector. Various types of ejectors were tested. The influence of the geometrical parameters is analyzed, and the problem of stable or instable conditions is presented. E.A.K.

N84-23595# Aircraft Research Association Ltd., Bedford (England).
RECENT DEVELOPMENTS IN STORE SEPARATION AND GRID SURVEY TECHNIQUES USING THE ARA TWO-STING RIG
M. E. WOOD *In* AGARD Wind Tunnels and Testing Tech. 13 p (SEE N84-23564 14-01) Feb. 1984 refs
Avail: NTIS HC A22/MF A01

The Two Sting Rig system provides captive trajectory and grid survey testing in the ARA 2.74 m x 2.44 m transonic wind tunnel, on models of the order of 10% scale. The system is used primarily in the captive trajectory mode to predict release characteristics for a wide range of stores/aircraft. The improvements to and developments of the system that have arisen from experiences gained during the last two years of its operational use are described. A brief description is given of the general arrangement of the rig. Improvements to performance, simulation capabilities and to wind tunnel productivity are described together with current design studies for new applications. An appraisal of the overall performance of the method against 3 other ground based techniques is used to illustrate its merits and defects, using results from recent Two Sting Rig wind tunnel tests and flight. M.A.C.

N84-23596# Fluidyne Engineering Corp., Minneapolis, Minn.
A SELF-CONTAINED CAPTIVE TRAJECTORY SYSTEM FOR A BLOWDOWN WIND TUNNEL
C. D. CHRISTOPHERSON, D. N. KAMIS, D. M. NELSON, and R. D. WEEK *In* AGARD Wind Tunnels and Testing Tech. 9 p (SEE N84-23564 14-01) Feb. 1984
Avail: NTIS HC A22/MF A01

The trajectory of a store which is released from an aircraft can be determined by model tests using a six component sting balance to measure the aerodynamic forces and moments on the shell. A completely self contained captive trajectory system is described which is configured to provide maximum efficiency in

the use of wind tunnel test time. There are three primary factors which contribute to achieving this goal: the self contained nature of the system, the use of high performance electrohydraulic servo positioning systems for all motions, the use of a modern high speed minicomputer and appropriately matched amplifier/multiplexer I/O equipment to acquire information, perform the mathematical manipulations required, and provide appropriate inputs to the servo systems. The system described is separated into four subsystems: the structural/mechanical system, the electrohydraulic positioning systems, the minicomputer based analyzer/programmer system, the software system. An overview of the wind tunnel circuit, a 4 ft by 4 ft (1.2 m x 1.2 m) trisonic blowdown configured to provide high quality by the use of a perforated sleeve valve flow control, perforated flow diffusers, acoustic baffles, a honeycomb, and screens, is given. M.A.C.

N84-23597# British Aerospace Aircraft Group, Brough (England).
THE ACCELERATED LIGHT MODEL TECHNIQUE OF STORE SEPARATION AS DEVELOPED AND USED AT BRITISH AEROSPACE, BROUGH
R. E. BURNS *In* AGARD Wind Tunnels and Testing Tech. 12 p (SEE N84-23564 14-01) Feb. 1984
Avail: NTIS HC A22/MF A01

The light model technique developments for use in the Brough High Speed Wind Tunnel, which succeeded in producing a reliable and practical method of virtually eliminating errors due to the usual compromises are examined. The theoretical concepts are described in detail, and results from a typical wind tunnel jettison test are presented. The method employed is light model scaling, with parent model acceleration to compensate for the gravitational deficiency inherent in this technique. A detailed analysis of residual errors in simulation has led to a method of minimizing the most significant of these (i.e. induced incidence deficiency), which has now been incorporated into the techniques. M.A.C.

N84-23598# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
VORTICAL FLOW EXPLORATION METHODS DEVELOPED FOR THE F1 WIND TUNNEL
Y. BROCARD and P. DESPLAS *In* AGARD Wind Tunnels and Testing Tech. 15 p (SEE N84-23564 14-01) Feb. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A22/MF A01

Flow field investigation methods are developed by Office National d'Etudes et de Recherches Aerospatiales for its large wind tunnels. The means - exploring device, motorized probe holders, piloting computer system - used to position and point the probes are described. For vortex flow investigations five hole probes and two or three hot wire probes are used. The measuring and data processing techniques for the various probes are given. Finally typical results obtained in the O.N.E.R.A. F1 wind tunnel are presented. M.A.C.

N84-23599# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NEW METHODS OF EXCITATION, ACQUISITION AND DATA REDUCTION ABOUT UNSTEADY WIND TUNNEL TESTS
A. GRAVELLE and R. DESTUYNDER *In* AGARD Wind Tunnels and Testing Tech. 15 p (SEE N84-23564 14-01) Feb. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A22/MF A01

The unsteady wind tunnel tests performed by the structures department at Office National a'Etude et de Recherches Aerospatiales (ONERA) consist in measuring unsteady pressure fields and forces during rigid body motions of the models, control surfaces motions, as well as in acceleration measurements in the case of flutter models. The different types of model installation, excitation devices, data acquisition and data reduction methods and units are described herein. Different examples and results are given. M.A.C.

N84-23600# Dornier-Werke G.m.b.H., Munich (West Germany).
EXPERIENCE IN ENGINE FACE, NON-STEADY, FLOW MEASUREMENTS THROUGH A SIDE AND BOTTOM ENGINE AIR INLET DUCT
D. RITCHIE and R. FRIEDRICHS (DFVLR, Brunswick) *In* AGARD Wind Tunnels and Testing Tech. 18 p (SEE N84-23564 14-01) Feb. 1984 Sponsored by German Ministry of Defense
Avail: NTIS HC A22/MF A01

Two types of turbine engine air inlets are described. Models of these inlets are instrumented with high frequency pressure sensors and turbulence levels are measured in the wind tunnel for various mass flow ratios, angles of attack and sideslip angles. The instrumentation and methods of data reduction and analysis are described. Some results are shown to support the merit of high frequency, non stationary instrumentation. Non stationary data are compared with stationary measurements taken at the same time. M.A.C.

N84-23601# Royal Aircraft Establishment, Bedford (England).
RECENT DEVELOPMENTS IN THE MEASUREMENT OF TIME-DEPENDENT PRESSURES
B. L. WELSH, C. R. PYNE, and B. E. CRIPPS *In* AGARD Wind Tunnels and Testing Tech. 17 p (SEE N84-23564 14-01) Feb. 1984
Avail: NTIS HC A22/MF A01

For flutter tests, involving time dependent force measurement, frequency sweep excitation is currently used to reduce tunnel running times, and minimize the risk of losing the model due to prolonged exposure to oscillatory conditions. This method is used to measure the time-dependent pressures on a wing oscillating in pitch using improved measurement and recording equipment. Wherever the system under test displays a linear response the raid sweep technique is in good agreement with the much slower method of discrete sinusoidal excitation. Where the system is non liner, eg in unsteady tunnels, significant differences between the techniques are expected and observed. The techniques and data from recent test are discussed. M.A.C.

N84-25613# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
WORKSHOP ON REQUIREMENTS FOR AIRCRAFT CORROSION CONTROL
W. M. IMRIE, ed. Mar. 1984 78 p refs Workshop held in London, 10-15 Apr. 1983
(AGARD-R-714; ISBN-92-835-1467-X; AD-A143237) Avail: NTIS HC A05/MF A01

Conference proceedings on aircraft corrosion and corrosion prevention are given. A number of topics are discussed in the areas of design specifications, manufacturing, maintenance, and cost. For individual titles, see N84-25614 through N84-25624.

N84-25614# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
CORROSION CONTROL REQUIREMENTS FOR UK MILITARY AIRCRAFT
V. C. R. MCLOUGHLIN *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 5 p (SEE N84-25613 16-01) Mar. 1984
Avail: NTIS HC A05/MF A01

The designer is given advice on the selection of materials based upon their resistance to corrosion, and mandatory requirements for processes and materials to be used in aircraft structures so as to minimize deterioration and corrosion. Details are given of these requirements and the various sequences of operations required for corrosion control purposes. R.J.F.

N84-25615# Naval Air Development Center, Warminster, Pa.
CURRENT PROCUREMENT SPECIFICATION DESIGN REQUIREMENTS FOR US NAVY AIRCRAFT
S. J. KETCHAM *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 2 p (SEE N84-25613 16-01) Mar. 1984
Avail: NTIS HC A05/MF A01

An important step in the acquisition of a new naval aircraft is the review of detailed specifications by materials and process specialists. The specifications are studied for compliance with SD-24, MIL-F-7179 and MIL-S-5002. In addition, reports on Adhesives, Lubricants, Finishes and Corrosion Control Plans are

furnished as a contractural requirement. Some of the most important considerations are the materials to be used, designs incorporating dissimilar metals, and water tightness. Test programs may be necessary to validate a particular choice of material of design. In the final analysis, however, cost and performance are the overriding considerations so some compromises usually have to be made. The challenge is to obtain as corrosion free a vehicle as possible within these constraints. Author

N84-25616# Army Materials and Mechanics Research Center, Watertown, Mass.
CURRENT DESIGN REQUIREMENTS FOR CORROSION CONTROL ON HELICOPTERS
M. LEVY and R. D. FRENCH *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 5 p (SEE N84-25613 16-01) Apr. 1984
Avail: NTIS HC A05/MF A01

Aeronautical Design Standard ADS-13C embodies the general requirements for the materials and processes utilized in the design and construction of Army aircraft. The materials and processes are utilized in accordance with AMCP706-203, the Engineering Design Handbook Helicopter Engineering, part three, Qualification Assurance. The properties of materials are generally obtained from MIL-HDBK-5, MIL-HDBK-17 and MIL-HDBK-23, for metallic materials, plastics, and structural sandwich composites respectively. All of the system parts are finished to provide protection from corrosion and other forms of material deterioration in accordance with a contractor prepared and Government-approved material deterioration prevention and control (MADPAC) plan which is detailed in the appendix to ADS-13. This appendix describes the managerial and technical responsibilities of Army contractors in the design, validation, development and production phases of Army aviation systems. It provides a mechanism for the implementation of sound materials selection practices and finish treatments during the life cycle of all Army aviation weapon systems and defines the organization and implemenation of a MADPAC finish specification which complies with MIL-F-7179. ADS-13C repesents the most recent revision of the standard which embodies some of the corrosion lessons learned from Army helicopters where weight reduction was the overriding concern in the design and construction of the aircraft. Author

N84-25617# Westland Aircraft Ltd., Yeovil (England).
THE INTERPRETATION OF DESIGN REQUIREMENTS FOR MULTI-MARKET HELICOPTERS
D. R. HAYWARD *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 3 p (SEE N84-25613 16-01) Mar. 1984
Avail: NTIS HC A05/MF A01

An approach to corrosion control in helicopters is given. All drawing are vetted before issue to ensure that obvious corrosion sites, sharp edges, and water traps are designed out and of course to obtain the most economical means of protecting components. Wherever possible a coat of pain is applied before assembly. Measures are taken to prevent ingress of water to joints and structures by the use of caulking materials; however, great care is taken to ensure structures are adequately drained. Specific treatments of aluminum, steel, and magnesium are detailed. R.J.F.

N84-25618# Saab-Space A.B., Linkoeping (Sweden). Materials Lab.
CURRENT REQUIREMENTS ON SPECIFICATIONS FOR CORROSION PREVENTION
E. HULTGREN *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 13 p (SEE N84-25613 16-01) Mar. 1984
Avail: NTIS HC A05/MF A01

The of aluminum, low alloy steel, magnesium, titanium, and composite materials in aircraft construction aimed at corrosion prevention and resistance is discussed. Protective coatings, adhesives and sealants are discussed. The importance of design considerations is explained. R.J.F.

N84-25619# Atlantic Fleet, Norfolk, Va.
US NAVY CORROSION CONTROL MAINTENANCE
G. T. BROWNE *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 11 p (SEE N84-25613 16-01) Mar. 1984
Avail: NTIS HC A05/MF A01

The U.S. Navy Aircraft Corrosion Prevention/Control Maintenance Program is described. Program elements, present maintenance practice, maintenance control procedures and corrective actions from discovery, resolution and documentation are discussed. A system of checks and balances which are accomplished through a material condition audit program that assesses the quality of information provided for use by mechanics and the ability of the aircraft operator to maintain the aircraft are discussed. The training for personnel involved in the program is also discussed. R.J.F

N84-25620# Vought Corp., Dallas, Tex. Materials and Processes Dept.
DESIGN AND MANUFACTURING PRACTICES TO MINIMIZE CORROSION IN AIRCRAFT
A. E. HOHMAN *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 5 p (SEE N84-25613 16-01) Mar. 1984 refs
Avail: NTIS HC A05/MF A01

Military weapon systems face tradeoffs of performance, cost of production and maintenance versus long term durability and reduced reliability resulting from corrosion. There is a broad set of requirements presented to contractors which represent the collective wisdom of what is needed for durability. These requirements are judged to be cost effective and near optimum in this tradeoff of performance/cost with corrosion resistance. A few examples of some specific designs, processes and materials which were found by one manufacturer to have significant advantages in this tradeoff by their excellence of protection with minimum tradeoff penalties are discussed. These details of successful experiences are intended to set the stage for two other theses. The first is that the data incorporated in United States Military documents, such as the requirements in MIL-F-7179, Protection of Aerospace Weapon Systems, Mil-Std-1568, Materials and Processes for Corrosion Control, and the materials portions of SD-24, Design and Construction of Weapon Systems, are indeed an excellent base from which we can begin the design of a weapon system. But it is an almost impossible situation to try to spell out the details required to actually obtain performance excellence in the design tradeoffs; or to define the required intricate details necessary to accomplish optimum protection from the pervasive thermodynamics of materials seeking lower free energy states. R.J.F.

N84-25621# National Defence Headquarters, Ottawa (Ontario). Directorate of Aerospace Support Engineering.
CORROSION CONTROL MAINTENANCE PRACTICES FOR CANADIAN AIRCRAFT
R. SIMARD *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 7 p (SEE N84-25613 16-01) Mar. 1984
Avail: NTIS HC A09/MF A01

The corrosion control program for aircraft of the Canadian Armed Forces is reviewed. Documentation outlining general guidelines and policy is presented along with excerpts from a manual specific to one particular aircraft. The effects of the operational environment on the extent of the corrosion control program for an aircraft is discussed, with Sea King helicopters and CF-104 aircraft serving as examples. The equipment contained in a corrosion control first aid kit for CF aircraft is highlighted, along with instructions for its use. The training given to CF aviation tradesmen is also outlined. Finally, the protective coating system selected for all CF aircraft is described and its importance to the overall corrosion contol program is noted. R.J.F.

N84-25622# Defence Research Establishment Pacific, Victoria (British Columbia). Materials Engineering Section.
CORROSION RESEARCH IN SUPPORT OF CANADIAN FORCES AIRCRAFT
D. R. LENARD *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 11 p (SEE N84-25613 16-01) Mar. 1984 refs
Avail: NTIS HC A05/MF A01

Two examples of research projects initiated by the Defense Research Establishment Pacific in direct support of aircraft operators and maintainers in the Canadian Armed Forces are presented. The first example involves a contract research project to investigate the effects of water displacing corrosion inhibiting preparations on the fatigue characteristics of structural joints. The initial experimental plan is outlined and preliminary results are presented. These early results indicated that the preparations did not have a significant effect on the fatigue of single strap, riveted butt joints. The second example concerns the prohibition against use of silicon carbide abrasive papers on aluminum in aircraft. Laboratory investigations including several electrochemical experiments and atmospheric exposure trials clearly demonstrated that the use of silicon carbide abrasive papers did not increase the severity of corrosion. R.J.F.

N84-25623# Naval Air Development Center, Warminster, Pa.
METHODOLOGY FOR ASSESSMENT OF CORROSION COSTS
I. S. SHAFFER *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 7 p (SEE N84-25613 16-01) Mar. 1984 refs
Avail: NTIS HC A05/MF A01

Corrosion has a significant impact on the life cycle costs of naval aircraft. Materials, energy, labor and technical expertise that would otherwise be available for alternative uses must be allocated for corrosion control. To help justify the added expense of designing more corrosion resistance in future Navy aircraft and spending more on corrosion research and technology, valid estimates of the magnitude of corrosion costs and the relative distribution of those costs among various aircraft types and aircraft systems are important. While many factors make up the Navy's cost of corrosion for aircraft ownership, the overwhelming one is the effort spent doing maintenance. The maintenance data collection system is discussed. Tables and graphs showing costs are given. R.J.F.

N84-25624# British Airways, Middlesex (England). Aircraft Engineering (Structures).
COST OF CORROSION FOR COMMERCIAL AVIATION
R. G. MITCHELL *In* AGARD Workshop on Requirements for Aircraft Corrosion Control 1 p (SEE N84-25613 16-01) Mar. 1984
Avail: NTIS HC A05/MF A01

A preliminary analysis of aircraft corrosion costs based on the annual costs of scheduled maintenance, modification, and replacement is discussed. The results show the financial cost of the corrosion problem which can be expressed in several ways. The direct cost per flying hour, depending on operators and aircraft type (not including maintenance overhead) was $8-$12 in 1979 and $8-$20 in 1983. The percentage of direct airframe maintenance cost was between 6% and 8%. The total annual direct cost for International Transport Association member airlines was $100 M based on 1976 operations and $200 M based on 1982 operations. It should be noted that the values represent costs for a range of operators and aircraft types. The lowest value is very conservative and is largely based on one operators actual modification project costs only. The higher value is probably closer to the true cost since it is based upon a breakdown of actual modification, routine maintenance and inspection costs. Closer examination of these figures reveal that the major component in the cost values associated with corrosion prevention and control is due to labor costs. An additional cost not reflected in the above figures is the unscheduled downtime both at main base and route stations. R.J.F.

N84-25625# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SPECIAL COURSE ON V/STOL AERODYNAMICS
Loughton, England Apr. 1984 383 p refs Course held in Rhode-Saint-Genese, Belgium, 14-18 May 1984, and in Moffett Field, Calif., 4-8 Jun. 1984
(AGARD-R-710; ISBN-92-835-1472-6; AD-A144214) Avail: NTIS HC A17/MF A01

The aim of the Special Course on V/STOL Aerodynamics was to outline and discuss the additional knowledge of aerodynamics needed to embark on the design of V/STOL aircraft. The influence of V/STOL features on wing design, layout considerations, engine and air intake considerations, effects of jet effluxes, wind tunnel and flight testing, maneuverability and control, performance assessment and special aspects of flight aerodynamics were discussed. For individual titles, see N84-25626 through N84-25637.

N84-25626# Kingston Polytechnic, Kingston-Upon-Thames (England). School of Mechanical, Aeronautical, and Production Engineering.
INTRODUCTION AND REVIEW OF SOME JET INTERFERENCE PHENOMENA RELEVANT TO V/STOL AIRCRAFT
E. C. P. RANSOM and J. R. SMY (British Aerospace Aircraft Group, Kingston-upon-Thames, England) *In* AGARD Spec. Course on V/STOL Aerodyn. 23 p (SEE N84-25625 16-01) Apr. 1984 refs
Avail: NTIS HC A17/MF A01

This introductory paper summarizes and discusses aspects of some fluid flows relevant to V/STOL aircraft. The principal sources of reference are the contributions to AGARD conferences which have been specifically concerned with V/STOL aerodynamics. Initially consideration has been given to the behavior of single axisymmetric jets discharging into stationary surroundings and the creation of the corresponding flow field. The effect that a change of fluid properties has on the flow field and plume development is then described and is extended to include jets discharging into a cross flow and into a coflowing stream. The aerodynamics of jets impinging on adjacent surfaces are reviewed with particular reference to induced lift losses generated during hovering in ground effect, to ground erosion and to recirculation. Internal fluid flows in thrust augmentors are described including the effect of losses, and the generation of unsteady flows which are used to enhance mixing rates. The paper concludes with a brief discussion of modelling techniques and wind tunnel methods including interference effects. Author

N84-25627# British Aerospace Aircraft Group, Kingston-upon-Thames (England).
THE INFLUENCE OF V/STOL ON WING DESIGN AND TAILPLANE DESIGN
C. L. BORE *In* AGARD Spec. Course on V/STOL Aerodyn. 6 p (SEE N84-25625 16-01) Apr. 1984
Avail: NTIS HC A17/MF A01

It is shown that one of the most powerful influences upon the payload/range of V/STOL aircraft is exerted by reducing the weight of the wing. The process of designing a lightweight wing involves meticulous effort to achieve exceptionally high maneuvering lift coefficients, combined with due attention to the geometrical and structural interactions. There are constraints all round, such as the need to avoid undue interference with jet effluxes below the wing roots, and the physical constraint of providing fuel volume and space for low drag store carriage. Any structural complexities which threaten to increase wing weight seriously (such as cut-outs, opening panels for fans or ejectors and so on) are inefficiences which should be entertained only for valuable benefits. B.W.

N84-25628*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
V/STOL CONCEPTS IN THE UNITED STATES: PAST, PRESENT, AND FUTURE
W. P. NELMS and S. B. ANDERSON *In* AGARD Spec. Course on V/STOL Aerodyn. 44 p (SEE N84-25625 16-01) Apr. 1984 refs Previously announced as N84-22532
Avail: NTIS HC A17/MF A01 CSCL 01C

Nonhelicopter types of V/STOL aircraft developed in the United States are reviewed, and some lessons learned from a selected number of concepts are highlighted. The AV-8B, which was

developed by modifications to the British Harrier is the only current concept examined. Configurations proposed for the future subsonic, multimissing aircraft and the future supersonic fighter/attack aircraft are described. Emphasis is on these supersonic concepts. B.W.

N84-25629# British Aerospace Aircraft Group, Warton (England). Advanced Projects Dept.
LAYOUT CONSIDERATIONS AND TYPES OF V/STOL AIRCRAFT
J. FLETCHER *In* AGARD Spec. Course on V/STOL Aerodyn. 36 p (SEE N84-25625 16-01) Apr. 1984 refs
Avail: NTIS HC A17/MF A01

This report summarizes V/STOL aircraft developed in the United States and describes concepts considered for future applications. The discussion is limited to non-helicopter types of vehicles. In particular, past V/STOL aircraft will be reviewed, and some lessons learned from a selected number of concepts will be highlighted. The only current concept described is the AV-8B, which was developed by modifications to the British Harrier. Configurations recently proposed for the future subsonic, multimission aircraft and the future supersonic fighter/attack aircraft will be described. Emphasis in the lecture will be on these supersonic concepts. B.W.

N84-25630# Rolls-Royce Ltd., Bristol (England).
V/STOL PROPULSION SYSTEM AERODYNAMICS
W. J. LEWIS *In* AGARD Spec. Course on V/STOL Aerodyn. 24 p (SEE N84-25625 16-01) Apr. 1984
Avail: NTIS HC A17/MF A01

Different V/STOL propulsion system concepts are briefly described. Highlighted are those features of the systems which present the aerodynamicist with either more severe problems or different problems from those present on conventional takeoff and landing engines. After illustrating some of the demands V/STOL makes on the engine cycle choice and some of the compromises necessary, the individual parts of the propulsion system are considered in turn. Because of the enormous scope of the subject, attention was limited to aspects which are common to a number of the different propulsion systems. Author

N84-25631*# *McDonnell Aircraft Co.*, St. Louis, Mo.
JET FLOWFIELDS
D. R. KOTANSKY *In* AGARD Spec. Course on V/STOL Aerodyn. 48 p (SEE N84-25625 16-01) Apr. 1984 refs
(Contract NAS2-9646; NAS2-10184; NAS2-11161; N62269-76-C-0086; N62269-81-C-0717; N00014-79-C-0130)
Avail: NTIS HC A17/MF A01 CSCL 01A

The unique aero/fluid mechanics of V/STOL jet flowfields both in and out of ground effect and how they influence and may be accommodated in the aircraft design process are described. Key topics addressed include the following: jet development in static and cross-flow conditions, jet impingement (round jets/rectangular jets including nozzle pressure ratio and temperature effects), multiple jet impingement and fountain upwash formation and development (ground surface flows, stagnation lines, fountain characteristics), fountain impingement on the airframe, jet induced effects on the airframe in and out of ground effect including trim and stability considerations, effects of forward (STOL) and cross-wind velocities, and exhaust gas ingestion (VTOL, STOL). Discussion of the above items will include their influence on vehicle design and system performance and their quantification and prediction via theoretical and empirical predictions, and small and large scale wind tunnel tests. Aero/propulsion devices discussed include V/STOL multiple jet lift systems (low and high pressure ratio) and STOL thrust vectoring/reversing nozzles. R.J.F.

N84-25632*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
V/STOL MANEUVERABILITY AND CONTROL
J. A. FRANKLIN and S. B. ANDERSON *In* AGARD Spec. Course on V/STOL Aerodyn. 47 p (SEE N84-25625 16-01) Apr. 1984 refs Prevously announced as N84-22584
Avail: NTIS HC A17/MF A01 CSCL 01C

Maneuverability and control of V/STOL aircraft in powered-life flight is studied with specific considerations of maneuvering in forward flight. A review of maneuverability for representative operational mission tasks is presented and covers takeoff, transition, hover, and landing flight phases. Maneuverability is described in terms of the ability to rotate and translate the aircraft and is specified in terms of angular and translational accelerations imposed on the aircraft. Characteristics of representative configurations are reviewed, including experience from past programs and expectations for future designs. The review of control covers the characteristics inherent in the basic airframe and propulsion system and the behavior associated with control augmentation systems. Demands for augmented stability and control response to meet certain mission operational requirements are discussed. Experience from ground-based simulation and flight experiments that illustrates the impact of augmented stability and control on aircraft design is related by example. Author

N84-25633*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
V/STOL WIND-TUNNEL TESTING
D. G. KOENIG *In* AGARD Spec. Course on V/STOL Aerodyn. 71 p (SEE N84-25625 16-01) Apr. 1984 refs
Avail: NTIS HC A17/MF A01 CSCL 01A

Factors influencing effective program planning for V/STOL wind-tunnel testing are discussed. The planning sequence itself, which includes a short checklist of considerations that could enhance the value of the tests, is also described. Each of the considerations, choice of wind tunnel, type of model installation, model development and test operations is discussed, and examples of appropriate past and current V/STOL test programs are provided. A short survey of the moderate to large subsonic wind tunnels is followed by a review of several model installations, from dimensional to large-scale models of complete aircraft configurations. Model sizing, power simulation, and planning are treated, including three areas in test operations: data acquisition systems, acoustic measurements in wind tunnels, and flow surveying. Author

N84-25634# British Aerospace Aircraft Group, Kingston-upon-Thames (England).
GROUND BASED TESTING WITHOUT WIND TUNNELS
C. L. BORE *In* AGARD Spec. Course on V/STOL Aerodyn. 6 p (SEE N84-25625 16-01) Apr. 1984 refs
Avail: NTIS HC A17/MF A01

Ground based tests of V/STOL aircraft *not requiring wind* tunnels are described. Harrier aircraft and the Bristol-Siddeley BS 53 (Pegasus) engine are given particular consideration. Tests of aircraft reaction controls, air intakes, anti-lift (suckdown) forces, and hot gas recirculation (HGR) are discussed. Jet thrust was the critical parameter studied in all of the test schemes. Modifications in aircraft design, such as the use of underfuselage strakes, were addressed. R.S.F.

N84-25635# British Aerospace Public Ltd. Co., Preston (England).
AERODYNAMICS OF V/STOL AIRCRAFT: PERFORMANCE ASSESSMENT
D. C. LEYLAND *In* AGARD Spec. Course on V/STOL Aerodyn. 26 p (SEE N84-25625 16-01) Apr. 1984 refs
Avail: NTIS HC A17/MF A01

Combat performance assessment of jet-borne V/STOL aircraft of the Harrier/AV8B family is discussed. Performance requirements for vertical takeoff and short takeoff are outlined and reviewed. Parameters considered for vertical operation include: margin for acceleration and maneuver, jet-induced lift losses, hot gas reingestion, and reaction control air bleed. Cruise, vectored thrust, jet lift enhancement, and the accelerating transition maneuver from jet-borne flight to aerodynamic lift are also discussed. R.S.F.

N84-25636*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
ASSESSMENT OF AERODYNAMIC PERFORMANCE OF V/STOL AND STOVL FIGHTER AIRCRAFT
W. P. NELMS *In* AGARD Spec. Course on V/STOL Aerodyn. 35 p (SEE N84-25625 16-01) Apr. 1984 refs Previously announced as N84-22536
Avail: NTIS HC A17/MF A01 CSCL 01C

The aerodynamic performance of V/STOL and STOVL fighter/attack aircraft was assessed. Aerodynamic and propulsion/airframe integration activities are described and small-and large-scale research programs are considered. Uncertainties affecting aerodynamic performance that are

associated with special configuration features resulting from the V/STOL requirement are addressed. Example uncertainties related to minimum drag, wave drag, high angle of attack characteristics, and power-induced effects. Engine design configurations from several aircraft manufacturers are reviewed. Author

N84-25637# British Aerospace Aircraft Group, Kingston-upon-Thames (England).
NOTES ON SPECIAL FLIGHT ASPECTS, SUCH AS STO, SKI-JUMP AND ODM
C. L. BORE *In* AGARD Spec. Course on V/STOL Aerodyn. 6 p (SEE N84-25625 16-01) Apr. 1984 refs
Avail: NTIS HC A17/MF A01

The dimensionless parameters which dominate the performance of jet-lift V/STOL aircraft are reviewed. Thrust ratings, forces extant in partially jet-borne flight, short takeoff, takeoff-weight ratio, ski-jump takeoff, and deck launch are considered. Harrier aircraft and the Bristol-Siddeley BS 53 (Pegasus) engine serve as the paradigms for the discussion. R.S.F.

N84-34396# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
FLIGHT TEST TECHNIQUES
Loughton, England Jul. 1984 367 p refs In ENGLISH and FRENCH Conf. held in Lisbon, 2-5 Apr. 1984
(AGARD-CP-373; ISBN-92-835-0359-7; AD-A147625) Avail: NTIS HC A16/MF A01

Flight testing techniques that evaluate flight control characteristics, aerodynamic characteristics, and avionics/weapons systems are presented. The analyses cover topics such as lift and drag quantification, autopilot and navigation equipment tests, external stores flight testing, and weapons system testing and integration. For individual titles see N84-34397 through N84-34421.

N84-34397# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
DETERMINATION OF EXTERNAL STORE DRAG
K. LUTZ and R. MATECKI *In* AGARD Flight Test Tech. 9 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

The evaluation of external stores concerns single store configurations and double store configurations. The necessary considered further work for completing external store statistical basic data is listed. The external store drag is evaluated in a classical manner for all configurations and configuration components beginning with the clean aircraft as first reference configuration and than evaluating step by step additional components (e.g., gun-pod, pylons, tanks e.a.). The main effort is directed on underwing stores, as the ALPHA-Jet has only one under-fuselage station for a gun-pod. M.A.C.

N84-34398# British Aerospace Aircraft Group, Preston (England).
THE FLIGHT TEST OF AN AUTOMATIC SPIN PREVENTION SYSTEM
P. S. BUTCHER and K. MCKAY *In* AGARD Flight Test Tech. 11 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

The flight testing of the Spin Prevention and Incidence Limiting System (SPILS) now fitted to the Tornado aircraft is investigated. The trial is carried out in parallel with the conventional stalling and spinning trial and the special aircraft equipment and test procedures are common to both trial and is considered in some detail. The SPILS flight testing is described with and without stores, and describes the reasons for the control law modifications required to fine tune the performance of the system. M.A.C.

N84-34399# Air Force Flight Test Center, Edwards AFB, Calif.
HIGH ANGLE OF ATTACK TEST AND EVALUATION TECHNIQUES FOR THE 1980S
G. L. JONES *In* AGARD Flight Test Tech. 13 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

The principles that guide the development of stall/post stall/spin flight test demonstration specification MIL-S-83691 and at how recent flight test experiences at the AFFTC have modified and expanded upon those ideas over the past decade are examined. Sixteen high angle-of-attack (AOA) flight test programs on four different series of fighter/attack aircraft are completed. The basic objectives of each one of those programs emphasized the determination of departure characteristics and the development of methods for departure prevention and spin avoidance. M.A.C.

N84-34400# National Aerospace Lab., Amsterdam (Netherlands).
DETERMINATION OF PERFORMANCE AND STABILITY CHARACTERISTICS FROM DYNAMIC MANOEUVRES WITH A TRANSPORT AIRCRAFT USING PARAMETER IDENTIFICATION TECHNIQUES
J. H. BREEMAN, L. J. J. ERKELENS, and A. M. H. NIEUWPOORT *In* AGARD Flight Test Tech. 18 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

A flight test program is executed with the Fokker F28 transport aircraft to investigate whether it is possible to determine performance and stability characteristics from dynamic maneuvers using parameter identification techniques, with sufficient accuracy for certification purposes. A research moving base flight simulator, programmed with the F28 aerodynamic model derived from conventional flight tests and wind-tunnel data, is used to select an optimal set of maneuvers from which the desired characteristics could be determined with a satisfactory degree of accuracy. Flight test data is analyzed, using the Two-Step method. This method starts by reconstructing the aircraft flight path as the first step. The second step is the calculation of all aerodynamic coefficients using straightforward regression analysis techniques. The advantage of this method over the more often used maximum likelihood estimation methods is that a large number of alternative non-linear aerodynamic models can be investigated in a short time using an interactive program. The flight test results are compared with results derived from conventional test programs. From this comparison it is clear that the data is sufficiently accurate. M.A.C.

N84-34401# Grumman Data Systems Corp., Calverton, N.Y.
APPLICATION OF ADVANCED PARAMETER IDENTIFICATION METHODS FOR FLIGHT FLUTTER DATA ANALYSIS WITH COMPARISONS TO CURRENT TECHNIQUES
H. J. PERANGELO and P. R. WAISANEN (*Grumman* Aerospace Corp., Calverton, N.Y.) *In* AGARD Flight Test Tech. 29 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

The implementation and evaluation of advanced parameter identification software for use in flutter test data processing operations is investigated. The maximum likelihood parameter identification algorithm is used in conjunction with a detailed physical aeroelastic aircraft model to perform optimal flutter test data analysis. Extended Kalman filtering is considered for eventual use as a second advanced parameter identification method. A mathematical description of the advanced parameter identification approach and least-squares flutter analysis procedures are presented. A comparison between this current analysis capability and prototype code for the maximum likelihood parameter identification algorithm on response data excited randomly (via atmospheric turbulence) and by swept shaker inputs indicates a significant improvement in analysis results with the advanced method. M.A.C.

N84-34402# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Flight Test Department.
A TECHNIQUE TO DETERMINE LIFT AND DRAG POLARS IN FLIGHT
A. KNAUS *In* AGARD Flight Test Tech. 14 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

Performance trials of the European combat aircraft Tornado concentrated on the systematic measurement of lift and drag polars. Such polars were successfully measured by means of well-adapted test instrumentation, a data reduction system, and a high calibration standard of the aircraft and engines. The use of a certain combination of steady state and dynamic test maneuvers resulted in a drastic reduction in the amount of flight time required to obtain sufficient data for the determination of the zero lift drag, induced drag characteristics, and drag increments due to aircraft configuration changes. Flight test results are presented which

demonstrate the advantage of the test technique utilized and the high data quality achieved. R.S.F.

N84-34403# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
FLIGHT TESTING A DIGITAL FLIGHT CONTROL SYSTEM: ISSUES AND RESULTS
B. W. VANVLIET *In* AGARD Flight Test Tech. 10 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

The AFTI/F-16 advanced development program modified a F-16A to be a testbed for evaluating new flight control related technologies. Some of the technologies developed on this program are: a triplex digital fly-by-wire flight control system which operates asynchronously, an analog independent backup unit (IBU), eight separate digital task-tailored control laws, and six decoupled controller options. Included among these task-tailored modes are normal operation modes, air-to-air combat modes, and air-to-surface combat modes. Two of these modes, the normal mode and the IBU, were flight tested on the AFTI/F-16 itself, and the flight test results were different from any of the simulators' predicted results. Several flight test issues are discussed in terms of how they were resolved and their effect especially on the aircraft handling qualities. Specific topics considered are: the IBU, the effect of the asynchronous computer operation and system redundancy management on the flight control laws and flight testing, and some handling qualities problems with combination coupled/decoupled control laws. R.S.F.

N84-34404# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Flight Test Department.
AIRCRAFT TESTS IN THE CLEARANCE PROGRAM FOR THE USE OF A COMBAT AIRCRAFT FROM A RUNWAY AFTER DAMAGE REPAIR
W. SEIDEL *In* AGARD Flight Test Tech. 16 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

The requirements of the repair quality of a damaged runway depend highly on the design capabilities and the strength of an aircraft and its undercarriage. This makes accurate knowledge of the behavior of the aircraft on non flat surfaces necessary and it is standard practice to develop a computer model of the aircraft and its undercarriage for analytical coverage of all operational cases. This analytical model requires comprehensive verification in tests; the tests are additionally necessary to optimize pilot techniques for the use of the aircraft under such conditions with minimum risk. Tests are described which were performed with a combat aircraft on a runway where mat repair was simulated. A description is given of the test setup, and the reasons for the selection of test configurations and test cases are discussed. Test instrumentation, data acquisition, and data processing are briefly described along with the test techniques which were used to meet predetermined test conditions. Examples of test results are presented and compared with predictions. A discussion of unpredicted results highlights the need for accurate test performance. Desirable improvements in measuring techniques and pilot supporting test equipment are considered. R.S.F.

N84-34405# Aeroplane and Armament Experimental Establishment, Boscombe Down (England).
THE HANDLING AND PERFORMANCE TRIALS NEEDED TO CLEAR AN AIRCRAFT TO ACT AS A RECEIVER DURING AIR-TO-AIR REFUELLING
J. BRADLEY *In* AGARD Flight Test Tech. 16 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

A brief description is given of the air to air refueling equipment and techniques presently used in the RAF. The handling and performance tests needed to clear a new receiver type aircraft are described, together with some of the results obtained when large transport aircraft are used in the receiver role. R.S.F.

N84-34406# Royal Aircraft Establishment, Farnborough (England).
REFERENCE SYSTEMS FOR THE EVALUATION OF DEAD-RECKONING NAVIGATION EQUIPMENT
R. F. STOKES and S. G. SMITH *In* AGARD Flight Test Tech. 17 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

Aircraft dead reckoning navigation systems present particular problems in their assessment, and diagnosis in development where a continuous measurement of their error pattern is required. The need for long range, long duration flights with a continuous high accuracy reference led to the development of an integrated navigation system. The recorded data is processed post-flight in a Kalman filter which is used to estimate the inertial system errors. The final reference is formed by compensating the inertial outputs for these errors and has the properties of high accuracy, low noise, and continuous availability. Although simple in concept the implementation of such a scheme is complex. The major problem lies in constructing suitable mathematical models of the various equipments, and the technique of pre-processing is described. The second difficult area is that of obtaining the statistical information regarding the performance of the equipments in a form suitable for inclusion in the models. Although the reference is produced off-line, it is possible to implement the techniques on-line. R.S.F.

N84-34407# Aeritalia S.p.A., Caselle Torinese (Italy). Combat Aircraft Group.
AUTOPILOT PERFORMANCE EVALUATION TORNADO EXPERIENCE AND FUTURE APPLICATIONS
R. CARABELLI and R. PELISSERO *In* AGARD Flight Test Tech. 17 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

The Tornado autopilot system performance was evaluated. Problems affecting equipments, control laws, system integration were studied. A digital processor to analyze data from fast data transmission lines and an avionic integration rig with real time closed loop simulation capability were employed. New facilities tailored to cover as much as possible of weapon system testing needs are developed to cope with requirements from oncoming projects which rely upon more advanced technologies. Trends for next trials conduct are discussed and engineering activities and ground facilities needs like simulation and system rig, required to support flight testing of prototype avionic systems are outlined. E.A.K.

N84-34408# Royal Aircraft Establishment, Bedford (England)
ASSESSING PILOT WORKLOAD IN FLIGHT
A. H. ROSCOE *In* AGARD Flight Test Tech. 13 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

A method by which a pilot's heart rate can be recorded to support, or occasionally question, his subjective rating of workload is described. Examples from RAE Bedford trials are presented to illustrate the technique, and the BAe 146 crew complement certification exercise is described. A flight experiment which compares heart rate levels and workload ratings in a more scientific manner is described. The rationale for using heart rate in this way is discussed. E.A.K.

N84-34409# Naval Air Test Center, Patuxent River, Md. Systems Engineering Test Directorate.
SIMULATION APPLIED TO THE AVIONICS SYSTEM TESTING IN THE F/A-18
A. C. CRUCE *In* AGARD Flight Test Tech. 9 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

The use of simulation in support of flight test which can be used to leverage the flight test available in many programs to adequately cover the complex test requirements of modern systems is discussed. The simulation facility is designed around the multiplex data bus structure found in modern aircrafts. This architecture makes the simulation problem easier but is not a necessary condition for the application of these techniques to support flight test. However, for nonmultiplex bus systems the simulation is by nature more single purpose and the difficulty in changing the simulation facility from one aircraft type to another is greatly increased. The facility is used to support F/A-18 and AV-8B avionics

system testing. The facility is being expanded to support flight system and flight control computer testing for the F/A-18, AV-8B, F-4S, F-14, and X-29 aircraft. It is asserted that the use of simulation to supplement flight test offers the opportunity to test highly complex and highly integrated weapons systems within the level of test assets expected to be available in future programs.
E.A.K.

N84-34410# Aeroplane and Armament Experimental Establishment, Boscombe Down (England).
FLIGHT TEST TECHNIQUES EMPLOYED IN THE NIMROD MR MK 2 WEAPON SYSTEM PERFORMANCE TRIALS
L. M. DUTTON *In* AGARD Flight Test Tech. 13 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

The potential accuracy of the Nimrod's ASW systems which was matched by the precision of trial data collection, in the air and on and below the sea surface is shown. To gain such precision, the aircraft were instrumented and the majority of the trials were conducted at the Atlantic Undersea Test and Evaluation Center (AUTEC) Range. The trial analysis technique which has to match the variety of combinations of the data which are needed to make a statement on overall system performance is outlined. It is shown how forward trial planning is drawing on experience gained so far.
E.A.K.

N84-34411# Air Force Flight Test Center, Edwards AFB, Calif.
F-16 AND A-10 DIFFRACTION OPTICS HEAD UP DISPLAY (HUD) FLIGHT TEST EVALUATION
H. G. F. WURFEL *In* AGARD Flight Test Tech. 19 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

The introduction of wide field of view (WFOV) diffraction optics head-up displays (HUDs) which provide potentially more capability than has been previously available is discussed. A direct head up, pilot to real world interface via video raster and stroke written symbology permits low level maneuvering flight at night and provides at least a survivable capability. Integration of the WFOV HUD with the F-16 and A-10 aircraft provides a useful ability to make single seat night attack a realistic and effective alternative. The major planning activities and test results of the F-16 and A-10 head-up displays (HUD) evaluations were examined. Relevant test procedures and test techniques applicable to HUD testing in general and night video raster testing in particular are reviewed. The unique test requirements and safety aspects of night attack system testing are addressed.
E.A.K.

N84-34412# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
IN-FLIGHT ACCURACY AND COVERAGE TESTS OF ESM- AND ECM-SYSTEMS
H. BOTHE and K. KLEIN *In* AGARD Flight Test Tech. 9 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

Electronic Support Measurement Systems (EMS) and Systems for Electronic Counter Measures (ECM) of military aircraft require antennas for signal transmission and reception. The coverage of these antennas is an important parameter in the effectiveness of the systems. As the radiation patterns of aircraft antennas are interfered to a high degree by the structure and configuration of the aircraft, flight tests are conducted in order to prove the coverage of the above-mentioned systems. In addition, the accuracy of ESM systems, which measure the direction of arrival of an incoming radio frequency signal on board, is mostly influenced by the characteristics of the receiving antennas and hence has to be determined in flight too. A system was developed which covers the aforesaid requirements. It consists of 3 subsystems: a ground emitter system illuminating the target up to frequencies of 18 GHz; an on-board receiving system, which detects the signals received by the antennas of the system under test; and a data acquisition and transmission system, which transfers on-board and ground data to a digital computer for quick-look and data processing. Results of accuracy and coverage tests are given.
R.J.F.

N84-34413# Messerschmitt-Boelkow-Blohm G m b.H., Munich (West Germany) Unternehmensbereich Flugzeuge
FLIGHT TEST TECHNIQUES USED FOR PROOF OF STRUCTURAL INTEGRITY OF TORNADO WHEN CARRYING EXTERNAL STORES
M. PEHL, F. J. RUDOLPH, E. BERTOLINA, and A. IPPOLITO *In* AGARD Flight Test Tech. 25 p (SEE N84-34396 24-01) Jul. 1984 refs Prepared in cooperation with Aeritalia S.p.A., Torino, Italy
Avail: NTIS HC A16/MF A01

The multirole characteristic of the MRCA (TORNADO) aircraft results in an almost universal capability to carry an array of existing stores in every conceivable combination, within different operational flight envelopes. In order to verify the structural integrity of the aircraft when carrying stores, a comprehensive flight loads survey program was set up to validate the store aerodynamics used for the design of pylon attachments to the main structure, the pylons, and the store structure. A description of the overall stores flight test program including the instrumentation and calibration procedures, the flight test techniques and a presentation of the to date available data are given. Finally an explanation of the most significant problems occurred during this task are pointed out.
R.J.F.

N84-34414# Centre d'Essais en Vol, Istres (France). Service Methodes et Moyens d'Essais.
REAL TIME FLIGHT TEST CONDUCTION AND MONITORING [CONDUITE ET SURVEILLANCE DES ESSAIS EN VOL EN TEMPS REEL]
B. SCHERRER *In* AGARD Flight Test Tech. 13 p (SEE N84-34396 24-01) Jul. 1984 In FRENCH
Avail: NTIS HC A16/MF A01

The principle responsibility of the flight test center at Istres is to conduct tests of performance, structures, and propulsion. Located in a flat region with a favorable climate in the south of France, the center is ideal for conducting the more dangerous kinds of tests such as spin, extended flight domain, and tests of engine extinction and relighting. A special effort is devoted to means and equipment for increasing the benefits and safety of such tests, especially those which cannot be repeated without increasing potential risks. The measuring infrastructure used is described including telemetry, trajectory calculation, the computation center, and information presentation which permits the simultaneous management and supervision of more tests during their execution. Examples of these techniques are described including the CIGALE system and the cinetheodolites, and radar.
Transl. by A.R.H.

N84-34415# Avions Marcel Dassault-Breguet Aviation, Istres (France). Dept. Moyens de Mesure et Essais.
FLIGHT TESTING AND REAL TIME DATA PROCESSING FOR DEVELOPMENT AND INTEGRATION OF WEAPON SYSTEMS
J. COSTARD *In* AGARD Flight Test Tech. 12 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

Flight tests conducted on thirteen different families of aircraft by a total of 1259 personnel at the Istres, Bretigny, and Cazaux test centers are discussed. The advantages of using real time telemetry and data processing are examined. Signal reception and processing facilities used at each center for flight tests of the airframe, the effects of external loads, certification, weapons systems development, EMC-EMI compatibility, and reconnaissance capabilities are described.
Transl. by A.R.H.

N84-34416# Grumman Aerospace Corp., Calverton, N.Y.
REAL TIME TESTING: THE NEXT GENERATION
J. D. DINKEL *In* AGARD Flight Test Tech. 8 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

The development of a new display and control system for use with an automated telemetry system for on-line processing of flight test data is discussed. The requirements set for the new system and the design developed to meet them are discussed.
R.J.F.

N84-34417# Royal Aircraft Establishment, Bedford (England).
USING AN AIRBORNE CO2 CW LASER FOR FREE STREAM AIRSPEED AND WINDSHEAR MEASUREMENTS
A. A. WOODFIELD and J. M. VAUGHAN (Royal Signals and Radar Establishment, Malvern, England) *In* AGARD Flight Test Tech. 18 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

Applications of a Laser True Airspeed System (LATAS) in flight are described with examples from trials with an exceptionally reliable and rugged system installed on the HS 125 research aircraft. The LATAS system is briefly described. Its remote sensing capability makes it particularly useful for measuring airflow conditions before they are disturbed by the aircraft. This is demonstrated with results from flight tests of LATAS as a self contained pressure error measurement system (when combined with total pressure and total temperature measurements), and also results from windshear measurements in a severe thunderstorm downburst (microburst). The possible extension of the system to measure turbulence by using a conical scanning beam is described, and several other possible uses such as an airspeed sensor that can discriminate instantaneously between small amplitude gusts and large disturbances for driving an intelligent autothrottle or a combined 3 axis air data and 3 axis ground velocity sensor for helicopters. R.J.F.

N84-34418# Air Force Western Space and Missile Center, Vandenberg AFB, Calif.
NAVSTAR GPS APPLICATIONS TO TEST AND TRAINING
K. A. GEORGE and J. B. MCCONNELL *In* AGARD Flight Test Tech. 7 p (SEE N84-34396 24-01) Jul. 1984 refs
Avail: NTIS HC A16/MF A01

A fifteen-month study on the uses of the NAVSTAR Global Positioning System (GPS) at the National Ranges operated by the United States Army, Navy, and Air Force for weapon system development, test, and training is summarized. It was conducted by a special triservice committee chartered by the Office of the Undersecretary of Defense for Research and Engineering. The primary objectives were to evaluate GPS application areas, identify and analyze technical issues, and recommend cost and mission effective applications. It was found that GPS technology will have a wide variety of use at the ranges with significant cost advantages and that the technical issues, some of which are quite challenging, do not pose serious obstacles to widespread employment. It will be necessary to design and develop a new family of GPS receiver hardware for range uses since the current generation of receivers does not satisfy the accuracy, data rate and continuity, and size demands of the typical range environment. The study provided the family definitions for GPS range equipment and the basis for a joint service development program under Air Force direction at Eglin AFB, Florida. R.J.F.

N84-34419# Boeing Commercial Airplane Co., Seattle, Wash.
AN EXTENDED REAL-TIME MICROWAVE AIRPLANE POSITION SYSTEM
P. L. PEREBOOM, J. H. LINCOLN, and R. N. SNOW *In* AGARD Flight Test Tech. 12 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

A real time Microwave Airplane Position System (MAPS) is currently being used by the Boeing Company for noise certification testing. The system measures ranges and range rates from several ground transponders to an airplane, and computes the airplane position using a Kalman Filter algorithm. Airplane position relative to a fixed Earth coordinate system is available for recording and cockpit display five times per second. Comparisons of position data from MAPS with data from Boeing phototheodolite systems have shown that MAPS accuracy is better than two meters when the airplane is within the design envelope of the ground transponder array. Unfortunately, the minimum practical altitude of a sign envelope is 50 meters, so MAPS cannot be used for takeoff and landing tests. To bridge the gap from the ground to 50 meters altitude, an alternate source of altitude information is required. The problems of obtaining absolute altitude information from other sources have been well documented. This report examines the inclusion of these alternate sources of altitude data in the Kalman Filter used by MAPS. Filter initialization was modified to include the calculation of bias errors found in the other sources derived from the original filter's estimate of airplane location. The measurement matrix was expanded to include the alternate sources in a manner that places emphasis on the most reliable sources of data with respect to the airplane's location. B.W.

N84-34420# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugmechanik.
GENERAL INTEGRATED MULTIPURPOSE INFLIGHT CALIBRATION SYSTEM (GIMICS)
R. GANDERT and R. KARMANN *In* AGARD Flight Test Tech. 17 p (SEE N84-34396 24-01) Jul. 1984
Avail: NTIS HC A16/MF A01

In 1985 the new Advanced Technology Testing Aircraft System (ATTAS) will be operable at the DFVLR in Braunschweig. Owing to the wide application spectrum of ATTAS and the varied range of users, a flight test instrumentation system having a very high degree of flexibility and testability was required. It was therefore decided that a versatile built in test and calibration system called GIMICS should form an integral part of the ATTAS flight test instrumentation system. GIMICS is an intelligent, computer controlled system having dedicated access to the ATTAS subsystems. The system architecture and application flexibility of GIMICS will be presented. Author

N84-34421*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
THE DEVELOPMENT OF AN AIRBORNE INSTRUMENTATION COMPUTER SYSTEM FOR FLIGHT TEST
G. A. BEVER *In* AGARD Flight Test Tech. 13 p (SEE N84-34396 24-01) Jul. 1984 refs Previously announced as N84-20521 Prepared in cooperation with NASA. Dryden Flight Research Facility
Avail: NTIS HC A16/MF A01 CSCL 01D

Instrumentation interfacing frequently requires the linking of intelligent systems together, as well as requiring the link itself to be intelligent. The airborne instrumentation computer system (AICS) was developed to address this requirement. Its small size, approximately 254 by 133 by 140 mm (10 by 51/4 by 51/2 in), standard bus, and modular board configuration give it the ability to solve instrumentation interfacing and computation problems without forcing a redesign of the entire unit. This system has been used on the F-15 aircraft digital electronic engine control (DEEC) and its follow on engine model derivative (EMD) project and in an OV-1C Mohawk aircraft stall speed warning system. The AICS is presently undergoing configuration for use on an F-104 pace aircraft and on the advanced fighter technology integration (AFTI) F-111 aircraft. Author

N85-15664# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
OPERATIONAL LOADS DATA
Loughton, England Aug. 1984 303 p refs In ENGLISH and FRENCH Conf. held in Sienna, Italy, 2-6 Apr. 1984 (AGARD-CP-375; ISBN-92-835-0363-5; AD-A149025) Avail: NTIS HC A14/MF A01

General principles followed in acquiring data on operational loads sustained by NATO aircraft, both fixed and rotary wing, in normal service were examined. Current and developing loads data acquisition programs were compared. The techniques used and data obtained from work on a variety of aircraft types were reported; microprocessor-based systems were seen as providing the essential technology for major advances in this field. Although the main emphasis was on fatigue loads, the acquisition of design loads data was also discussed, together with the validity of current data bases for loads calculations on high-agility designs representative of the next generation of combat aircraft. For individual titles see N85-15665 through N85-15683.

N85-15665# Ministry of Defence, London (England). Materials and Structures Dept.
OPERATIONAL LOADS MEASUREMENT: A PHILOSOPHY AND ITS IMPLEMENTATION
D. M. HOLFORD and J. R. STURGEON *In* AGARD Operational Loads Data 22 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

A philosophy of operational data acquisition, for structural objectives, within the general field of in-flight load measurement is reviewed, highlighting the constraints such activities place on the data acquisition system. One such system which can be tailored

to perform a variety of tasks ranging from the collection of time histories of flight parameters or strain gauges to complex fatigue load analyses throughout the airframe is described. The system comprises a digital cassette recorder and a data acquisition unit within which a microprocessor is used for control of data acquisition and in-flight data analysis. System requirements in terms of accuracy, bandwidth and sampling rates are discussed for a range of aircraft types and operating conditions. The various modes of operation of the system are illustrated by examples drawn from operational experience with the system. These demonstrate the capability of the system to produce data suitable for automatic analysis in a variety of operational environments in both fixed and rotary wing aircraft. The examples clearly show the value of studying operational data in terms of fatigue life management, fatigue life monitoring, operational practices and design procedures. B.W.

N85-15666# McDonnell Aircraft Co., St. Louis, Mo. Structural Dynamics and Loads Dept.

THE F-15 FLIGHT LOADS TRACKING PROGRAM

J. T. JOHNSTON, R. E. PINCKERT, and R. A. MELLIERE *In* AGARD Operational Loads Data 7 p (SEE N85-15664 07-01) Aug. 1984 refs

Avail: NTIS HC A14/MF A01

The F-15 flight loads tracking program is described. The tracking program consists of four phases: (1) data collection; (2) data reduction; (3) fatigue damage analysis; and (4) fleet management. Data collection is accomplished with a multi-channel recorder and a load factor (g) exceedance counter. Twenty percent of the fleet is equipped with the multi-channel recorder and every F-15 has a g exceedance counter installed. After the fleet data have been reduced by the Air Force it is sent to McDonnell Aircraft for conducting fatigue damage analyses. Quarterly Service Aircraft Fatigue Estimate (SAFE) reports inform the Air Force how much fatigue life has been expended on each aircraft. These reports are used for establishing inspections and aid in fleet management of the F-15 Eagles. This mature program, approaching, 1,000,000 flight hours, has been valuaable for solving in-service structural problems, understanding why the problems occurred, developing repairs, and for redesign. Future aircraft design will also benefit from this information. B.W.

N85-15667# National Aerospace Lab., Amsterdam (Netherlands).

STRUCTURAL LOAD MEASUREMENTS ON A NORTHROP NF-5A

D. J. SPIEKHOUT *In* AGARD Operational Loads Data 15 p (SEE N85-15664 07-01) Aug. 1984

Avail: NTIS HC A14/MF A01

Load measurements were carried out on an NF-5A aircraft instrumented with a large number of strain gage bridges in the wing and the tail surfaces. Measurements included: (1) Specific stationary maneuvers; (2) Specific dynamic maneuver conditions, and (3) Complete mission segments typical for RNLAF-operational conditions. Using ground calibration results, recorded strains were converted to sectional loads and with flight parameters like V, H, acc. etc., stored in a structural load data base (15 flights covering 7 configurations and 715 measuring runs). By means of an interactive computer program the data stored in this data base are easily accessible. The results can be presented in tables or in graphical form. The Data Base may be used to evaluate the effect of changes in operational procedures, stores and store configurations on the fatigue load experience in various structural areas. A general description is given of the instrumentation used, the data handling and the flight conditions that were recorded. The possible use of the data base is illustrated by means of a number of examples. B.W.

N85-15668# Naval Air Development Center, Warminster, Pa. Airframe Engineering Branch

NAVY OPERATIONAL LOADS DATA SOURCES AND SYSTEMS

A. H. JOHNSON and M. J. DUBBERLY (Naval Air Systems Command) *In* AGARD Operational Loads Data 20 p (SEE N85-15664 07-01) Aug. 1984

Avail: NTIS HC A14/MF A01

An overview of the Navy's total Aircraft Structural Life Surveillance Program is presented. Current Fatigue Monitoring Program operational achievements and costs are described. The loads data acquisition systems for the F-14, F-18, A-7, and A-3 aircraft are also described. Future expectations regarding operational features, results, and costs are discussed. Operational loads data from the Tactical Air Combat Training System for air combat training, and the 70 mm film system for landing loads, are also described. B.W.

N85-15669# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).

OPERATIONAL LOADS DATA EVALUATION FOR INDIVIDUAL AIRCRAFT FATIGUE MONITORING

R. SCHUETZ and R. NEUNABER *In* AGARD Operational Loads Data 23 p (SEE N85-15664 07-01) Aug. 1984 refs

Avail: NTIS HC A14/MF A01

The utility of individual aircraft tracking (IAT) as an effective instrument for introducing the necessary maintenance activities which need to be adapted individually to each aircraft is examined. One of the most important activities within the IAT scope is the processing of operational loads data in order to calculate to consumed fatigue life of individual aircraft. The installed operational service load recording systems for military aircraft within the German Air Force include logforms, counting accelerometers and digital flight recorders. Under consideration are sytems for direct measurement of loads and damage. The main activities of individual aircraft tracking include: (1) loads and component data acquisition; (2) damage calculation; (3) calculation of allowable fatigue life; (4) prediction of maintenance actions; (5) derivation of standard load sequences or spectra; (6) cost effectiveness consideration; (7) verification of fatigue load monitoring; and (8) selection of load monitoring systems. B.W.

N85-15670# Messerschmitt-Boelkow-Blohm G.m.b.H., Toulouse (France). Airbus Program

STRUCTURAL FLIGHT LOAD MEASUREMENT DEMONSTRATION OF STRUCTURAL INTEGRITY

E. RAUSCHER *In* AGARD Operational Loads Data 9 p (SEE N85-15664 07-01) Aug. 1984

Avail: NTIS HC A14/MF A01

Structural flight load testing is an important part of the certification of an aircraft. Calibration of strain gauges and bridge selection and evaluation of flight parameters for fatigue and static test problems are described. Procedures presented as an example here were used for flight testing on different types as fighters and military and civilian transport aircrafts. There are several evaluation methods for short and long flight periods to check design loads for static and fatigue criteria. The Maximum Likelihood method is used to investigate aerodynamic coefficients. Counting procedures are used for statistical purposes. B.W.

N85-15671# British Aerospace Aircraft Group, Stockport (England). Structures Dept.

ADVANCED FATIGUE MONITORING ON SERVICE AIRCRAFT

A. WALKDEN *In* AGARD Operational Loads Data 16 p (SEE N85-15664 07-01) Aug. 1984 refs

Avail: NTIS HC A14/MF A01

An exercise on a Royal Air Force aircraft where typical service data was collected to: (1) define the loading actions which should be included in a full scale wing fatigue test; (2) enable theoretical fatigue lives for wing, tailplane, fin and undercarriage to be calculated; and (3) define which parameters might be measured in a comprehensive fit of advanced fatigue meters so that the life of the main structural components of each aircraft could be accurately measured is described. R.J.F.

N85-15672# British Aerospace Aircraft Group, Preston (England).

EXPERIENCES OBTAINED FROM SERVICE FATIGUE MONITORING EXERCISES

A. P. WARD *In* AGARD Operational Loads Data 16 p (SEE N85-15664 07-01) Aug. 1984 refs

Avail: NTIS HC A14/MF A01

Two recent empennage fatigue load monitoring exercises involving the Jaguar and the Jet Provost aircraft are described. In each case digital recording technique were used and rainflow analysis techniques were employed to determine fatigue loading matrices. Problems were encountered in analysing the recorded data and these are enumerated. The more recent assessment of the Jet Provost provided a high rate of data recovery and benefited

from experiences gained from the Jaguar exercise. The conventional method of assessing fin load spectra was found not to provide an adequate safeguard for the later Marks of Jet Provost where significant changes in operating patterns and speeds could not be taken into account adequately by theoretical methods. R.J.F.

N85-15673# Canadair Ltd., Montreal (Quebec). Military Support, Technical Dept.
CF-5 VERTICAL STABILIZER FLIGHT LOAD SURVEY
N. N. TRONG *In* AGARD Operational Loads Data 12 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

In order to arrive at a reliable life prediction for the CF-5 vertical stabilizer, a flight load survey was carried out to determine the load spectra. Specific missions were flown with an instrumented aircraft and the resulting load spectra were factored to represent the reported mission profiles for squadron aircraft. Subsequently, it was decided to monitor a percentage of the fleet during routine operation and derive more representative spectra. The results of the flight load survey and the load monitoring program were compared. The effect of the results on fatigue life prediction and damage tolerance analysis is discussed. It is concluded that a short flight test program gives valid results which are useful for immediate use, and that the fleet wide load monitoring program consolidates and verifies the findings. R.J.F.

N85-15674# General Dynamics Corp., Fort Worth, Tex. F-16 Loads and Criteria Dept.
F-16 FORCE MANAGEMENT, YESTERDAY, TODAY AND TOMORROW
R. L. CULP *In* AGARD Operational Loads Data 15 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

United States Air Force regulations specify that a Force Management Program will be established for each aircraft system within its inventory. The approach taken by General Dynamics to fulfill the objectives of the Force Management Program for the F-16 aircraft is discussed. The methodology employed, the current status and the future plans for the F-16 Force Management Program in the areas of operational data acquisition, processing and airframe structural maintenance planning are discussed in detail. R.J.F.

N85-15675# Army Research and Technology Labs., Fort Eustis, Va. Applied Technology Lab.
US ARMY HELICOPTER OPERATIONAL FLIGHT LOADS
D. J. MERKLEY and H. K. REDDICK, JR. *In* AGARD Operational Loads Data 26 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

The findings from the Army's helicopter service usage programs and the Operational Loads Survey program are discussed. The development and capability of the Structural Integrity Recording System is described. R.J.F.

N85-15676# Westland Aircraft Ltd., Yeovil (England).
HELICOPTER DATA ACQUISITION IN WHL
F. S. GRAINGER *In* AGARD Operational Loads Data 17 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

An approach to loads monitoring designed to fulfil two requirements is discussed. The first requirement is the elimination, as far as possible, of costly parts being thrown away because of overly conservative assumptions with respect to usage. The second requirement is to assure the assumed safety standards by knowledge of the in-service aircraft utilization. Specific problems appropriate to the helicopter make this task more difficult, but nevertheless the fundamental steps were taken to commence data acquisition. The nature of the task requires considerable aircraft management to ensure that as many role configurations are covered as possible. Since the data is acquired in real time, the acquisition of a statistically significant amount will be spread over the next few years. Nevertheless, early signs indicate that a considerable number of improvements will be accrued from even early data received. This approach also provides the ability to encompass new roles for an in-service aircraft type, in a much more rigorous way than current estimating methods. The methodology should also provide an information database against which to test loading theories (such as random load) and extend statistical scatter knowledge on times. R.J.F.

N85-15677# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany). Load Criteria Section.
EVALUATION OF OPERATIONAL LOADS TO VERIFY STRUCTURAL DESIGN
H. STRUCK and H. BALKE *In* AGARD Operational Loads Data 16 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

A load evaluation method derived from operational maneuvers and the design requirements applied were presented. The method is based on the hypothesis that all maneuvers trained and flown by the Air Force can be standardized. Relevant parameters that are suitable to describe the maneuver time history with respect to load analysis were chosen. The standardization of maneuver parameters is demonstrated for two fighter aircraft and a few maneuver types. The correlated parameters necessary to derive structural loads, including control surface deflections can be determined, by standardized maneuvers. Operational loads on main structural components are evaluated by application of maneuver model. Extreme operational loads evaluated with the maneuver model and those determined by the design requirements are compared. E.A.K.

N85-15678# Canadair Ltd., Montreal (Quebec).
TUTOR (CL-41A) TAIL FLIGHT LOAD SURVEY
A. PAQUIN and J. SKOTNICKI (National Defence Headquarters) *In* AGARD Operational Loads Data 15 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

An inflight structural failure of the Canadair Tutor aircraft horizontal tail fitting resulted in a flight load survey. An instrumented test aircraft was flown to the extremes of its structural envelope, and strains were recorded at 43 different locations on the rear fuselage and the empennage of the aircraft. The test instrumentation, the calibration performed on the test article, and the resulting formulation of load equations for estimating shear, bending moment and torque at various locations on the rear fuselage, the vertical and the horizontal stabilizer are described. The various missions and maneuvers flown to gather the necessary data and the data acquisition, verification and reduction methods are discussed. E.A.K.

N85-15679# Avions Marcel Dassault, Saint-Cloud (France).
AEROELASTIC ANALYSIS AND THE IDENTIFICATION OF FLIGHT LOADS [ANALYSE AEROELASTIQUE ET IDENTIFICATION DES CHARGES EN VOL]
C. PETIAU and M. DELAVIGNE *In* AGARD Operational Loads Data 22 p (SEE N85-15664 07-01) Aug. 1984 refs In FRENCH
Avail: NTIS HC A14/MF A01

A coupling procedure was developed for static analysis and load calculation in which pressure loads, obtained using aerodynamic theory, are transferred directly onto the finite element model. This sophisticated method singularly complicates the problem of smoothing models of the results of wind tunnel or flight tests. Processes of identification were studied with a view to easily reflecting the results of flight tests in complex aeroelastic models and to review, as rapidly as possible, the calculations justifying the structure and the static loads from ground tests. Transl. by A.R.H.

N85-15680# British Aerospace Aircraft Group, Preston (England).
TORNADO: STRUCTURAL USAGE MONITORING SYSTEM (SUMS)
A. P. WARD *In* AGARD Operational Loads Data 13 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

The background for the establishment of the tornado structural usage monitoring system (SUMS) is reviewed. The possible monitoring methods and the decision to opt for two approaches using flight parameters and load calibrated strain gauges are amplified. The calibration and instrumentation requirements are described and the use of SUMS data is discussed. E.A.K.

N85-15681# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
KEEPING UP WITH OPERATIONAL LOADS IN THE FRENCH AIR FORCE: DEFINING NEW EQUIPMENT [SUIVI DES CHARGES EN SERVICE DANS L'ARMEE DE L'AIR FRANCAISE DEFINITION D'UN NOUVEAU MATERIEL]
L. BARANES and J. P. CORNAND *In its* Operational Loads Data 12 p (SEE N85-15664 07-01) Aug. 1984 In FRENCH
Avail: NTIS HC A14/MF A01

To remedy the lacunae of present statistical accelerometers for following the operational loads of French Air Force aircraft a system was developed which offers the possibility of acquiring multiple parameters in association with a better data reduction logic. Topics covered include: (1) following real loads with emphasis on problems posed by using simple accelerocomputers; (2) defining the characteristics of the system developed and experience using the prototype; (3) a description of the series version of the prototype system for studying structural damage (SPEES); and (4) applications envisioned and future development considered for SPEES. Transl. by A.R.H.

N85-15682# Aeritalia S.p.A., Torino (Italy). Gruppo Velivoli da Combattimento.
FLIGHT PARAMETERS RECORDING FOR STRUCTURE FATIGUE LIFE MONITORING
F. STAROPOLI *In* AGARD Operational Loads Data 7 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

The Tornado flight parameter recording system and its role in structure fatigue life monitoring are described. The system performs both on-board and on-ground recording and analysis functions. The fatigue analysis block program, data filtering subroutine, and damage calculation subroutine are described. The benefits of the system to fleet life management and safety are discussed.
E.A.K.

N85-15683# Aeronautical Systems Div., Wright-Patterson AFB, Ohio. Force Management Group.
USAF APPROACH TO AIRBORNE STRUCTURAL DATA RECORDING: AIRBORNE DATA ACQUISITION MULTIFUNCTION SYSTEM (ADAMS)
R. J. VELDMAN *In* AGARD Operational Loads Data 3 p (SEE N85-15664 07-01) Aug. 1984 refs
Avail: NTIS HC A14/MF A01

Current approaches to structural recording and considerations of future instrumentation systems are presented. The current state of the art of microprocessor technology lends itself to the development of airborne recording systems capable of onboard processing and data compression with solid state data storage. Such systems reduce supportability requirements because of increased reliability inherent to solid state electronics while providing processing and self diagnostic capability which were heretofore unachievable. These microprocessor based systems which record structural operational information are designated within the Air Force as the (ADAMS) airborne data acquisition multifunction system. E.A.K.

N85-16731# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
DESIGN FOR TACTICAL AVIONICS MAINTAINABILITY
Loughton, England Oct. 1984 281 p refs In ENGLISH and FRENCH Conf. held in Brussels, 7-10 May 1984
(AGARD-CP-361; ISBN-92-835-0366-10; AD-A149199) Avail: NTIS HC A13/MF A01

Advanced methods and tools to support design for avionic maintainability and testability are discussed. Both hardware and software design for maintainability issues and approaches are addressed. For individual titles see N85-16732 through N85-16756.

N85-16732# Breguet-Aviation, Saint Cloud (France).
OBJECTIVES IN STUDYING THE MAINTAINABILITY OF AIRCRAFT SYSTEMS [OBJECTIFS D'ETUDE DE LA MAINTENABILITE DES SYSTEMES AVIONNES]
M. COURTOIS *In* AGARD Design for Tactical Avionics Maintainability 10 p (SEE N85-16731 08-01) Oct. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

Increased use of electronic equipment in combat aircraft results in an increased cost of avionics and of the total purchase price of aircraft. The maintenance of more numerous, more complex, and more costly electronic systems involves maintenance methods which are themselves both numerous and complex. Given the very important acquisition costs of future systems (supplies and replacements will be limited), the maintenance of electronic systems will be an essential function in assuring the maximum operational availability of aircraft. System costs must be reduced to allow for troubleshooting and the verification of aircraft equipment. Different levels of maintenance are analyzed using solutions developed for the Mirage aircraft. Specifications for the maintainability of all equipment, at all levels of maintenance must be established as a function of system architecture and the tests to be conducted. These specifications must be considered from the beginning of prototype equipment study. Transl. by A.R.H.

N85-16733# Naval Surface Weapons Center, Dahlgren, Va.
JOINT SERVICE DESIGN FOR TESTABILITY PROGRAM
W. L. KEINER *In* AGARD Design for Tactical Avionics Maintainability 5 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

As electronics become more complex and more critical to weapon system operation, there is an acknowledge that new designs must be somehow constrained to be more easily tested or they may become completely unsupportable. As a result, design for testability is becoming increasingly important to the services. The Joint Logistics Commanders (JLC) Panel on Automatic Testing established a comprehensive program to coordinate the development of testing technology and its management within the military services. One important part of the program deals with the design aspects of the prime equipment which permit weapon systems to be more easily and confidently tested using automatic test resources. A JLC Testability Subpanel was established under the JPLC Panel to provide acquisition support tools and research and development programs in design for testability (DFT).
Author

N85-16734# STTE, Paris (France).
THE EMBEDDED TEST (BIT): IMPACT ON THE TOTAL COST OF POSSESSION [TEST INTEGRE (BIT): IMPACT SUR LE COUT GLOBAL DE POSSESSION]
I. M. KERVELLA *In* AGARD Design for Tactical Avionics Maintainability 4 p (SEE N85-16731 08-01) Oct. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

The application of an embedded (built-in) test to digital systems is analyzed. Technical and operational aspects of such tests are discusserd and their characteristics as experienced by the French Air Force, are described. The total cost of having built-in tests comprises development, purchase, and operational costs. Results show that the cost of acquiring an embedded test is lightly increased, but is sharply diminished with respect to the cost of acquiring the on-line test formerly used. The cost of using the test should be likewise lower. By taking into consideration the observed operational results, the choice of the embedded test is shown to be satisfactory with respect to service rendered and cost. Transl. by A.R.H.

N85-16735# Aeritalia S.p.A., Torino (Italy).
STUDY AND REALISATION OF A 3RD LEVEL MAINTENANCE CENTER BASED ON ATE SYSTEMS UTILIZATION
F. BOZZOLA *In* AGARD Design for Tactical Avionics Maintainability 7 p (SEE N85-16731 08-01) Oct. 1984
Avail: NTIS HC A13/MF A01

The development of the actual working program for the realisation of a 3rd level maintenance center for the avionics electronics modules of the MRCA Tornado aircraft is discussed. Starting from the initial requirement and from the primary goals of the program, and going through the different study and data

collection phases, the adopted general criteria for the definition of the technical characteristics and quantities of the automatic test equipment to be used are described taking into account the testability problems shown by the different electronic boards to be maintained; problems connected with the boards available documentation are also measured. All the problems related to the management, installation, programming, interfacing, expandability and flexibility of the adopted automatic test equipment are discussed. In addition, using the actual maintenance problems faced during the activity development as a starting point, some general maintainability criteria that can be taken into account for similar future programs are outlined. Author

N85-16736# Ferranti Ltd., Edinburgh (Scotland). Product Support Dept.
A PRACTICAL EXAMPLE OF REDUCING LIFE CYCLE COSTS AND INCREASED AVAILABILITY
R. P. F. LAUDER *In* AGARD Design for Tactical Avionics Maintainability 11 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The principles underlying effective operational availability are explored and quantified. It is shown that although large sums of money are expended on producing reliable components, these are vitiated if the end equipment is not exposed to a reliability growth program, because only 10% of the calculated mean time between failures (MTBF) will be realised in practice. It is claimed that costs can be reduced by using common commercial components without loss of MTBF provided it is followed by a reliability growth program. A practical example is given of the expensive and time consuming steps which have to be taken in resucing a low MTBF radar, and increasing its availability. The steps and the methodology leading to them are described and the results shown. M.G.

N85-16737# STTE, Paris (France).
ATE USER'S VIEW ON DESIGN FOR MAINTAINABILITY
J. M. G. B. MASCARENHAS *In* AGARD Design for Tactical Avionics Maintainability 16 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The main features of the Automatic Test Equipment (ATE) that PoAF is using are described. The hardware and software capabilities and limitations are emphasized. Techniques available for test program generation and validation are examined. Views on board design for maintainability (particularly with TE) are presented. B.W.

N85-16738# Dowty Electronics Ltd., London (England). Controls Div.
EXPERIENCE OF ONE UK ELECTRONIC EQUIPMENT SUPPLIER WITH BITE ON ENGINE/FLIGHT CONTROL SYSTEMS OVER THE PAST TEN YEARS
R. DEGAYE *In* AGARD Design for Tactical Avionics Maintainability 18 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

Early analogue electronic controllers for gas turbine control and A/C flight control applications were complex and poorly understood by A/C maintenance personnel - they were relatively easy to remove from their installation compared with the surrounding hydro-mechanical components. Both of these factors led to high unconfirmed defect rates, since these electronic black boxes were usually the first to be blamed for system problems. There was a clear need for some kind of built in fault identification system. The history of Dowty electronics involvement in BITE over the last ten years is traced. The techniques used, successes and failures, and customer reactions are described. A range of civil and military, analogue and digital applications are discussed and four civil applications described in detail. B.W.

N85-16739# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
BUILT-IN-TEST FOR FIRST LINE TESTING
W. R. H. BEHM *In* AGARD Design for Tactical Avionics Maintainability 7 p (SEE N85-16731 08-01) Oct. 1984
Avail: NTIS HC A13/MF A01

Built-In-Test requirements were established more than a decade ago to give the maintenance personnel at flight line a help for diagnosis tasks. The prospect of new technology offered automatic, quick, accurate, effective and easy interpretable GO/NOGO information of Line Replaceable Units with built-in self test (BIT) facilities. Typical design goals were: (1) Detection and location of defects down to LRU level with 80% probability and a 90% confidence level at minimum time, and (2) Defective LRUs shall automatically be identified on a Central Maintenance Panel. Whereas the general line of requirements were followed through, some problems occured, which influenced the final results. These problems are briefly: (1) false alarm probability is higher than was expected; (2) BIT capabilities are less than specified; and (3) BIT is not totally independent of operators interpretation. On the basis of experience gathered during the development of BIT these problems and their reasons were analyzed. B.W.

N85-16740# National Aerospace Lab., Amsterdam (Netherlands).
FUNCTIONAL BUILT-IN-TEST IN A PIPELINED IMAGE PROCESSOR
H. A. VANINGENSCHENAU, A. PLEIJSIER, and A. MONKEL *In* AGARD Design for Tactical Avionics Maintainability 8 p (SEE N85-16731 08-01) Oct. 1984
Avail: NTIS HC A13/MF A01

A method for built-in-test (BIT) is described which is applied to the test of function modules of a pipeline image processor. The built-in-test is used as a support tool during the early stages of development and for integration and maintenance. The test method takes advantage of the microprocessors used to interface and control the processor modules. Test programs are inserted in the microprocessor software to test the image processor functionally with a similar data and control flow as in real-time operation. The result is a number of test picture which can be interpreted in relation to the programmed functions of the image processing. Use is made of the 2-dimensional image formats to check the performance of the unit at one glance for several functions and parameter values. Author

N85-16741# Edinburgh Univ. (Scotland). Dept. of Electrical Engineering.
BUILT-IN TEST AND SELF REPAIR MECHANISMS IN A DIGITAL CORRELATOR INTEGRATED CIRCUIT
W. S. BLACKLEY, M. A. JACK, and J. R. JORDAN *In* AGARD Design for Tactical Avionics Maintainability 10 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

A Very Large Scale Integration digital correlator architecture which incorporates built-in self test and self repair mechanisms is described. The architecture offers testability and reliability, and the overhead for the test and repair circuitry is only one latch and two multiplexers per correlator stage. The correlator was fabricated on a 5-micron n metal oxide semiconductor process and results from the first batch of processed chips are reported. R.J.F.

N85-16742# Institut de Mathematiques Appliquees de Grenoble (France).
DESIGN OF SELF-CHECKING N-MOS (H-MOS) INTEGRATED CIRCUITS
M. NICOLAIDIS and B. COURTOIS *In* AGARD Design for Tactical Avionics Maintainability 20 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The design of self-checking N metal oxide semiconductor circuits is discussed. Two types of test are planned for the use of these circuits: on-line testing to detect failures during the function run of software; and off-line testing, with an emphasis on detection and localization for maintainability. The design of these circuits is based on transistor level fault hypotheses. The design of a functional part, the design of a checker, and procedures/design rules for a design for maintainability are addressed. R.J.E.

N85-16743# AEG-Telefunken, Ulm (West Germany).
MAINTAINABILITY: AN ILS EFFORT TO MANIPULATE LCC
M. BOEHM *In* AGARD Design for Tactical Avionics Maintainability 15 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The concept of maintainability is discussed. The importance of maintainability in controling the life cycle costs of avionics and radar equipment is evaluated. R.J.F.

N85-16744# Toronto Univ. (Ontario).
THE PRODUCTION OF MAINTAINABLE, TRUSTWORTHY, AND PORTABLE SOFTWARE
E. S. LEE and R. C. HOLT *In* AGARD Design for Tactical Avionics Maintainability 10 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

A method for writing computer programs in a way that promotes their maintainability, their trustworthiness, and their portability is discussed. Sound software engineering practice will produce a design which solves the right program. A fundamental decision affecting maintainability, trustworthiness, and portability is the choice of programming language and compiler. Trustworthiness is a direct result of our approach to maintainability. The language concurrent Euclid, which incorporates features to support maintainability, trustworthiness, and portability, is introduced and discussed. Several relevant properties of the Concurrent Euclid compiler are described. The technique of compiler construction used for the Concurrent Euclid compilers ensures ease of portability, with consequent extension to the practical lifetime of the program. R.J.F.

N85-16745# LITEF, Freiburg (West Germany).
DOCUMENTATION AND SEPARATE TEST PROGRAM DEVELOPMENT IS MOST IMPORTANT FOR TEST/MAINTENANCE
B. GUSMANN and N. SANDNER *In* AGARD Design for Tactical Avionics Maintainability 11 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

Well defined development phases with standardized documentations supported by computer based tools are important for test and maintenance. Systems for transport aircraft and military applications are discussed. Documentation is stressed throughout the life cycle and the independent testing. B.G.

N85-16746# Pacific Missile Test Center, Point Mugu, Calif. Electronic Warfare Computer Resources Div.
EFFECTIVE LIFE CYCLE SOFTWARE SUPPORT: A STUDY IN DISCIPLINE AND VERSATILITY
G. H. SMITH *In* AGARD Design for Tactical Avionics Maintainability 7 p (SEE N85-16731 08-01) Oct. 1984
Avail: NTIS HC A13/MF A01

An effective life cycle software support capability that has evolved from emphasis being placed on a disciplined management process and a versatile set of laboratory facilities is characterized. The evolution of the capability described is still in progress. Much is yet to be accomplished in several areas. It is still very difficult to gain information in the early stages of the development cycle of a software system. Information that would enhance supportability and reduce eventual software support costs is elusive. Many of the configuration and data management functions are far too labor intensive. Great strides are possible in the automation and integration of data and documentation. As system complexities are certain to continually increase, so will the challenge to improve the approach to maintainability of the new generations of software. B.G.

N85-16747# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
EXPERIENCE IN USING ON-AIRCRAFT SOFTWARE FOR TESTING INTEGRATED SYSTEMS
K. NUMBERGER *In* AGARD Design for Tactical Avionics Maintainability 20 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

A need exists for test software capable of monitoring complex avionic systems during flight and delivering the collected information immediately after the mission for debriefing and maintenance, and testing complex avionic system with respect to correct functioning and integration status. It is very important that during the test run easy switching between the operational program without reloading is possible. The following feature of the co-resident program have proved the most useful input data display, in-flight moniter, and extended individual equipment/system tests. The highest priority is therefore given to optimizing the co-resident software, especially the Advanced Ground Test Facility (AGTF), while the priority for the External Ground Test Program (EGTP) refinement was downgraded. B.G.

N85-16748# California Univ., Irvine. Dept. of Information and Computer Science.
SOFTWARE TESTING IN AN ADA PROGRAMMING ENVIRONMENT
R. N. TAYLOR *In* AGARD Design for Tactical Avionics Maintainability 12 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

A variety of techniques for aiding in the software analysis and testing process have appeared over the years. Recently new techniques were developed which specifically aid in the check out of concurrent programs. These developments are considered here with an eye towards their integrated incorporation in an Ada programming support environment (APSE). Particular attention is paid to the problem of debugging concurrent software which is developed on a host machine but tested on a separate target machine. Three programming environments which illustrate some important environment design principles are described. An APSE which embodies these principles and which incorporates the new analysis and testing technologies needs to be developed.
Author

N85-16749# International Business Machines Corp., Research Triangle Park, N.C.
INVESTIGATING VERSION DEPENDENCE IN FAULT-TOLERANT SOFTWARE
R. K. SCOTT, J. W. GAULT (ARO, Research Triangle Park, N.C.), D. F. MCALLISTER (North Carolina State Univ., Raleigh), and J. WIGGS (North Carolina State Univ., Raleigh) *In* AGARD Design for Tactical Avionics Maintainability 11 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The results are reported of an experiment conducted to validate the ability of several fault tolerant software reliability models to accurately predict system reliability. It was demonstrated that the dependent form of the model for the recovery block could predict reliability. The independent model failed to predict reliability due to version dependence. This dependence appeared to be due to the difficulty factor and not due to algorithmic dependence as might be expected. The recovery block does provide reliability gain over a single version of a program. It was demonstrated that the consensus recovery block approach to software fault tolerance was superior to the N version programming approach. R.S.F.

N85-16750# Dowty Electronics Ltd., London (England). Controls Div.
THE EFFECT ON SOFTWARE DESIGN OF TESTING BY SYMBOLIC EXECUTION
D. A. RUTHERFORD and F. LAM *In* AGARD Design for Tactical Avionics Maintainability 5 p (SEE N85-16731 08-01) Oct. 1984
Avail: NTIS HC A13/MF A01

Some special characteristics of real time software are addressed. The cost impact on applying symbolic execution is discussed. The results obtained in a symbolic test are more comprehensive as the conditions that lead to a particular path being executed are recorded as well as the final contents of variables. A symbolic value can represent a class of numeric values. This offers the advantages of time saving in test data preparation. In the extreme, test specifications can be eliminated completely which means that the maintenance cost for the associated text document is eliminated also. An unquantifiable advantage is that symbolic execution gives the programmer more insight into the working of the module under test and thus helps to check the specification of the routine. The test captures the philosophies behind both black and white box testing. R.S.F.

N85-16751# LABEN Space Instrumentation and Systems, Milan (Italy).
RELIABLE SOFTWARE DESIGN FOR AVIONICS AND SPACE APPLICATIONS
P. DONZELLI and G. GIANNINI *In* AGARD Design for Tactical Avionics Maintainability 11 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The fundamental quality requirements of space software are the reliability and testability of software products. Only a structured methodology of software design can satisfy these pecularities producing software modules with low coupling and high strength. The production of software with these features becomes more

complex when the work environment of software is a real time one. The first step toward the creation of reliable software is the introduction of a structured software design methodology properly devoted to real time applicatures. The software design methodology developed by LABEN to produce software for real time systems for space applications is discussed. R.S.F.

N85-16752# Naval Electronic Systems Command, Washington, D. C.
A WEAPON SYSTEM DESIGN APPROACH TO DIAGNOSTICS
G. W. NEUMANN (Giordano Associates, Inc., Arlington, Va.) and M. BATTAGLIA *In* AGARD Design for Tactical Avionics Maintainability 6 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

Providing a diagnostics capability for today's weapon systems requires a multifaceted combination of hardware, software, and personnel. The approach to providing this capability is fractionated among a number of different communities (e.g., testing, training, human engineering, publication writers). The result is reflected in the field, where the technician has been furnished a myriad of tools and documentation, which is confusing, complex and often contradictory. The result is lengthy repair times and a waste of manpower and dollars. The basic reason for this diagnostic deficiency is the lack of an integrated design approach to providing this capability and the inability to transition technological advancements to weapon systems acquisitions. Recent Department of Defense and U.S. industry efforts to solve this problem are discussed. R.S.F.

N85-16753# Research Triangle Inst., Research Triangle Park, N.C.
HARDWARE/SOFTWARE CODESIGN FOR MAINTAINABLE SYSTEMS
G. A. FRANK *In* AGARD Design for Tactical Avionics Maintainability 6 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The codesign of software/hardware which can improve the maintainability of military systems is discussed. The following methods are outlined: (1) support of the design verification process to make it more complete and less costly; (2) reduction of the cost of a system modification by providing accurate, machine readable documentation of the system design; and (3) support of the detection, isolation, and correction of faults on both software and hardware. Development of techniques for software/hardware codesign of high performance signal processors is examined. The methodology is based on the representation of both software and hardware as directed graphs. The system of computer aided design (CAD) tool that support this methodology is the architecture design and assessment system (ADA). The system has two types of components: graph processing modules, which can be applied to any graph, and interfaces to specialized tools, which operate on specific kinds of graphs. The graph processing tools include an interactive graphics editor, a library manager, a Petri net analysis tool, and a Petri net simulator. The interfaces include an HDL interface, and Ada interface, and a reliability tool interface. E.A.K.

N85-16754# Duisburg Univ. (West Germany). Dept. of Electrical Engineering.
DATA STIMULATED ON-LINE-CHECKING (IROLD)
M. TRAUTWEIN *In* AGARD Design for Tactical Avionics Maintainability 9 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

Concurrent monitoring of the main parts of a microprogrammable microprocessor is presented by implementation of suitable coding on addresses and operands. To check transfer and storage of information and the modification of information, i.e., arithmetical and logical operations, inverse residue code (IR-code) is chosen. Error modes, IR coding theory, the hardware realization considering the microcontrol unit (MCU) and the micro-CPU (MCPU) are discussed. The overhead of hardware and processing time will be compared to a simple MP configuration without check modules. E.A.K.

N85-16755# McDonnell Aircraft Co., St. Louis, Mo.
AVIONICS FAULT TREE ANALYSIS AND ARTIFICAL INTELLIGENCE FOR FUTURE AIRCRAFT MAINTENANCE
M. E. HARRIS and T. D. SNODGRASS *In* AGARD Design for Tactical Avionics Maintainability 12 p (SEE N85-16731 08-01) Oct. 1984 refs
Avail: NTIS HC A13/MF A01

The avionics fault tree analyzer (AFTA) was developed as an interim support tool for the Navy prior to attainment of total organic support capability, and as an alternate method of support to reduce life cycle/cost for F/A-18 foreign military sales. With the transformation of the AFTA concept from ground support equipment to avionics, a quantitative improvement in life cycle costs will be obtained through the application of artificial intelligence (AT) techniques. The AI is expected to see applications to practical problems in many disciplines; and one of which is the implementation of military fault diagnostic systems. A smart BIT was developed which will reduce false alarms, identify intermittent failures, and improve fault isolation to the lowest possible element by AI technique. Increasing density of computer memory, modularly designed avionic functions and the use of very large scale, and high speed integrated devices will allow future aircraft to fly with the AFTA function. Ramifications such as eliminating the need for intermediate avionic repair facilities, increased aircraft operational readiness, decrease in aircraft recurring costs, and a reduction in spares investment are discussed. The AFTA concept, life cycle cost advantages, and the implementation of artificial intelligence in future avionic designs relative to improved reliability and maintainability are summarized. E.A.K.

N85-16756# LABEN Space Instrumentation and Systems, Milan (Italy).
AUTOMATIC ERROR DETECTION AND RECOVERY TECHNIQUES IN ONBOARD INTELLIGENT UNITS FOR SPACE AND AVIONIC APPLICATION
R. RANIERI and R. REDAELLI *In* AGARD Design for Tactical Avionics Maintainability 4 p (SEE N85-16731 08-01) Oct. 1984
Avail: NTIS HC A13/MF A01

The introduction of the microprocessors onboard spacecrafts has given a powerful tool to the system designers but has on the other hand created a lot of problems to the reliability engineers. The fault tolerance of intelligent units are characterized and the most useful design tools that are available are described. Some hints on their implementation as a result of several years of experience with spaceborne microprocessor based units are presented. E.A.K.

N85-16771# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
IMPROVEMENT OF AERODYNAMIC PERFORMANCE THROUGH BOUNDARY LAYER CONTROL AND HIGH LIFT SYSTEMS
Loughton (England) Aug. 1984 423 p refs In ENGLISH and FRENCH *Conf. held in Brussels, 21-23 May 1984*
(AGARD-CP-365; ISBN-92-835-0358-9; AD-A147396) Avail: NTIS HC A18/MF A01

Theoretical and experimental developments are reported in the use of both traditional and non-traditional means of boundary layer control for external flow applications such as lift-augmentation, drag reduction and improved effectiveness of controls, and for internal flow applications such as air intakes and exit configurations. Techniques included shaping (geometry) suction and blowing transverse blowing; vortex generators; heating and cooling; and turbulent boundary layer manipulation. Boundary layer control on characteristics of wings and wing-body arrangements that involve flaps, slats and jets (blown flaps), and vortex flaps is covered. For individual titles see N85-16772 through N85-16796.

N85-16772# British Aerospace Aircraft Group, Weybridge (England).
RECENT PROGRESS OF DEVELOPMENT AND UNDERSTANDING OF HIGH LIFT SYSTEMS
D. J. BUTTER *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 26 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

The mechanical high lift device as it is used for transport type aircraft is discussed. Current design approaches are reviewed along with progress on both the development of high lift device design

and on the understanding of the related flow physics. Likely future developments and the fundamental research required to achieve them are also addressed. M.G.

N85-16773# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.

INVESTIGATIONS INTO THE EFFECTS OF SCALE AND COMPRESSIBILITY ON LIFT AND DRAG IN THE RAE 5M PRESSURIZED LOW-SPEED WIND TUNNEL

S. P. FIDDES, D. A. KIRBY, D. S. WOODWARD, and D. H. PECKHAM *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 7 p (SEE N85-16771 08-01) Aug. 1984 refs

Avail: NTIS HC A18/MF A01

Results obtained from experiments in the RAE 5m low speed pressurized wind tunnel are presented. The tunnel is capable of operation over a range of pressures (from one to three atmospheres) so that the effects of Mach and Reynolds number may be separated. This decoupling of scale and compressibility effects makes possible reliable extrapolation of test results to full-scale conditions (where this is necessary) as well as giving greater insight into the underlying flow mechanisms. The large size of the tunnel, combined with pressurization to three atmospheres, enabled some tests, on small combat/trainer aircraft and on bomb-like stores, to be carried out at full scale. Three facets of the work of the 5m tunnel are described: work aimed at predicting or improving the high lift performance of specific aircraft; work of a more fundamental nature concerned particularly with the optimization of high-lift devices on generalized research models; and work on the drag of stores carried externally on combat aircraft. Author

N85-16774# National Aerospace Lab., Amsterdam (Netherlands).

RECENT ADVANCES IN COMPUTATIONAL METHODS TO SOLVE THE HIGH-LIFT MULTI-COMPONENT AIRFOIL PROBLEM

B. OSKAM, D. J. LAAN, and D. F. VOLKERS *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 31 p (SEE N85-16771 08-01) Aug. 1984 refs

Avail: NTIS HC A18/MF A01

Recent advances made in the analysis of viscous flow over high-lift multi component airfoil configurations are described. The calculation of viscous wakes subjected to large adverse pressure gradients is considered. The local supersonic flow over the slat of a high-lift configuration, with a free stream Mach number of around 0.2, is also addressed. Development of a computational method for turbulent wakes in adverse pressure gradient, including strong inviscid-viscous interaction, has improved the understanding of such phenomena as the off-the-surface pressure recovery capability of viscous wakes. The example of a wing with double-slotted flap shows that the wake, flowing into a region of higher pressure, may play a critical role that has not been recognized before. Results of the transonic panel method, solving the full potential equation, and the experimental data both show high local velocities reaching Mach numbers up to 1.6 at a free stream Mach number of 0.225. R.S.F.

N85-16775# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

DETAILED STUDY OF THE FLOW AROUND A MULTI-ELEMENT AIRFOIL. COMPARISON WITH CALCULATIONS [ETUDE DETAILLEE DE L'ECOULEMWNT AUTOUR D'UN PROFIL HYPERSUSTENTE COMPARISONS AVEC LES CALCULS]

B. PORCHERON and J. J. THIBERT *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 7 p (SEE N85-16771 08-01) Aug. 1984 refs In FRENCH; ENGLISH summary

Avail: NTIS HC A18/MF A01

Results are discussed for studies using a theoretical method for computing the viscous incompressible flow around multi-element airfoils as well as an experimental study of the flow around such configurations. The velocity profiles and the turbulence measurements around a multi-element airfoil clearly show the interaction between boundary-layer and wakes even when these are not merging and they have been used to draw accurate maps of the flow. The computing method of the flow around these configurations is based upon a panel method (both sources and vortices) for the inviscid part of the flow and a method providing calculation and coupling for boundary layers and wakes, under strong viscous interaction conditions. This method has given quite good results even when there are several simultaneous separated flow regions. The comparisons between computation and experiment described underline the necessity of improving the computing method in the region located above the flap. A.R.H.

N85-16776# Manchester Univ. (England). Dept. of the Mechanics of Fluids.

INVISCID COMPRESSIBLE FLOW PAST A MULTI-ELEMENT AEROFOIL

I. M. HALL and A. SUDDHOO *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 15 p (SEE N85-16771 08-01) Aug. 1984 refs

Avail: NTIS HC A18/MF A01

A conformal transformation method is used to generate an orthogonal curvilinear grid for two and three-element airfoil configurations. The compressible potential flow equations are solved by finite difference methods. The solution could serve as a starting point for an iterative solution of the full viscous compressible flow case. R.S.F.

N85-16777# National Aerospace Lab., Amsterdam (Netherlands).

DESIGN OF AN AIRFOIL LEADING EDGE SLAT USING AN INVERSE AERODYNAMIC CALCULATION METHOD

J. A. VANEGMOND and B. VANDENBERG *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 11 p (SEE N85-16771 08-01) Aug. 1984 refs

Avail: NTIS HC A18/MF A01

In order to evaluate the applicability of the design system MAD (multi-element airfoil design), a design study was performed for a two-dimensional wing with leading edge slat. The problem is representative for that of a transport airplane operating out of high altitude airfields requiring a high lift-to-drag ratio at takeoff. A two-dimensional high life configuration tested earlier in a low speed wind tunnel was selected as the starting configuration. The design system MAD is described briefly. The actual leading edge slat design is given. The new slat-wing configuration as tested in a wind tunnel and some of the test results are presented together with results of the baseline configuration. R.S.F.

N85-16778# Southampton Univ. (England).

MODELLING CIRCULATION CONTROL BY BLOWING

M. M. SOLIMAN, R. V. SMITH, and Y. I. C. CHEESEMAN *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 7 p (SEE N85-16771 08-01) Aug. 1984 refs

Avail: NTIS HC A18/MF A01

A theoretical representation of circulation control based on discrete vortex modelling techniques is described. The application of discrete vortex modelling to the prediction of circulation control is initially momentum, due to viscous and entrainment effects was represented in the model by decaying the strength of each vortex as it flows downstream from the slot. The model's application was extended to predict the effect of circulation control on other shapes of airfoil. The application of the model to an elliptic section is included as an example of any airfoil section that can be represented in a potential flow. The model has had considerable success in predicting the lift produced from such bodies due to the jet, but information about the drag requires additional modelling of the surface boundary layer. A similar technique was used to represent the boundary layer by discrete vortices and doublets. The model's prediction was compared with the experimental data of an unblown circular cylinder. R.S.F.

N85-16779# Naples Univ. (Italy).
TURBULENT BUBBLES BEHIND AIRFOILS AND WINGS AT HIGH ANGLE OF ATTACK
V. LOSITO and G. TORELLA *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 13 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

More accurate inviscid and viscous flow models are needed for simulating the main features of the turbulent bubbles in the near wakes behind airfoils at high angles of attack. Descriptions of these flows are not sufficiently detailed to allow accurate modelling for the recirculating flow regions. Numerical and wind tunnel experiments are required to ensure convergence criteria and wake closure conditions at different Reynolds numbers. A simple relation was found which correlates the airfoils viscous lift loss with the location of the upper surface separation point and lift predicted in full attached flow conditions. This simple two-dimensional model was extended to three-dimensional wing flows with embedded turbulent bubbles after a set of wind tunnel experiments and oil-flow visualizations. A fast and efficient method is given for predicting spanwise load distribution and C sub L max for finite unswept wings. R.S.F.

N85-16780# Boeing Military Airplane Development, Seattle, Wash.
AERODYNAMIC ISSUES IN THE DESIGN OF HIGH-LIFT SYSTEMS FOR TRANSPORT AIRCRAFT
B. DILLNER, F. W. MAY, and J. H. MCMASTERS *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 22p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

The design of the high lift system has a profound effect on the sizing and total performance of transport aircraft, both civil and military. The fundamentals of high lift system design are reviewed along with the phenomena that govern their performance. The computational methods available to the high lift designer, with examples of their validity, are presented. New developments in flow diagnostic techniques are reviewed. Examples of several Boeing high lift design efforts are given. Emphasis is placed on the use of computational aerodynamic methods and the synergistic effect of using those methods in parallel with testing. A list of todays ten most important issues in high lift aerodynamics is presented. R.S.F.

N85-16781# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario).
AN UPDATE OF THE CANADA/USA AUGMENTOR-WING PROJECT
D. C. WHITTLEY *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 8 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

Following extensive tests of a half scale model in the NASA, Ames 40' x 80' wind tunnel, a minimum cost flight demonstrator was built based on the de Havilland Buffalo airframe. Following completion of the NASA trials in 1980, work has continued in Canada covering four main areas of interest using the augmenter wing powered lift concept: (1) additional flight trials on the technology demonstrator aircraft; (2) propulsion system development; (3) experimental investigation of a new compound supercritical airfoil; and (4) project definition studies. E.A.K.

N85-16782# Lockheed-Georgia Co., Marietta. Advanced Flight Sciences.
AIRCRAFT DRAG REDUCTION TECHNOLOGY
A. S. W. THOMAS *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 20p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

The current techniques of aircraft viscous drag reduction and some of the more recent developments that have taken place in this technology are reviewed. The various sources and relative contributions of aircraft drag are described including skin friction drag, pressure drag, interference drag and lift induced drag. The physical processes that lead to these drag contributions are emphasized and methods of reducing the impact of these drag sources are discussed. It is shown how innovative and optimized aircraft configurations can lead to drag benefits. E.A.K.

N85-16783# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
APPLICATION OF TWO AND THREE-DIMENSIONAL CRITERIA FOR CALCULATING TRANSITIONS AND BOUNDARY LAYERS OVER SWEPT WINGS
D. ARNAL and E. COUSTOLS *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 19 p (SEE N85-16771 08-01) Aug. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A18/MF A01

The possible origins of turbulence on an infinite swept wing are examined. A method for calculating the beginning of transition, and the transition region itself, is suggested for the three dimensional flow. The influence of sweep angle on transition and on drag coefficient of the airfoil and the efficiency of wall suction are discussed. E.A.K.

N85-16784# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
THEORETICAL STUDY OF BOUNDARY-LAYER CONTROL
E. H. HIRSCHEL *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 11p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

The inviscid flow past the upswept rear part of a fuselage is directed beneath the fuselage. This leads to an accumulation of boundary layer material at the lower side of the fuselage which might be prone to separation. The cross sections of the rear end of a typical transport airplane fuselage were modified from the original circles to rounded triangles, in this way shifting downward the centers of gravity of the cross sections. The side view contour, the width of the fuselage and the volume remain unchanged. Three different configurations without wing and tail unit were studied, the original and two modified ones. The inviscid flow was computed with the MBB panel method, the boundary layer development with the integral method of Cousteix and Aupoix for three dimensional turbulent, compressible flow. It is shown that less boundary layer material is transported under the rear part of the fuselage in the modified cases. The tendency of the skin friction lines to converge is reduced. The whole flow pattern at the base is improved. In the frame of boundary layer theory, however, no statement can be made about possible pressure drag reductions. An improvement of the elevator performance appears to be probable. The study shows that the upsweep of the fuselage is the main factor in the boundary layer development. The addition of the wing and the tail unit will only modify the picture. E.A.K.

N85-16785# Bochum Univ. (West Germany).
DRAG REDUCTION DUE TO BOUNDARY-LAYER CONTROL BY COMBINED BLOWING AND SUCTION
J. WIEDEMANN and K. GERSTEN *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 10p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

The boundary control system of combined blowing and suction was investigated. Blowing is applied in the front part of the body where the pressure gradient is favorable, whereas suction is applied in the rear part of the body where adverse pressure gradients exist. To avoid the sink drag the volume rate of suction should be equal or smaller than the blowing volume rate. Theoretical investigations of laminar flows include optimization of the blowing velocity distribution and second order boundary layer effects such as pressure drag and displacement effects on friction drag. Experimental results of turbulent boundary layers with very strong blowing velocities near the stagnation point of a circular cylinder are used as a basis of a simple prediction method. Experiments on a circular cylinder show considerable drag reductions due to the combined blowing and suction boundary layer control system. E.A.K.

N85-16786# Technische Hogeschool, Delft (Netherlands). Dept. of Aerospace Engineering.
DESIGN STUDIES OF THICK LAMINAR FLOW AIRFOILS FOR LOW SPEED FLIGHT EMPLOYING TURBULENT BOUNDARY LAYER SUCTION OVER THE REAR PART
J. L. VANINGEN, J. J. H. BLOM, and J. H. GOEI *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 19 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

Computational tools, used to analyze and design airfoils for low speed flight (prediction of potential flow pressure distributions, laminar boundary layer flows, transition prediction using the e(n) method and Head's entrainment method for the calculation of turbulent boundary layers are described. These tools are used to design pressure distributions and corresponding airfoil shape producing long runs of natural laminar flow. Inevitably this results in airfoils with the maximum thickness far backwards, eventually leading to separation of the turbulent boundary layer over the rear part of the airfoil. This turbulent boundary layer separation is prevented by selecting a proper pressure distribution over the rear part and/or suction of the turbulent boundary layer through slots or distributed perforations. Design charts are presented which help to select the required pressure distributions for laminar and turbulent flow. B.W.

N85-16787*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TECHNOLOGY DEVELOPMENTS FOR LAMINAR BOUNDARY LAYER CONTROL ON SUBSONIC TRANSPORT AIRCRAFT
R. D. WAGNER, D. V. MADDALON, and M. C. FISCHER *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 13 p (SEE N85-16771 08-01) Aug. 1984 refs Previously announced in IAA as A84-33137
Avail: NTIS HC A18/MF A01 CSCL 01A

The development of laminar flow technology for commercial transport aircraft is discussed and illustrated in a review of studies undertaken in the NASA Aircraft Energy Efficiency (ACEE) program since 1976. The early history of laminar flow control (LFC) techniques and natural laminar flow (NLF) airfoil designs is traced, and the aims of ACEE are outlined. The application of slotted structures, composites, and electron beam perforated metals in supercritical LFC airfoils, wing panels, and leading edge systems is examined; wind tunnel and flight test results are summarized; studies of high altitude ice effects are described; and hybrid (LFC/NLF designs are characterized. Drawings and photographs are provided. (IAA)

N85-16788*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TURBULENT DRAG REDUCTION RESEARCH
D. M. BUSHNELL, J. B. ANDERS, M. J. WALSH, and R. V. MCINVILLE (North Carolina State Univ.) *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 13 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01 CSCL 01A

Research in the area of turbulent drag reduction for attached flows is summarized. The most promising passive techniques utilize non-planar geometry. Of particular interest is the suitability of these devices for retrofit of existing vehicles. Five methods for reducing turbulent skin friction drag on bodies/fuselages are discussed. They are: (1) large-eddy breakup devices; (2) riblets; (3) slot injection optimization; (4) control of Emmons spot generation; and (5) relaminarization through massive suction. Except for the Emmons spot work these methods all indicate the possibility of sizable net reductions in skin friction for laboratory conditions. B.W.

N85-16789*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ON THE RELAXATION OF A TURBULENT BOUNDARY LAYER AFTER AN ENCOUNTER WITH A FORWARD FACING STEP
D. I. A. POLL and R. D. WATSON (Cranfield Inst. of Tech., Bedford, England) *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 10 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01 CSCL 01A

An experiment was performed in a low speed wind-tunnel to determine the mean flow relaxation characteristics for a zero pressure gradient turbulent boundary layer which encounters a small forward facing step. Of primary interest is the behavior of the local wall shear stress downstream of the step. This was determined by the use of a series of buried hot-wire gauges. The mean velocity profiles downstream of the step were measured using a traversing Pitot tube and these have indicated that a step produces very marked changes in the distribution for both the inner and outer regions of the flow. The results shed new light upon the variation of wall shear stress downstream of a severe perturbation and also indicate that the use of Preston tube or Clauser chart methods for the determination of wall shear may lead to very large errors. As a consistency check on the data, estimates of the step drag based upon force-momentum conservation considerations were compared with previously published drag balance measurements. The agreement between the data sets is very good. B.W.

N85-16790*# Aeronautical Research Inst. of Sweden, Bromma.
FULL SCALE EXPERIMENTS INTO THE USE OF LARGE EDDY BREAKUP DEVICES FOR DRAG REDUCTION ON AIRCRAFT
A. BERTELRUD *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 16 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

An experimental investigation in flight was performed to explore the feasibility of using LEBU (Large-Eddy-Breakup) devices to reduce the drag of aircraft. Two geometrical shapes of ribbons were used, and the development of local skin friction was monitored downstream. The aircraft was a swept-wing attack aircraft, and the flights covered the entire subsonic regime from M = 0.92 down to stall conditions; flight altitudes were 1, 4.5, 7 and 10 km to explore various combinations of angle of attack, Mach · and Reynolds numbers. Some information was obtained concerning the turbulence characteristics downstream, and a discussion of the downstream amplification due to the drag at the device is also presented. B.W

N85-16791# Technische Hogeschool, Delft (Netherlands).
PNEUMATIC TURBULATORS: A DEVICE FOR DRAG REDUCTION AT REYNOLDS NUMBERS BELOW 5 MILLION
K. H. HORSTMANN, A. QUAST, and L. M. M. BOERMANS *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 19 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

At Reynolds numbers below 5 million, airfoils are affected by laminar separation bubbles which in many cases considerably increase the drag. By blowing air from a row of orifices at the beginning of the laminar separation bubble, the bubble can be prevented and the drag can be reduced substantially. This device is called a pneumatic turbulator. Free-stream total pressure is sufficient to provide the turbulator bleed air. The additional drag caused by the bleed air and the air jets is negligible. The low drag Reynolds number range of laminar airfoils can be extended by using pneumatic turbulators. R.J.F.

N85-16792# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SHOCK/TURBULENT BOUNDARY LAYER INTERACTION AND ITS CONTROL
J. DELFRY *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 41 p (SEE N85-16771 08-01) Aug. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A18/ MF A01

Some fundamental properties of the interaction between shock waves and boundary layers are considered for the basic

configuration. The following features are examined: upstream interaction length, incipient shock-induced separation and the evolution of the boundary-layer main characteristics. Both transonic and supersonic flows are considered. The most investigated means for controlling shock/boundary-layer interaction are presented, with emphasis on the physical description of the flow phenomena involved in this process. Briefly speaking, control methods can be classified into two categories: those acting on the boundary-layer properties before interaction with the shock (e.g., wall cooling, wall mass transfer, upstream blowing), and those having a local action in the shock foot region (suction or injection, boundary-layer removal). The most appropriate technique depends in fact on the specific application under consideration. Finally, some calculation methods are briefly presented. Most of them are restricted to laminar interactions. R.J.F.

N85-16793# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
INTEREST OF INTERNAL BLEED FOR A TWO-DIMENSIONAL AIR INTAKE OPERATING IN A WIDE MACH NUMBER RANGE (1.6-3 PLUS)
G. LARUELLE, C. SANS, and R. LEFEBVRE (Societe National Industrielle Aerospatiale, Chatillon, France) *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 10 p (SEE N85-16771 08-01) Aug. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A18/MF A01

From a two-dimensional air intake with an internal bleed and optimized for approximately Mach number 2, a new configuration is sought allowing still good performance up to Mach number 3 plus, but with the minimum of movable parts. The main geometrical parameters are: the slope of the external compression ramp; the internal section law of the diffuser; and the inlet section of the internal bleed. The internal bleed and the advantage of a variable geometry are discussed, as well as the model which was built at large scale and its equipment; motorizations, measurement devices, and internal visualizations. The tests were performed in a supersonic wind tunnel. A movie shows shadowgraphs of the flow in the air intake geometrical throat, where the internal bleed is located, for several configuration changes (external ramp or diffuser wall rotations, increases of Mach number or angle of attack), and variable internal obstruction. Some results obtained with this air-intake model are explained. The choice of two configurations allowing correct performance in the studied Mach number range, by optimization of the internal bleed geometry, is commented on. R.J.F.

N85-16794# Centre d'Etudes Aerodynamiques et Thermiques, Poitiers (France).
OBLIQUE SHOCK WAVE-TURBULENT BOUNDARY LAYER INTERACTION ON A POROUS WALL WITH SUCTION [INTERACTION ONDE DE CHOC OBLIQUE: COUCHE LIMITE TURBULENTE SUR PAROI POREUSE AVEC ASPIRATION]
D. B. LEE and R. LEBLANC *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 11 p (SEE N85-16771 08-01) Aug. 1984 refs In FRENCH
Avail: NTIS HC A18/MF A01

The interaction of an oblique shock wave with a turbulent boundary layer subjected to two rates of suction was analyzed theoretically and experimentally. The general equations were solved using a finite different method. The approach is direct and used a prescribed pressure gradient. Cebeci and Smith's algebraic turbulence model is completed by taking into account mass transfer. First comparisons with the experiment at M = 1.43, for a boundary layer of a smooth wall without interaction, shows that it is necessary to simulate roughness upstream of the suction zone, for a correctly adapted blowing. Three cases of oblique shock waves interactions created by a deviation of 3 deg at M = 1.43 with the turbulent boundary layer of the wall are studied. The experimental methods describe the interaction region, differing according to whether the wall is solid or porous and according to the suction rate. The evolution of the subsonic layer is more destabilized by the roughness which is influenced by moderate suction. It is concluded that both mass transfer and roughness must be considered together to study a coupling which considers the vertical pressure gradient. Transl. by A.R.H.

N85-16795# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany).
ACTIVE AND PASSIVE SHOCK/BOUNDARY LAYER INTERACTION CONTROL ON SUPERCRITICAL AIRFOILS
P. THIEDE, P. KROGMANN (Deutsch Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany), and E. STANEWSKY (Deutsch Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany) *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 13 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

Experimental investigations aiming at the improvement in the off-design performance of supercritical airfoils by active or passive control of the shock/boundary layer interaction (SBLI) through boundary layer suction in the shock region or ventilation respectively are presented. The experiments were carried out in a transonic wind tunnel using an advanced supercritical airfoil designed to have a largely fixed shock position at off-design conditions. The basic model was equipped with an exchangeable control device within the shock region of allow measurements with either surface clean, suction through a single slot, double slot or perforated strip, or ventilation through a double slot or perforated strip. The effectiveness of the different SBLI control methods is evaluated from surface pressure distribution, wake and boundary layer measurements, and Schlieren observations. It is shown that local boundary layer suction in the shock region mainly delays the shock-induced separation to greater shock strength and stabilizes the shock in its rearward position up to higher incidence, resulting in substantial improvements in the airfoil characteristics at off-design conditions. Without any suction a favorable passive effect is observed by boundary layer ventilation on the double slot and perforated strip configurations with a plenum underneath. A weakening of the shock wave results, offering a large potential for off-design drag reductions. R.J.F.

N85-16796# West Virginia Univ., Morgantown.
TRANSONIC SHOCK INTERACTION WITH A TANGENTIALLY-INJECTED TURBULENT BOUNDARY LAYER
G. R. INGER *In* AGARD Improvement of Aerodynamic Performance Through Boundary Layer Control and High Lift Systems 10 p (SEE N85-16771 08-01) Aug. 1984 refs
Avail: NTIS HC A18/MF A01

A non-asymptotic triple deck theory of transonic shock/turbulent boundary layer interaction is described which takes into account the influence of upstream tangential injection on a curved wall. In addition to Reynolds number and the shock strength, the theory is parameterized by arbitrary values of the incoming boundary layer shape factor, wall jet maximum velocity ratio, and the nondimensional height of this ratio; results of a comprehensive parametric study are then presented. It is shown that the wall jet effects significantly reduce both the streamwise scale and displacement thickening of the interaction zone. While increasing the upstream and downstream skin friction levels, these effects also reduce the minimum interactive skin friction and thus actually hasten the onset of incipient separation at the shock foot. Author

N85-16797# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
HELICOPTER GUIDANCE AND CONTROL SYSTEMS FOR BATTLEFIELD SUPPORT
Loughton, England Aug. 1984 284 p refs In ENGLISH and FRENCH Conf. held in Monterey, Calif., 8-11 May 1984
(AGARD-CP-359; ISBN-92-835-0365-1; AD-A149970) Avail: NTIS HC A13/MF A01

Requirements and operational use of future helicopters: new methods of briefing helicopter crews and tactically setting up the mission systems before and during the flight, flight control, displays, communications, and navigation; sensors and weapon systems integration in overall cockpit design; and simulation and flight research are discussed. For individual titles see N85-16798 through N85-16821.

N85-16798# Aerospace Engineering Test Establishment, Cold Lake (Alberta).
OPERATIONAL REQUIREMENTS VERSUS TECHNOLOGICAL CAPABILITIES
S. COYLE *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 9 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

The lessons learned in the wartime use of helicopters, and the impact that modern technology can have on what have become common themes are discussed. Lessons learned, the constraints on helicopter operations, and the requirements of the battlefield helicopter are integrated to show where technology would better serve the operators. Performance monitoring, handling qualitites and radio communications examples are presented, and a brief outline of how existing technology could be used to update an existing helicopter is made. Author

N85-16799# Ferranti Ltd., Edinburgh (Scotland) Navigation Systems Dept.
AUTOMATIC BRIEFING AND MISSION MANAGEMENT SYSTEMS FOR BATTLEFIELD SUPPORT
C. G. W. ROADS *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 6 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

Mission planning and briefing systems were used for almost a decade to make the best use of advanced avionics fitted to high performance fixed-wing aircraft. As similar equipment is fitted to helicopters to enable them to perform on the battlefield the need for mission briefing systems will become apparent. How such a system might be used in the context of a hypothetical future operation is described and in doing so seeks to highlight some of the technical problems which will be encountered in developing and fielding such equipment. The interaction of the databases which could be exploited by such system are considered, and whether the equipment in service today is developing towards the future systems described. B.G.

N85-16800# Anacapa Sciences, Inc., Santa Barbara, Calif.
A COMPUTER-GENERATED TOPOGRAPHIC DISPLAY SYSTEM FOR NAVIGATION AND MISSION PLANNING IN HELICOPTERS
S. P. ROGERS *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 11 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

The Integrated Mission-Planning Station (IMPS) is a computer-generated topographic display system. The IMPS will provide not only a greatly enhanced navigation capability, but also a combination of dramatic improvements in cartographic support, map information content, and aviator-map interactions. The powerful computational capability of the IMPS can be used to present a shaded relief map, to display areas masked from visual or radar observation, to construct perspective views of key terrain, to support a self-contained terrain correlation navigation system, and to permit rapid solutions to problems of previously forbidding complexity. The tasks conducted to provide detailed human factors engineering specifications for the construction and programming are described. The outcome of these efforts is described in terms of an overview of system components and functions. Each of the major functions of the IMPS system is discussed, and the operational requirements, present deficiencies, and IMPS capabilities are identified. Author

N85-16801# Thomson-CSF, Issy les Moulineaux (France).
MAP DISPLAY FOR HELICOPTERS
P. CHOLLE *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 16 p (SEE N85-16797 08-01) Aug. 1984 refs In ENGLISH and FRENCH
Avail: NTIS HC A13/MF A01

Modern combat helicopters have to be adapted to a context of constantly increasing crew work load. The electronic map display is a way to greatly reduce navigation tasks. Present position of the aircraft is continuously provided and allows for very fast navigation up-dating. North-up and Track-up modes are also possible. A continuous zoom is used to enlarge some details. A joystick is used to manually move the map for visualization of other zones. Different maps scales are available. If the helicopter's display system is powerful enough it is also possible to create an interactive console giving the crew the ability to memorize data on the map before the mission and in real time during the flight. Author

N85-16802# Department of National Defence, Ottawa (Ontario).
DEVELOPMENT OF A HELICOPTER INTEGRATED NAVIGATION SYSTEM
D. F. LIANG, W. R. CLUBINE, L. C. VALLOT (Honeywell Systems and Research Center, Minneapolis, Minn.), and J. K. MAHESH (Honeywell Systems and Research Center, Minneapolis, Minn.) *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 19 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

The Canadian Department of National Defence has initiated a project to develop and test a helicopter integrated navigation system (HINS) that is capable of satisfying all the operational requirements of shipborne, antisubmarine warfare helicopters. The HINS mission requirements, development plan and its basic hardware and software configurations are discussed. The integrated system is expected to bring forth vital benefits in mission reliability, operational efficiency and navigation accuracy. Additional benefits are in terms of the size, weight, height and cost, etc. In the current phase of this work, extensive simulation software packages have been generated to accurately represent the operational characteristics of various off-the-shelf candidate subsystems. An Integrated System Evaluation Program has been developed which takes into account the various characteristics of the navigation subsystems and the mission requirements to systematically evaluate a sequence of candidate configurations. B.W.

N85-16803# Standard Elektrik Lorenz A.G., Stuttgart (West Germany).
HIGH ACCURACY DOPPLER NAVIGATION EMPLOYING OPTIMUM INTEGRATED POSITION FIX INFORMATION
H. HUG *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 8 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

The basic accuracy limitations of today's Doppler navigation systems are mainly caused by sensor errors and calibration errors. The navigation error of a typical Doppler system equipped with a magnetic compass is therefore about 1 % to 2 % of the distance travelled. The presented approach for improved accuracy is based on the usually applied method of position fixing to reset the error at specific waypoints. The measured errors are used as an input to a Kalman Filter which estimates various error parameters and continuously compensates for the actual navigation error. Details of the implemented Kalman Filter algorithm are given. Simulation results based on computer generated synthetic flight data and recorded real flight data are presented. B.W.

N85-16804# Naval Air Development Center, Warminster, Pa.
STANDARD ATTITUDE HEADING REFERENCE SYSTEM (SAHRS) FULL SCALE DEVELOPMENT PROGRAM
K. L. BACHMAN *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 12 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

There is a recognized need within the military services for reliable, low cost-of-ownership Attitude Heading Reference Systems (AHRS) capable of operating for extended periods without the need for calibration or regularly scheduled maintenance. In recognition of this need, the military services have embarked upon a joint service full scale engineering development program to provide a Standard Attitude Heading Reference System (SAHRS) utilizing strapdown technology for a multiplicity of rotary and fixed wing platforms. System design concepts, and performance characteristics are described. Procurement and schedules are also discussed. B.W.

N85-16805# Racal Avionics Ltd., New Malden (England).
INTEGRATED CONTROL AND DISPLAY SYSTEMS FOR HELICOPTER BATTLEFIELD MISSION MANAGEMENT
M. A. RICHARDSON *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 7 p (SEE N85-16797 08-01) Aug. 1984
Avail: NTIS HC A13/MF A01

The avionics requirements of an integrated crew station for battlefield helicopters are discussed. An example of the approach taken to equip a multi-role light attack helicopter is provided. B.W.

N85-16806# Societe de Fabrication d'Instruments de Mesure, Massy (France).
A DIGITAL PILOTING SYSTEM FOR THE COMBAT HELICOPTER [SYSTEME NUMERIQUE DE PILOTAGE POUR HELICOPTERE DE COMBAT]
J. C. DERRIEN *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 13 p (SEE N85-16797 08-01) Aug. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

For several years, SFIM has specialized in the development of digital systems for piloting the helicopter. A sophisticated environment for simulation for the design of future systems has been created and used in recent years for the design and adjustment of systems for complete in-flight evaluation on several types of helicopters. General methods for the design and integration of such systems, the PAN 1 digital piloting system coupled to the 26SH strap-down attitude unit, and an HCL coupling system for hovering which is itself, connected to the VENUS pointing system are discussed. The system being developed at SFIM which was completely adapted for the combat helicopter is examined. Transl. by A.R.H.

N85-16807# Elmer, Rome (Italy).
TACTICAL HF COMMUNICATION FOR MILITARY HELICOPTERS USING THE NVIS MODE
G. PUCCETTI and P. L. COMO *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 9 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

The use of loop antennas for tactical HF communications on board of military helicopters was investigated. The helo platform is considered for land or maritime scenarios. The experiments on the SH-3D helicopter compared the loop antennas and existing wire antennas. Groundwave radiated field at different azimuth angles were measured for the two antenna types, particularly at the lower end of the frequency range where the difference in the antenna geometry is more significant. A consistent better performance of the loop over the wire, typically a 16 dB to 8 dB improvement is indicated. Skywave propagation tests at different distances and altitude of the helicopter were conducted. It is found that the performance of the loop antenna is superior to the wire. It is concluded that the loop antenna is an ideal radiator for use onboard aircraft and helicopters because of its dimensions, increased efficiency, and radiation characteristics. E.A.K.

N85-16808# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
EVALUATION OF NOSE, ROOF, AND MAST MOUNTED SENSOR PLATFORMS FOR PILOTING AND SIGHTING, INTEGRATED IN FUTURE COMBAT HELICOPTERS
H. D. V. BOEHM and R. D. V. RETH *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 16 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

The piloting and sighting tasks under day, night and adverse weather conditions for a combat helicopter are different. For sighting the helicopter needs a well adapted sensor package, which may consist of a high performance FLIR, a direct view glass optic, a TV-channel and a tracker with a boresighting module. For the piloting task it is possible to use a complex sensor system including a helmet mounted sight and display (HMS/D) and/or night vision goggles (NVG). Different aspects of nose-, roof-, and mast-mounted sights (NMS, RMS, NMS) for a gunner and present and future weapon systems are discussed. Advanced electro-optical systems with a high performance telescope, allowing an increased combat range are considered. An advanced multisensor approach where the more conventional systems are supplemented or partially replaced by a multimode imaging radar is examined. The sensor for piloting can be integrated with the sighting system or located in a position remote from the sight. The pilot needs a dedicated display in the form of either a head-down display (HDD) or a helmet mounted display (HMD). A superimposed symbology adapted to the phase of the mission e.g., cruise, transition or hover, is required in either case. E.A.K.

N85-16809# Crouzet Aerospace and Systems, Valence (France).
RECENT METHODS FOR CALIBRATING THE ANEMOMETRY OF HELICOPTERS AT LOW SPEEDS [NOVELLES METHODES D'ETALONNAGE DE L'ANEMOMETRIE DES HELICOPTERES AUX BASSES VITESSES]
J. MANDLE *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 12 p (SEE N85-16797 08-01) Aug. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

Improvements made by Crouzet to make classic methods of calibrating anemometry compatible with the flight domain of helicopters are discussed as well as proposed new material. The limitations of the classic methods are examined, the improvements defined, and equipment installed for these new methods at the Brittany Flight Test Center are described. Transl. by A.R.H.

N85-16810# AEG-Telefunken, Ulm (West Germany).
LPI-RADAR FOR HELICOPTER OBSTACLE WARNING
H. MEINEL, H. G. WIPPICH, B. REMBOLD, and W. F. X. FRANK *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 7 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

Employing the frequency range of maximum atmospheric attenuation around 60 GHz, a short range obstacle warning radar for helicopters was developed which can be operated under low probability of intercept conditions. Test flights with this noncoherent solid state radar showed that power cables as well as tall trees can be detected, even under adverse weather conditions. System considerations and test results are described. R.J.F.

N85-16811# Westland Helicopters Ltd., Yeovil (England).
THE DESIGN AND DEVELOPMENT OF AN INTEGRATED CORE SYSTEM FOR BATTLEFIELD HELICOPTERS
S. D. ROY and P. L. SHILLITO *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 10 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

Integrated control systems for Lynx and Westland combat helicopters are discussed. Navigation, communications, and weapons systems integration is addressed, as well as an architecture which not only enables the crew to manage and control the systems and aircraft on the battlefield, but provides a means of extending the performance of the total system-crew, avionics, and aircraft. R.J.F.

N85-16812# Army Avionics Research and Development Activity, Fort Monmouth, N. J.
EVOLUTION TOWARD A MULTI-BUS ARCHITECTURE FOR ARMY HELICOPTER AVIONIC SYSTEMS
J. A. DASARO *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 7 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

An attempt to arrive at an architecture which fits the avionics technology available today and that which will be available in the near future is described. Current efforts to implement this technology in the U.S. Army Avionics Laboratory are using currently available microprocessors configured as a multiprocessor and an available Ada compiler. A procurement strategy evolved in parallel with this architecture that uses form, fit, function specifications and interface control documents so as not to restrict future procurements to today's technology. Certainly much work remains to be accomplished to evolve the concept presented here; however, it is fully expected that over the next several years, enough experience should be gained to achieve an architecture that should meet the needs for the demanding helicopter missions of the future. A.R.H.

N85-16813# Bell Helicopter Co., Fort Worth, Tex.
INTEGRATION OF SENSOR FUSION IN ADVANCED HELICOPTER COCKPIT DESIGN
G. L. COHILL, D. D. STROTHER, and H. B. HENDERSON (Texas Instruments, Dallas, Tex.) *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 9 p (SEE N85-16797 08-01) Aug. 1984
Avail: NTIS HC A13/MF A01

Effective operation and survival in the battlefield of the future can impose great demands on helicopter weapon systems and the crews who manage them. Among these are: time to detect and respond to threats and targets; ability to integrate many types of sensor data and assess the intelligence portrayed by these sensors; and requirements for highly trained systems management personnel who can process highly technical information while operating in the very demanding NOE environment. Helicopter cockpit designs for the future and how crew performance can be improved are discussed and subsystems are addressed which can improve human performance. Sensor fusion systems, related misconceptions and their proposed use are highlighted. It is shown that the fused system is more reliable, less costly, lighter, and has more performance potential. System fusion provides a way to unload the harried system operator and assure mission success at a cost/performance ratio that decreases proportionally with overall system complexity. A.R.H

N85-16814*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
A REVIEW OF US ARMY AIRCREW-AIRCRAFT INTEGRATION RESEARCH PROGRAMS
D. L. KEY and E. W. AIKEN *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 15 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01 CSCL 01C

The desire of the Army for a one crew helicopter that can perform the scout and attack role is forcing the integration of handling qualities and mission management disciplines and concerns. Some recent studies and results in these disciplines are reviewed. The need for a more unified approach to support new helicopter development is described along with a plan to develop fundamental principles needed for efficient man machine interface design. R.S.F.

N85-16815# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
ADVANCED FLIGHT SIMULATION FOR HELICOPTER DEVELOPMENT
H. HUBER, H. J. DAHL, and A. INGLSPERGER *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 14 p (SEE N85-16797 08-01) Aug 1984 refs
Avail: NTIS HC A13/MF A01

A simulation capability for both fixed wing and rotary wing aircraft has been developed. The fixed based simulator consists of interchangeable cockpit stations, a computer generated imagery (CGI) visual system, both coupled with the math model simulation computer. Specific integration rigs for avionics, flight controls, and weapon systems can be operated with the simulator. The simulation system is described including cockpit/interface hardware, visual display system, and mathematical modeling. The simulation validity is demonstrated by the verification of the mathematical model and by pilot judgments. Typical simulation tasks for future military applications are discussed. It is concluded that the existing simulator provides a valid tool for helicopter system development. R.S.F.

N85-16816# Centre d'Electronique de l'Armement, Bruz (France).
A SIMULATOR FOR STUDYING HELICOPTER WEAPONS SYSTEMS [UN SIMULATEUR D'ETUDES DE SYSTEMS D'ARMES HELICOPTERE]
M. HUON *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 12 p (SEE N85-16797 08-01) Aug. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

A simulator designed to study air to air missile and cannon fire against a helicopter is described. The pilot station is fixed and located in a sphere which serves as a screen on which a TITUS tube projects a synthetic image of the landscape defined by 10,000 facets (SOGITEC G I 10,000 processor). The field is covered from 80 degrees around and is completed by horizon projection. A 250 faceted projector generates the target. A transparent, symbolic sighting tube is projected on the sphere by a power tube. The pilot uses a helmet mounted display. The marksman's apparatus is offset and involves a main sighting tube with presentation of a G I 10,000 image and weapons control. Vibration seats are provided. Ambient noise is supplied by a programmable noise generator. The complete simulator is operated from a test direction station. A.R.H.

N85-16817# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
ASSESSMENT OF SIMULATION FIDELITY USING MEASUREMENTS OF PILOTING TECHNIQUE IN FLIGHT
W. F. CLEMENT (Systems Technology, Inc., Mountain View, Calif.), W. B. CLEVELAND, and D. L. KEY *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 12 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01 CSCL 14B

The U.S. Army and NASA joined together on a project to conduct a systematic investigation and validation of a ground based piloted simulation of the Army/Sikorsky UH-60A helicopter. Flight testing was an integral part of the validation effort. Nap-of-the-Earth (NOE) piloting tasks which were investigated included the bob-up, the hover turn, the dash/quickstop, the sidestep, the dolphin, and the slalom. Results from the simulation indicate that the pilot's NOE task performance in the simulator is noticeably and quantifiably degraded when compared with the task performance results generated in flight test. The results of the flight test and ground based simulation experiments support a unique rationale for the assessment of simulation fidelity: flight simulation fidelity should be judged quantitatively by measuring pilot's control strategy and technique as induced by the simulator. A quantitative comparison is offered between the piloting technique observed in a flight simulator and that observed in flight test for the same tasks performed by the same pilots. R.S.F.

N85-16818# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
FLIGHT TESTS WITH A NEW HELICOPTER FORCE FEEL SYSTEM (FFS)
R. D. VONRETH, H. KOENIG, and G. TURCK *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 11 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

An artificial force feel system for the control of the pitch and roll axes of a Bo 105 helicopter was studied. Goals of the program were to investigate if the use of such an artificial force feel system for the helicopter control would increase flight safety, allow a more precise control of a flight path, increase stability, and reduce pilot workload. An experimental flight worthy system using the electro-hydraulic actuators for the pitch and roll axis respectively was implemented in the flying simulator Bo 105-53. A number of different force control laws were derived and flight tested. Although some contributions to the total control force were rated very differently by the various test pilots (e.g., contributions from the normal acceleration), as a general trend very favorable ratings were obtained. Two examples of these favorable ratings for highly dynamic maneuvers (slalom and dolphin) are an improved stability of the trim state and an improved flight path control in general. M.G.

N85-16819# Rome Univ. (Italy).
HELICOPTER ACTIVE CONTROL WITH ROTOR BLADES RELAXATION
A. DANESI and A. DANESI *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 17 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

An active modal control for high performance combat helicopters in forward flight is presented. A gust alleviation control (G.A.C.) strategy based on the spectral data computed from the flexible blade structural mode of vibration measurements, is employed to relax, by appropriate longitudinal cyclic pitch modulation, the flat wise bending moments induced by environmental disturbances. The restoring cyclic pitch commands are derived processing the output data from an electro-optical

laser sensor by means of a microprocessor performing the spectral power density real time computations; these data, obtained implementing a fast fourier transform algorithm and observed within a frequency window centered at the first bending mode frequency, are employed as a measure of the actual vibrational level existing on the blade. To reduce the helicopter rigid response sensitivity to the G.A.C. system actuators, its driving signals are applied to the longitudinal pitch decoupling unit making the helicopter attitude and vertical velocity component decoupled, the last one regulated by the collective pitch channel through a radioaltimeter closure. The effectiveness of the G.A.C. system is investigated by digital simulations. M.G.

N85-16820# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
FLIGHT RESEARCH ON VISUSL AIDS AND NAVIGATION EQUIPMENT FOR HELICOPTER LOW-LEVEL FLIGHT AT NIGHT
R. BEYER *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 8 p (SEE N85-16797 08-01) Aug. 1984 refs
Avail: NTIS HC A13/MF A01

An avionic/optronic system comprising night goggles, electronic head down display and Doppler navigation was tested in a Bo 105 helicopter in low level flight at night. Particular emphasis was given to the assessment of system performance and pilot workload. The results obtained as well as the methods and procedures applied are discussed in a way that similar experiments in the future may benefit from the outcome. Author

N85-16821*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
DEVELOPMENT AND FLIGHT TEST OF A HELICOPTER COMPACT, PORTABLE, PRECISION LANDING SYSTEM CONCEPT
J. S. BULL, G. R. CLARY, T. J. DAVIS, and J. P. CHISHOLM (Sierra Nevada Corp., Reno) *In* AGARD Helicopter Guidance and Control Systems for Battlefield Support 8 p (SEE N85-16797 08-01) Aug. 1984 refs Previously announced as N84-24566
Avail: NTIS HC A13/MF A01 CSCL 01D

An airborne, radar based, precision approach concept is being developed and flight tested as a part of NASA's Rotorcraft All-Weather Operations Research Program. A transponder based beacon landing system (BLS) applying state of the art X band radar technology and digital processing techniques, has been built and is being flight tested to demonstrate the concept feasibility. The BLS airborne hardware consists of an add on microprocessor, installed in conjunction with the aircraft weather/mapping radar, which analyzes the radar beacon receiver returns and determines range, localizer deviation, and glide slope derivation. The ground station is an inexpensive, portable unit which can be quickly deployed at a landing site. Results from the flight test program show that the BLS concept has a significant potential for providing rotorcraft with low cost, precision instrument approach capability in remote areas. Author

N85-17025# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
HAZARD STUDIES FOR SOLID PROPELLANT ROCKET MOTORS
Loughton, England Sep. 1984 297 p refs In ENGLISH and FRENCH Conf. held in Lisse, Netherlands, 28-30 May 1984 (AGARD-CP-367; ISBN-92-835-0361-9; AD-A150458) Avail: NTIS HC A13/MF A01

The needs for NATO standardization as related to solid propellant rocket motors are reviewed and technology issues associated with solid rocket motor hazards are discussed. The following topics associated with solid propellant rocket motors are considered: (1) application of hazard technologies; (2) *fragmentation and high rate deformation of solid propellants*; (3) mechanism, theory, and experiments; and (4) thermal sensitivity and cook-off. For individual titles see N85-17026 through N85-17046.

N85-17026# Royal Marines, London (England).
AIMS AND REQUIREMENTS OF NATO GROUP AC/310
G. G. W. BRACE *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 11 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

One aim of NATO is to achieve increased military effectiveness *through the efficient use of resources allocated by nations* for their defence. This involves cross procurement between nations and in the case of weapons and stores containing explosives, there can be economy of resources if there is a common approach within NATO to the safety of designs and the test requirements necessary to demonstrate safety. Such demonstrations must commence with the assessment of the energetic materials chosen for use. Commonality of test procedures is not envisaged, but a base line requirement for the data to enable safety assessments by purchasing nations has been agreed. It is recognized that, for propellant formulations in particular, problems exist because of the need to adjust compositions during development. A method to accommodate such problems when meeting the NATO data requirements is proposed. A base line requirement is created for the data considered necessary for the assessment of explosive compositions for their safety and suitability for service use. Such data should enable any nation receiving explosives to make a judgement, and thereby qualify the material. R.S.F

N85-17027# Air Force Rocket Propulsion Lab., Edwards AFB, Calif.
REVIEW OF USAF TREATMENT OF SOLID PROPELLANT ROCKET MOTOR HAZARDS
R. R. WEISS, N. VANDERHYDE, and C. MERRILL *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 15 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Efforts pursued under the air-launched missile behavior program are summarized. The impact effects on solid rocket propellants are discussed along with the explosive hazards of air-launched propulsion systems. Various tests to assess propellant stability are enumerated. The results of experimental investigations to standardize shotgun/relative quickness bomb testing and to improve the sensitivity of the dynamic shear/deflagration-to-detonation transition test are reported. R.S.F

N85-17028# Bundesinstitut fuer Chemisch-Technische Untersuchgen, Swisttal-Heimerzheim (West Germany).
SENSITIVITY TESTS FOR SOLID PROPELLANTS IN GERMANY
F. TRIMBORN *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 5 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Sensitivity tests are very important for the investigation and acceptance of solid propellants according to the regulations for the safety of explosives in Germany. The background for this is provided by a philosophy of safety involving the concept of primary safety. To achieve primary safety, it is necessary to know and to consider the explosive properties of the solid propellants. German methods for testing the sensitivity to impact, friction, shockwaves heating and DDT are discussed. From the results trained experts can draw conclusions for the safety of solid propellants and/or for the risk emanating from them. Comparisons with accidents/incidents show that the results of the German test methods within the context of the expert's own experience can be used to characterize at least the different types of solid propellants. A.R.H

N85-17029# Propellants, Explosives and Rocket Motor Establishment, Waltham Abbey (England).
SENSITIVENESS AND EXPLOSIVENESS ASSESSMENT AT PERME WALTHAM ABBEY
D. C. MULLENGER *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 8 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

The schemes used at PERME for testing propellants, for the production of MOD Safety Certificates, for the assignment of the UN Hazard Division, and for the Ordnance Board Qualification for Service use are presented. The types of test used these schemes are described. Typical results for a range of rocket propellant compositions are given and discussed. Author

N85-17030# Illinois Univ., Urbana-Champaign. Dept. of Mechanical and Industrial Engineering.
ANALYSIS OF DEFLAGRATION TO SHOCK TO DETONATION TRANSITION (DSDT) IN POROUS ENERGETIC SOLID PROPELLANTS
P. B. BUTLER and H. KRIER *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 10 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Explosive-based propellants are susceptible to detonation from the controlled deflagration mode of combustion. In certain instances (i.e., when the propellant/explosive is fragmented) the likelihood of a catastrophic event is greater. Fragment size, gas permeability through the packed bed, chemical decomposition rate and product gas confinement all play an important role in determining whether a convective deflagration wave will make a transition to a steady state detonation wave. The governing equations defining such a transient two-phase reactive flow process are analyzed. Computer generated results are presented showing the development of a steady state detonation wave from an accelerating deflagration wave M.G.

N85-17031# Norwegian Defence Research Establishment, Kjeller
PENGUIN WARHEAD SAFETY TESTS
E. STROMSOE, A. ODDAN, and L. OMHOLT *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 9 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Safety tests according to the Naval Weapons Requirement WR-50 were carried out with Destex filled Penguin warheads. To simulate fuel fire and magazine heating the fast and slow cook-off tests were chosen; for projectiles the bullet impact test; and for fragments the propagation test where another warhead is used as fragment generator (donor). Six categories of warhead response were used to characterize the severeness of explosive reaction: high order detonation, violent low order detonation, non-violent low order detonation, deflagration, burning, no reaction. The main lesson which can be learned from these experiments is that even if the prescribed test procedure is faithfully followed, great scattering of the test results can be expected. Decisive conclusions should therefore not be drawn from two few experiments. Other valuable experience connected with each separate test is presented. Author

N85-17032# Centre de Recherches du Bouchet, Vert de Petit (France)
STUDY OF THE TRANSITION FROM DEFLAGRATION TO DETONATION OF PREVIOUSLY FRAGMENTED PROPELLANTS [ETUDE DE LA TRANSITION DE LA DEFLAGRATION A LA DETONATION DES PROPERGOLS PREALABLEMENT FRAGMENTES]
J. BRUNET and J. L. PAULIN *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 22 p (SEE N85-17025 08-20) Sep. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

The problem of the possibility of transition from deflagration to detonation in a body from the time of firing an engine with a charge of solid propellants is approached by considering a local fragmentation stage. A method of characterizing the resistance of solid propellants to hazardous fragmentation is described which uses specific tests: impact against a smooth wall, combustion of fragments in a manometrical bomb, and a transition test. This resistance is manifested by an impact velocity limit. Numerous velocity impact limits were measured on several compositions and parametric studies of formulations yielded orientations or obtaining a better behavior of propellant materials in the future with regards to the risks of hazardous fragmentation. Transl. by A.R.H.

N85-17033# Imperial Metal Industries Ltd., Kidderminster (England).
THE VULNERABILITY OF CAST DOUBLE BASE ROCKET MOTORS TO THERMOMECHANICAL ATTACK
G. I. EVANS, J. F. BINGHAM, and J. H. SINDALL *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 14 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Fragment penetration and fire trials were conducted on a dual thrust motor employing a cast double base propellant. The propellant in the motor is bonded to the case wall and thus the type of damage that can occur to a cartridge loaded charge is prevented. When the motor is attacked by single fragments an area, depending on size and weight of the fragment, of strip delamination in the case is created about the fragment exit point. On ignition of the propellant, hot gas flowing from this area steadily increases the delamination and prevents pressure build up to explosive levels. The reaction to multi-fragment attack is similar to that of a single fragment except when the attacking projectile explodes in close proximity to the motor. Under these conditions the case construction allows the motor to snap into a number of pieces and again prevents motor explosion. When subjected to heat, the resin used for strip bonding begins to break down. At the instant of propellant ignition only very low pressures are required to disrupt the motor case and thus provide a multitude of paths for gas to exhaust to prevent explosive pressure build up. M.G.

N85-17034# Propellants, Explosives and Rocket Motor Establishment, Waltham Abbey (England).
CRACK GROWTH IN PROPELLANTS
R. A. GLEDHILL and A. J. KINLOCH *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 7 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

A continuum fracture mechanics approach for characterizing crack growth in a nitrocellulose/nitroglycerine based propellant is presented. Firstly, the measurement of the stress-intensity factor, K sub c, at the onset of crack propagation over a wide range of test temperatures and under relatively slow rates of loading is discussed. The use of the Williams-Landel-Ferry equation for relating the effects of rate and temperature is then examined. Secondly, crack growth resulting from impact loading is examined. The instrumented impact test equipment is described and the experimentally obtained values of K sub c are discussed. R.J.F.

N85-17035# Lawrence Livermore National Lab., Calif.
RESPONSE OF PROPELLANTS TO HIGH DYNAMIC STRESSES: THE USES OF GUN LAUNCH TECHNIQUES
E. L. LEE, E. JAMES, L. GREEN, W. VONHOLLE, C. TARVER, D. CURRAN (Stanford Research Intern., Menlo Park, Calif.), W. MURRI (Stanford Research Intern., Menlo Park, Calif.), and D. SEAMAN (Stanford Research Intern., Menlo Park, Calif.) *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 32 p (SEE N85-17025 08-20) Sep. 1984 refs Previously announced as N85-11259
Avail: NTIS HC A13/MF A01

High energy propellants that ignite and begin to release chemical energy when they are subjected to sufficiently high stresses are discussed. The ensuing response can vary from mild reaction to high order detonation. Experimental and calculation efforts were made to understand, predict, and modify this response. Experimental work which uses guns to impact flat plates on oriented propellant samples is emphasized. R.J.F.

N85-17036# Ballistic Research Labs., Aberdeen Proving Ground, Md.
SOME ASPECTS OF THE MICROMECHANICS OF HOT SPOT FORMATION IN ENERGETIC MATERIALS
R. B. FREY *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 14 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

The mechanics of cavity collapse in an energetic material were studied. During cavity collapse, several mechanisms can act individually or collectively to produce high temperature hot spots. The goal is to understand how pressurization rate, cavity size, and material parameters affect hot spot formation. The collapse of spherical cavities using a modified form of the model of Carroll and Holt was considered. Using this analysis, hot spots produced by plastic work, viscoplastic work, gas phase heating, or solid

phase compression (which occurs as the result of high pressures produced when material collides at the center of the cavity) can be studied. Under the proper conditions, each of these mechanisms may be dominant, but viscous heating is the most efficient mechanism and is dominant when the rise time of the pressure is short, viscosity is high, and/or yield stress is low. The conditions under which the other mechanisms are dominant and the dependence of hot spot temperatures on the pressurization rate, cavity size, and material properties are discussed. R.J.F.

N85-17037# Naval Weapons Center, China Lake, Calif. Engineering Sciences Div.
TRANSIENT COMBUSTION: AN IMPORTANT CONSIDERATION IN DEFLAGRATION-TO-DETONATION TRANSITION
T. L. BOGGS, C. F. PRICE, and R. L. DERR *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 16 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Transient combustion events which range from igniter initiation to events just prior to detonation, are discussed. An analytical model of the deflagration of porous energetic materials leading to deflagration to detonation transition (DDT) in closed tube experiments is presented. The analysis not only describes transient deflagration behavior but also includes the highly coupled interaction of the deflagration with the sample and its environment compaction behavior for example. The model calculates the following as functions of distance and time from igniter initiation: (1) gas pressure; (2) intergranular stress; (3) gas temperature; (4) surface temperatures of the particle; (5) compaction; (6) development of gas phase reaction over the particles; (7) amount of solid pyrolyzed; and (8) amount of pyrolysis gas converted to final products. It is concluded that the combustion behavior essential to understanding DDT is entirely transient and must be treated in its full complexity of interrelated and highly coupled phenomena. E.A.K.

N85-17038# Naval Surface Weapons Center, Silver Spring, Md.
THE DDT PROCESS FOR HIGH ENERGY PROPELLANTS
R. R. BERNECKER *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 16 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

The deflagration-to-detonation transition (DDT) process is reviewed for cast and porous systems of energetic propellants. Analysis of DDT studies with cast explosive systems indicate that it is highly improbable that cast, well-manufactured propellant grains will undergo DDT. The DDT experiments are described which relate the nature of the damaged (granulated) propellant samples to their tendency to undergo DDT. The parameters, which influence the outcome of these DDT experiments are discussed. One of the more practical pieces of information pertaining to hazards that can be obtained in DDT work is a quantitative measure of the propensity of various porous propellant systems to undergo DDT. This type of data is presented for various energetic propellants for both high and low confinement conditions. An example of this type of experiment, where dynamic shearing occurs during confined burning is discussed. Data are presented from low confinement DDT experiments, utilizing flash radiography, which provided quantitative data useful for the development of physical and theoretical/numerical models of the DDT process. It is shown that knowledge of the shock sensitivity of the porous propellant system is important in assessing its DDT susceptibility under low confinement conditions. E.A.K.

N85-17039# Centre de Recherches du Bouchet, Vert de Petit (France).
NUMERICAL SIMULATION OF THE SHOCK DETONATION TRANSITION [SIMULATION NUMERIQUE DE LA TRANSITION CHOC DETONATION]
B. NOUGUEZ, A. BERTRAND, and J. MALA *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 10 p (SEE N85-17025 08-20) Sep. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

A study was conducted at S.N.P.E. which attempts to model numerically the shock-detonation transition of explosive materials. A model of combustion was developed and implanted in the HEMP bidimensional computer code. General hypothesis about the model, the principal equations retained to describe the phenomena, and the first application of the model to validate the code on PETN - TATB type products and HMX are presented. Transl. by A.R.H.

N85-17040# Los Alamos Scientific Lab., N. Mex.
SHOCK AND IMPACT RESPONSE OF SOLID ROCKET PROPELLANTS: EXPERIMENTAL AND THEORETICAL
J. K. DIENES and J. J. DICK *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 16 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Data on plane-shock-initiation sensitivity of a number of propellant formulations are reviewed and shock sensitivity results for 35% porous HMX are presented. These data were obtained using transit time technique and statistical analysis. Though the sensitivity of propellants is of central importance in considering their reliability and safety, and underlying mechanisms are not very well understood. These problems are underscored by cylinder impact tests that demonstrate a wide variety of behavior. In particular, most shots in one series of low speed impact tests led to a mild deflagration, while a fraction of ostensibly identical shots resulted in violet detonations. Since continuum descriptions of such behavior fail to explain the lack of repeatability, a variety of hot-spot mechanisms were considered. Order-of-magnitude studies indicate that interfacial sliding of closed cracks constitutes the most critical type of hot spot, and detailed analysis confirms that this mechanisms explains the observations. B.G.

N85-17041# Bundesinstitut fuer Chemisch-Technische Untersuchgen, Swisttal-Heimerzheim (West Germany).
BALLISTIC/DETONIC TRANSITION OF PROPELLANTS
C. O. LEIBER *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 14 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Occasional catastrophic failures of propellant systems, such as those resulting in breech blows or rocket explosions, may be caused basically by an anomalous increase of the static or dynamic pressure in the gas phase and/or in the condensed phase. Using the classical principles of pressure wave generation by a hydrodynamic flow of Lord Rayleigh and Lighthill, it is demonstrated that interior ballistics splits both into a classical and also a detonic branch, the latter correponding to the Low-Velocity-Detonation (LVD)-regime. According to the physical model, this transition is favored by increased dynamics. The region between these limits corresponds to the Gallwitz regime. B.G.

N85-17042# Propellants, Explosives and Rocket Motor Establishment, Waltham Abbey (England).
HAZARD ASSESSMENT OF A HYPOTHETICAL LARGE ROCKET MOTOR
D. C. MULLENGER *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 5 p (SEE N85-17025 08-20) Sep. 1984
Avail: NTIS HC A13/MF A01

The relationship between sensitiveness, explosiveness and hazard is discussed. Stimuli relevant to this particular problem are listed and their relative importance is discussed. The difficulty of scaling up from test samples to the full motor is considered and the present philosophy for tackling this problem is given. Author

N85-17043# Prins Maurits Lab. TNO, Rijswijk (Netherlands).
THE HEAT SENSITIVITY OF SOLID PROPELLANTS
M. A. SCHRADER, M. W. LEEUW, and A. C. VANDERSTEEN *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 6 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

The temperature dependence of the induction times of composite propellants are measured and compared to those of pure ammonium perchlorate. The induction times of the composite propellants appear to be considerably shorter: at 600 K the differences is about a factor of fifty. The addition of aluminum, nitroguanidine or a burning catalyst to ammonium perchlorate does not influence its induction time. The increased rate of decomposition is attributed to the polyurethane binder whose decomposition products possibly catalyze the decomposition reaction of ammonium perchlorate. The plasticizer in a double base propellant does not affect the induction times. Author

N85-17044# Centre de Recherches du Bouchet, Vert de Petit (France).
MODELLING THE THERMAL EXPLOSION PHENOMENON IN SOLID PROPELLANTS: THE CASE OF FIXED AND VARIABLE TEMPERATURES [MODELISATION DU PHENOMENE D'EXPLOSION THERMIQUE DANS LES PROPERGOLS SOLIDES: CAS DES TEMPERATURES FIXES ET VARIABLES]
D. CASENAVE and P. RACIMOR *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 14 p (SEE N85-17025 08-20) Sep. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

The state of the art of work at S.N.P.E on thermal explosion phenomena as part of the study of solid propellant stability is presented. In the case of a product subjected to successive increases in temperature, the base theory of the phenomena led to a test method which established for each composition tested, a model for evaluating the critical temperature and the induction time of the product as a function of the size and the configuration of the bulk propellant. The thermal explosion phenomena is also shown for the case of a product subjected to a progressive increase in temperature. A computer code was also developed which can model the thermal explosion phenomenon. Theoretical results are in good agreement with experiment and confirm, in the case of variable temperature, that a decrease in the speed of temperature rise favors the appearance of violet phenomena.
Transl. by A.R.H.

N85-17045# Institut fuer Chemie der Treib- und Explosivstoffe, Pfinztal (West Germany).
DETERMINATION OF THE DECOMPOSITION BEHAVIOR OF DOUBLE BASE PROPELLANTS AT LOW TEMPERATURES
F. VOLK *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 7 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

Aging in double-base solid propellants was explored using chemical, physico-chemical, and mechanical methods. High-pressure liquid chromatography was used to calculate the chemical life by determining the decrease in stabilizer to 50% of its original content. Gel permeation chromatography was used to track the depolymerization of the nitrocellulose contained in the relevant propellant by measuring the reduction in molecular weight. Measurement of the strain at break and the tensile strength of the product deter[illegible]he deterioration of its mechanical properties. Suitable samples [illegible]ropellant were subjected to thermic stress between 60 C and [illegible] C for different lengths of time to establish the actual temperature dependency of the three aging processes considered. The best temperature correlation was shown through measurement of the stabilizer decrease; however, both the reduction in the molecular weight of the nitrocellulose and the drop in mechanical properties could not be determined with the same accuracy. The results show that a depolymerization of the nitrocellulose takes place more rapidly than the drop in tensile strength.
B.W.

N85-17046# Politecnico di Milano (Italy).
THE PRESSURE DEFLAGRATION LIMIT OF SOLID ROCKET PROPELLANTS
L. DELUCA, G. RIVA, C. ZANOTTI, R. DONDE, V. LAPEGNA, and A. OLEARI *In* AGARD Hazard Studies for Solid Propellant Rocket Motors 16 p (SEE N85-17025 08-20) Sep. 1984 refs
Avail: NTIS HC A13/MF A01

The concept of pressure deflagration limit in the combustion of solid rocket propellants is reviewed. It is shown that the existence of a pressure deflagration limit is due not to lack of the appropriate steady state solution, but to burning instability (even for adiabatic combustion). The peculiar behavior of solid propellants near the pressure deflagration limit is confirmed by numerical and experimental tests of ammonium perchlorate based composite formulations. Self-sustained oscillatory burning, existing immediately before reaching the pressure deflagration limit, was investigated. Attention was focused on those physico-chemical properties and operating conditions capable to raise the value of the pressure deflagration limit. This should allow safer handling and storage of solid propellants.
Author

N85-22350# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GROUND AND FLIGHT TESTING FOR AIRCRAFT GUIDANCE AND CONTROL
R. ONKEN, ed. (DFVLR, Brunswick, West Germany) and H. A. REDIESS, ed. (Hydraulic Research Textron, Inc., Irving, Calif.) Loughton, England Dec. 1984 195 p refs
(AGARD-AG-262; ISBN-92-835-1482-3) Avail: NTIS HC A09/MF A01

Aircraft guidance and control functions, components, and systems are evaluated with emphasis on specific examples of user oriented test programs rather than descriptions of the facilities. Topics include control handling and active control testing; tests on flight path control; navigation system testing; combat guidance and control evaluation; and testing of flight-crucial digital systems in guidance and control. For individual titles see N85-22351 through N85-22362.

N85-22351*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
SPACE SHUTTLE PILOT-INDUCED-OSCILLATION RESEARCH TESTING
B. G. POWERS *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 7 p (SEE N85-22350 13-01) Dec. 1984 refs Original language document was announced as N84-20566
Avail: NTIS HC A09/MF A01 CSCL 01C

The simulation requirements for investigation of pilot-induced-oscillation (PIO) characteristics during the landing phase are discussed. Orbiters simulations and F-8 digital fly-by-wire aircraft tests are addressed.
Author

N85-22352# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugmechanik.
DYNAMIC WIND TUNNEL TESTING FOR ACTIVE CONTROL RESEARCH
K. WILHELM and B. GMELIN *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 26 p (SEE N85-22350 13-01) Dec. 1984 refs
Avail: NTIS HC A09/MF A01

For the investigation of problems associated with the application of active control systems a technique was developed, which allows a comprehensive treatment of flight mechanics problems including the effects of aerodynamics, aeroelastics and control systems. Since this technique, the dynamic wind tunnel test technique, is a synthesis of both computer simulation and wind tunnel test a variety of information on specific flight mechanical phenomena can be obtained. At DFVLR two experimental devices were developed: the installation for dynamic simulation in wind tunnels for investigation in the field of fixed-wing aircraft; and the rotor test stand for investigation in the field of rotary-wing aircraft. At first a brief description of the test facilities is given, further advantages and special problems associated with the application of this test technique are shown. In addition, test results of completed test programs are presented.
Author

N85-22353*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DYNAMIC WIND-TUNNEL TESTING OF ACTIVE CONTROLS BY THE NASA LANGLEY RESEARCH CENTER
I. ABEL, R. V. DOGGETT, J. R. NEWSOM, and M. SANDFORD *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 23 p (SEE N85-22350 13-01) Dec. 1984 refs
Avail: NTIS HC A09/MF A01 CSCL 01C

Dynamic wind-tunnel testing of active controls by the NASA Langley Research Center is presented. Seven experimental studies that were accomplished to date are described. Six of the studies focus on active flutter suppression. The other focuses on active load alleviation. In addition to presenting basic results for these experimental studies, topics including model design and construction, control law synthesis, active control system implementation, and wind-tunnel test techniques are discussed.
Author

N85-22354# Royal Aircraft Establishment, Bedford (England). Operational Systems Div.
CIVIL AVIONICS FLIGHT TESTING WITH THE RAE(B) BAC1-11
R. R. NEWBERY and P. ENGLAND *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 22 p (SEE N85-22350 13-01) Dec. 1984 refs Original contains color illustrations
Avail: NTIS HC A09/MF A01

The BAC 1-11 research aircraft and test flight facility are described. Significant results were achieved in the fields of automatic control, improved accuracy of navigation, the use of CRT flight deck displays, the development of time control maneuvers, and the use of direct voice input. The role of avionics systems in the total air traffic management system is addressed. The development of flight path and time control algorithms will be extended to deal with multiple constraints. Further attention will be paid to the interfaces between the aircraft systems, crew, and air traffic control. B.G.

N85-22355# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
GUIDANCE AND CONTROL RESEARCH FLIGHT TESTING WITH HFB 320 TEST AIRCRAFT
V. ADAM and W. LECHNER *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 13 p (SEE N85-22350 13-01) Dec. 1984 refs
Avail: NTIS HC A09/MF A01

Flight testing is the last and decisive phase in the development process of new aircraft guidance and control methods, procedures and equipment to give evidence of the expected functional performance. No highly elaborated ground-based simulation can replace this phase unless there is complete knowledge of the aircraft system characteristics and no restriction on expenditure. On the other hand there is no doubt that simulation including most of the real system hardware is a necessary phase to pass before flight testing can be started. This is the means for step by step system validation on the ground under reproducible conditions. In-flight simulation, direct lift control, side stick control, fly-by-wire and integrated navigation tests on the German aircraft HFB 320 are reported. Ground-based experimental systems and flight test equipment are also described. B.G.

N85-22356*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
A FLIGHT MANAGEMENT ALGORITHM AND GUIDANCE FOR FUEL-CONSERVATIVE DESCENTS IN A TIME-BASED METERED AIR TRAFFIC ENVIRONMENT: DEVELOPMENT AND FLIGHT TEST RESULTS
C. E. KNOX *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 17 p (SEE N85-22350 13-01) Dec. 1984 refs
Avail: NTIS HC A09/MF A01 CSCL 01C

A simple airborne flight management descent algorithm designed to define a flight profile subject to the constraints of using idle thrust, a clean airplane configuration (landing gear up, flaps zero, and speed brakes retracted), and fixed-time end conditions was developed and flight tested in the NASA TSRV B-737 research airplane. The research test flights, conducted in the Denver ARTCC automated time-based metering LFM/PD ATC environment, demonstrated that time guidance and control in the cockpit was acceptable to the pilots and ATC controllers and resulted in arrival of the airplane over the metering fix with standard deviations in airspeed error of 6.5 knots, in altitude error of 23.7 m (77.8 ft), and in arrival time accuracy of 12 sec. These accuracies indicated a good representation of airplane performance and wind modeling. Fuel savings will be obtained on a fleet-wide basis through a reduction of the time error dispersions at the metering fix and on a single-airplane basis by presenting the pilot with guidance for a fuel-efficient descent. Author

N85-22357# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugfuehrung.
AVIONICS FLIGHT EVALUATION SYSTEM (AFES)
K. HURRASS *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 9 p (SEE N85-22350 13-01) Dec. 1984 refs
Avail: NTIS HC A09/MF A01

New avionic systems require thorough testing. Particularly as far as navigation systems are concerned, very accurate reference trajectories have to be established. For this purpose, DFVLR has developed an Avionics Flight Evaluation System (AFES). A tracking radar, a laser tracker, and an inertial navigation system (INS) on board the test aircraft are used in order to measure flight trajectories. The data of all these sensors are combined by optimal filters. In order to be able to evaluate in real time, computers are used at different locations. All elements of this measurement system are linked together by an efficient data transfer system. Besides the reference system, AFES contains subsystems for artificial traffic loading and measuring multipath effects. Author

N85-22358# Royal Aircraft Establishment, Farnborough (England).
REFERENCE SYSTEMS FOR THE EVALUATION OF DEAD-RECKONING NAVIGATION EQUIPMENT
R. F. STOKES and S. G. SMITH *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 17 p (SEE N85-22350 13-01) Dec. 1984 Original language document was announced as N84-34406
Avail: NTIS HC A09/MF A01

Aircraft dead reckoning navigation systems present particular problems in their assessment, and diagnosis in development where a continuous measurement of their error pattern is required. The need for long range, long duration flights with a continuous high accuracy reference led to the development of an integrated navigation system. The recorded data is processed post-flight in a Kalman filter which is used to estimate the inertial system errors. The final reference is formed by compensating the inertial outputs for these errors and has the properties of high accuracy, low noise, and continuous availability. Although simple in concept the implementation of such a scheme is complex. The major problem lies in constructing suitable mathematical models of the various equipments, and the technique of pre-processing is described. The second difficult area is that of obtaining the statistical information regarding the performance of the equipment in a form suitable for inclusion in the models. Although the reference is produced off-line, it is possible to implement the techniques on-line. R.S.F.

N85-22359# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).
AIR COMBAT SIMULATION: METHODS, MODELS, TRENDS
G. WUNDERLICH and H. P. FEHRENZ *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 17 p (SEE N85-22350 13-01) Dec. 1984 refs
Avail: NTIS HC A09/MF A01

Various methods are described briefly to evaluate weapon system parameters needed during air combat. The influences and connections between unmanned and manned combat simulation are derived as well as the main differences between 1 vs 1 and m vs n combat including relevant pilot behavior. Finally unmanned and manned m/n air combat simulations are described and it is shown how both methods support each other thus broadening the validity of application and results. Author

N85-22360# Societe Nationale Industrielle Aerospatiale, Marignane (France). Avionics and Systems Group.
GROUND EVALUATION OF HELICOPTER AIR-TO-AIR WARFARE
G. CATANI *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 13 p (SEE N85-22350 13-01) Dec. 1984
Avail: NTIS HC A09/MF A01

Air to air capability has become a necessity for armed helicopters. The simulation models allow theoretical evaluation of given air to air fire controls through a large area of air to air scenarios. During definition phases, they represent a powerful means of building and ground testing every fire control. On the other hand increased efficiency during development phases makes

it possible to avoid expensive in-flight tests of non-optimized systems. Simple gun pilot fire control systems and definition and evaluation of complex gun/missile fire control systems were described. B.G.

N85-22361# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Military Aircraft Div.
TESTING OF THE DIGITAL FLIGHT CONTROL SYSTEM OF THE GERMAN CCV FIGHTER EXPERIMENTAL AIRCRAFT
U. KORTE *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 12 p (SEE N85-22350 13-01) Dec. 1984 refs Original language document was announced as N83-22110
Avail: NTIS HC A09/MF A01

A quad redundant digital FBW Control System for a highly unstable fighter aircraft has been developed and flight tested by MBB in a a single seater F-104 G which had been modified as a CCV demonstrator. The CCV program was funded by the German MOD. From Dec. 1977 to Nov. 1981 a total of 118 flights has been conducted. During these flights the quadruplex system was successfully tested for five different configurations starting with the highly stable basic aircraft and ending up with the highly unstable canard configuration with a static instability up to 22% mean aerodynamic chord (MAC). Some of the results obtained regarding control system design, handling evaluation and redundancy management with the digital system will be presented. Author

N85-22362*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
AIRLAB: A LABORATORY FOR FLIGHT-CRUCIAL-ELECTRONICS SYSTEM RESEARCH
H. M. HOLT, D. G. HOLDEN, and A. O. LUPTON *In* AGARD Ground and Flight Testing for Aircraft Guidance and Control 12 p (SEE N85-22350 13-01) Dec. 1984 refs
Avail: NTIS HC A09/MF A01 CSCL 01C

A new laboratory, AIRLAB, recently completed at the NASA Langley Research Center was developed as a focus for conducting research on fault-tolerant electronic systems for flight-crucial applications. The laboratory was conceived and implemented to enhance the utilization of aeronautical research for improving the performance of future aerospace vehicles. Advanced vehicles will require highly reliable digital electronic systems to perform flight-crucial functions which if lost, would cause total failure of the vehicle. Techniques to form the basis for a validation methodology that can be used to determine the performance and reliability of advanced digital systems are being developed. Included are the development of analytical models, emulation techniques, and experimental procedures. The techniques and methods are verified using these specimens of fault-tolerant computers and systems and the capabilities of AIRLAB. Author

N85-25170*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
MISSIONS AND VEHICLE CONCEPTS FOR MODERN, PROPELLED, LIGHTER-THAN-AIR VEHICLES
M. D. ARDEMA and A. D. YOUNG, ed. (Queen Mary Coll., London) Feb. 1985 52 p refs
(NASA-TM-87461; NAS 1.15:87461; AGARD-R-724; ISBN-92-835-1492-0; AD-A153278) Avail: NTIS HC A04/MF A01 CSCL 01B

Missions and vehicle concepts for modern propelled lighter-than-air vehicles were assessed. Utilization of these vehicles for patrol and surveillance, vertical heavy-lift, high altitude platforms and transportation missions are reported. E.A.K.

N85-25171# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TRANSONIC UNSTEADY AERODYNAMICS AND ITS AEROELASTIC APPLICATIONS
Loughton, England Jan. 1985 318 p refs In ENGLISH and FRENCH Conf. held in Toulouse, 2-7 Sep. 1984
(AGARD-CP-374; ISBN-92-835-0371-6; AD-A154078) Avail: NTIS HC A14/MF A01

Theoretical, numerical, and experimental techniques in transonic unsteady aerodynamics and their application to aeroelastic problems of aircraft loads, stability, and flutter are discussed. Supercritical, rectangular, and swept wing configurations are considered. For individual titles see N85-25172 through N85-25187.

N85-25172*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
TRENDS IN COMPUTATIONAL CAPABILITIES FOR FLUID DYNAMICS
V. L. PETERSON *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 9 p (SEE N85-25171 15-01) Jan. 1985 refs Document previously announced as N84-33383
Avail: NTIS HC A14/MF A01 CSCL 20D

Milestones in the development of computational aerodynamics are reviewed together with past, present, and future computer performance (speed and memory) trends. Factors influencing computer performance requirements for both steady and unsteady flow simulations are identified. Estimates of computer speed and memory that are required to calculate both inviscid and viscous, steady and unsteady flows about airfoils, wings, and simple wing body configurations are presented and compared to computer performance which is either currently available, or is expected to be available before the end of this decade. Finally, estimates of the amounts of computer time that are required to determine flutter boundaries of airfoils and wings at transonic Mach numbers are presented and discussed. Author

N85-25173# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Aeroelastik.
TRANSONIC PRESSURE DISTRIBUTIONS ON A TWO-DIMENSIONAL 0012 AND SUPERCRITICAL MBB-A3 PROFILE OSCILLATING IN HEAVE AND PITCH
H. TIEBSTEIN and R. VOSS *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 24 p (SEE N85-25171 15-01) Jan. 1985 refs
Avail: NTIS HC A14/MF A01

Steady and unsteady aerodynamic data were measured on 2-d rectangular wings with a NACA 0012 and a supercritical MBB-A3 profile. The tests were performed in the DFVLR Transonic Wind Tunnel in Gottingen. Both wings were oscillated in pitch about the c/4 axis, the wing with the MBB-A3 profile was also oscillated in heave to generate the unsteady aerodynamic pressure data. The purpose of the wind tunnel tests was primarily to measure data for use in the development and assessment of transonic analytical codes. Systematic measurements were performed with respect to Mach number, reduced frequency, incidence and amplitude of oscillation. The test results show clearly the peculiar unsteady behavior of transonic flow, particularly the strong nonlinearities associated with shock and higher incidences. Emphasis is also placed on the higher harmonic parts of unsteady pressure induced by the occurrence of shock. The measured data serve well as a basis for comparison with corresponding theoretical results. Comparisons between measurements and numerical results from the finite difference code LTRAN2 and the field panel code PTRAN2 show fairly good agreement. Most of the results in this presentation were obtained from MBB-A3 profile. M.G.

N85-25174# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
NUMERICAL STUDIES OF UNSTEADY TRANSONIC FLOW OVER OSCILLATING AIRFOIL
W. J. CHYU and S. S. DAVIS *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 22 p (SEE N85-25171 15-01) Jan. 1985 refs Document previously announced as N83-12316
Avail: NTIS HC A14/MF A01 CSCL 01A

A finite difference solution to the Navier-Stokes equations combined with a time varying grid generation technique was used to compute unsteady transonic flow over an oscillating airfoil. These computations were compared with experimental data (obtained at Ames Research Center) which form part of the AGARD standard configuration for aeroelastic analysis. A variety of approximations to the full Navier-Stokes equations was used to determine the effect of frequency, shock wave motion, flow separation, and airfoil geometry on unsteady pressures and overall air loads. Good agreement is shown between experiment and theory with the limiting factor being the lack of a reliable turbulence model for high Reynolds number, unsteady transonic flows. Author

N85-25175# National Aerospace Lab., Amsterdam (Netherlands).
ANALYSIS OF TRANSONIC AERODYNAMIC CHARACTERISTICS FOR A SUPERCRITICAL AIRFOIL OSCILLATING IN HEAVE, PITCH AND WITH OSCILLATING FLAP
R. C. DENBOER and R. HOUWINK *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 15 p (SEE N85-25171 15-01) Jan. 1985 refs Sponsored in part by Netherlands Agency for Aerospace Programs
Avail: NTIS HC A14/MF A01

An analysis is given of the unsteady aerodynamic characteristics of an oscillating supercritical airfoil with a thickness of 12% chord. Experimental data were obtained in the National Aerospace Laboratory (NLR) pilot tunnel for pitching, heaving and flap rotation, with Mach number, mean incidence, frequency and amplitude as parameters. The influence of these parameters is discussed in physical terms, with special emphasis on flow conditions with shock induced separation and aerodynamic resonance. Both for attached and separated flow, examples are presented of the use of experimental unsteady airloads in flutter computations for a wind tunnel model of a supercritical wing, and in correlation with results of viscous transonic flow computations. M.G.

N85-25176*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va. Unsteady Aerodynamics Branch.
EXPERIENCE WITH TRANSONIC UNSTEADY AERODYNAMIC CALCULATIONS
J. W. EDWARDS, S. R. BLAND, and D. A. SEIDEL *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 21 p (SEE N85-25171 15-01) Jan. 1985 refs Document previously announced as N84-32353
Avail: NTIS HC A14/MF A01 CSCL 01A

Comparisons of calculated and experimental transonic unsteady pressures and airloads for four of the AGARD Two Dimensional Aeroelastic Configurations and for a rectangular supercritical wing are presented. The two dimensional computer code, XTRAN2L, implementing the transonic small perturbation equation was used to obtain results for: (1) pitching oscillations of the NACA 64A010A; NLR 7301 and NACA 0012 airfoils; (2) flap oscillations for the NACA 64A006 and NRL 7301 airfoils; and (3) transient ramping motions for the NACA 0012 airfoils. Results from the three dimensional code XTRAN3S are compared with data from a rectangular supercritical wing oscillating in pitch. These cases illustrate the conditions under which the transonic inviscid small perturbation equation provides reasonable predictions. Author

N85-25177# Royal Aircraft Establishment, Farnborough (England).
CALCULATION OF HARMONIC AERODYNAMIC FORCES OF AEROFOILS AND WINGS FROM THE EULER EQUATIONS
D. J. SALMOND *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 17 p (SEE N85-25171 15-01) Jan. 1985 refs
Avail: NTIS HC A14/MF A01

A method developed to solve the Euler equations to obtain transonic aerodynamic forces on oscillating and wings is described. It is an extension of the implicit, finite difference method used by Pulliam and Steger to solve the Euler equations for the steady, transonic flow past an airfoil. Results in the form of steady pressure distributions and unsteady first harmonic, unsteady pressure coefficients are presented. Comparisons with the experimental results of Davis and Malcolm for the NACA 64A010 (Ames model) airfoil and those of Mabey for the AGARD tailplane are included. M.G.

N85-25178# Office National d'Etudes et de Recherches Aerospatiales, Leclerc (France).
CALCULATION OF UNSTEADY TRANSONIC SEPARATED FLOWS BY VISCOUS-INVISCID INTERACTION
P. GIRODROUX-LAVIGNE and J. C. LEBALLEUR *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 18 p (SEE N85-25171 15-01) Jan. 1985 refs In FRENCH; ENGLISH summary Original document previously announced as A85-12621
Avail: NTIS HC A14/MF A01

A technique based on viscid-inviscid flow interaction is used to describe separated and unseparated unsteady transonic flows over airfoils. A semi-implicit and time-consistent numerical formulation with semi-implicit relaxation provides strong coupling, and a local mesh clustering expresses the shock wave-boundary layer interaction. Direct and inverse mode solutions are defined for the boundary layer and wake defect integrals. The integral equations are closed by using instantaneous boundary layer profiles and defining a set of transport equations for turbulence. A small perturbation equation accounts for the inviscid flow. Sample results are calculated for flows over a NLG 7301 airfoil, a NACA 64 A 010 airfoil with shock-induced separation, and an oscillating RA 16 SC1 airfoil with a spoiler. M.S.K. (IAA)

N85-25179# British Aerospace Aircraft Group, Woodford (England).
A SEMI-EMPIRICAL UNSTEADY TRANSONIC METHOD WITH SUPERSONIC FREE STREAM
M. J. GREEN and D. LAMBERT *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 16 p (SEE N85-25171 15-01) Jan. 1985 refs
Avail: NTIS HC A14/MF A01

Garner's semi-empirical method for predicting oscillatory transonic aerodynamic characteristics on wings was extended to Mach numbers greater than unity. The object is to provide an economical means of carrying out transonic flutter calculations at a time when more sophisticated and costly methods are not available for routine use. To predict the unsteady transonic behavior, the method combines steady transonic pressures, obtainable from theory or experiment, with unsteady velocity potentials provided by linearized supersonic theory. Experimental quasisteady data obtained from a series of wind tunnel tests carried out at RAE Bedford on a low aspect ratio wing were used to predict the unsteady pressures at non-zero frequencies. These results were compared with the corresponding unsteady measurements. The method was found to be inadequate near the wing tip and an alternative approach is proposed. Preliminary results show a marked improvement in this region. M.G.

N85-25180# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
STATUS AND PROSPECTS OF COMPUTATIONAL FLUID DYNAMICS FOR UNSTEADY TRANSONIC FLOW
W. J. MCCROSKEY (Army Aeromechanics Lab.), P. KUTLER, and J. C. BRIDGMAN *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 24 p (SEE N85-25171 15-01) Jan. 1985 refs Document previously announced as N85-12037
Avail: NTIS HC A14/MF A01 CSCL 20D

Applications of computational aerodynamics to aeronautical research, design, and analysis have increased rapidly over the past decade, and these applications offer significant benefits to aeroelasticians. The past developments are traced by means of a number of specific examples, and the trends are projected over the next several years. The crucial factors that limit the present capabilities for unsteady analyses are identified; they include computer speed and memory, algorithm and solution methods, grid generation, turbulence modeling, vortex modeling, data processing, and coupling of the aerodynamic and structural dynamic analyses. The prospects for overcoming these limitations are presented, and many improvements appear to be readily attainable. If so, a complete and reliable numerical simulation of the unsteady, transonic viscous flow around a realistic fighter aircraft configuration could become possible within the next decade. The possibilities of using artificial intelligence concepts to hasten the achievement of this goal are also discussed. Author

N85-25181# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
IMPROVEMENT AND EXTENSION OF A NUMERICAL PROCEDURE FOR THE THREE DIMENSIONAL UNSTEADY TRANSONIC FLOWS
P. MULAK and J. J. ANGELINI *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 12 p (SEE N85-25171 15-01) Jan. 1985 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A14/MF A01

A numerical procedure was developed at ONERA to solve the unsteady transonic flow problems under potential flow and small disturbance approximations, in the case of rectangular or simple swept wings. The use of an alternating direction implicid procedure (ADI) and a functional approach for potential flow allowed a very little computer time consummation and a correct approximation for the small disturbance equation with consistent boundary conditions. The purpose is to extend the method to most general planform wings, including highly swept wings, and to insure correct swept shock jump conditions in any case. Calculations will be compared with experiments made on supercritical wings. Author

N85-25182# National Aerospace Lab., Amsterdam (Netherlands).
APPLICATION OF TIME-LINEARIZED METHODS TO OSCILLATING WINGS IN TRANSONIC FLOW AND FLUTTER
H. H. L. HOUNJET and J. J. MEIJER *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 16 p (SEE N85-25171 15-01) Jan. 1985 refs
Avail: NTIS HC A14/MF A01

Unsteady aerodynamic loads in the transonic domain were obtained with time-linearized methods in which a so-called field panel method is embedded which accounts for a proper radiation of signals towards infinity. The methods are used to predict the unsteady loads and first harmonic pressure distributions on an airfoil and a transport type wing. Results obtained with these methods were correlated with data of unsteady experiments and also with results of other calculation methods. Transonic flutter applications were made to a fighter-type configuration. Author

N85-25183# Lockheed-Georgia Co., Marietta.
COMPUTATION OF UNSTEADY TRANSONIC FLOWS ABOUT TWO-DIMENSIONAL AND THREE-DIMENSIONAL AGARD STANDARD CONFIGURATIONS
J. B. MALONE, S. Y. RUO, and N. L. SANKAR (Georgia Inst. of Tech.) *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 14 p (SEE N85-25171 15-01) Jan. 1985 refs
Avail: NTIS HC A14/MF A01

Three state-of-the-art, finite-difference computer programs which were developed for the prediction of unsteady transonic flows about airfoil and wing configurations are examined. Descriptions of each computational procedure are given. Numerical results are compared to experimental data for several 2D and 3D AGARD standard configurations. In addition, computational results are presented for a low aspect-ratio wing planform for which a large, experimental data-base is available. Author

N85-25184# Dassault-Breguet Aviation, St. Cloud (France).
CALCULATION OF UNSTEADY TRANSONIC FLOW AROUND A HIGH SWEPT WING
A. LAURENT *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 24 p (SEE N85-25171 15-01) Jan. 1985 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A14/MF A01

The calculation of the unsteady transonic flow around a highly swept wing has led to development of a three-dimensional fully conservative code from the two-dimensional ideas of Murman and Cole using a finite difference scheme and an alternating direction implicit method. Extension to the three dimensional-problem of the transonic small disturbance method (the NLR equation) requires the investigation of the direction and type of flow locally. This approach allows the calculation in the physical plan (i.e., without any space transformation). Results on a NACA0012 thirty degrees swept wing, at a flying point, show the co-existence, along the span, of the three kinds of shock motion, as TIDJEMAN found in two-dimensional flows. Some calculations correlated with the experiment on the clean MIRAGE F1 wing tested by ONERA in 1982 will be shown as well as a few test cases of the NORA wing. In view of the aeroelastic implications, attention will be paid to the non-linearities of the phenomena encountered. Author

N85-25185*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
UNSTEADY TRANSONIC AERODYNAMIC AND AEROELASTIC CALCULATIONS ABOUT AIRFOILS AND WINGS
P. M. GOORJIAN and G. P. GURUSWAMY (Informatics General Corp., Palo Alto, Calif.) *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 31 p (SEE N85-25171 15-01) Jan. 1985 refs Document previously announced as N84-31092
Avail: NTIS HC A14/MF A01 CSCL 20D

The development and application of transonic small disturbance codes for computing two dimensional flows, using the code ATRAN2, and for computing three dimensional flows, using the code ATRAN3S, are described. Calculated and experimental results are compared for unsteady flows about airfoils and wings, including several of the cases from the AGARD Standard Aeroelastic Configurations. In two dimensions, the results include AGARD priority cases for the NACA 54A006, NACA 64A010, NACA 0012, and MBB-A3 airfoils. In three dimensions, the results include flow about the F-5 wing, a typical wing, and the AGARD rectangular wings. Viscous corrections are included in some calculations, including those for the AGARD rectangular wing. For several cases, the aerodynamic and aeroelastic calculations are compared with experimental results. M.A.C.

N85-25186# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany).
THE APPLICATION OF TRANSONIC UNSTEADY METHODS FOR CALCULATION OF FLUTTER AIRLOADS
H. ZIMMERMANN *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 21 p (SEE N85-25171 15-01) Jan. 1985 refs
Avail: NTIS HC A14/MF A01

With the development of supercritical profiles for aircraft wings the nonlinear unsteady aerodynamic methods in the application for flutter calculation became important. These nonlinear methods demand numerical methods of high accuracy and the inclusion of more physical effects was necessary than for the linear aerodynamic theory. For a representative section with two degrees of freedom and with the aerodynamic shape of the MBB-3 profile unsteady aerodynamic pressure distributions and coefficients for pitch and heave motions were calculated according to different unsteady aerodynamic methods. The steady and unsteady pressure distributions and coefficients were calculated by the Euler, the TSP, the Lin, TSP-Equation and by the Doublet Lattice method, with and without steady corrections. For the Lin, TSP (Linearized Transonic Small-Perturbation) the steady results of TSP and the full Potential Equation were used as the steady velocity potential. With the unsteady aerodynamic coefficients obtained with the different methods flutter calculations were done for the two-degree of freedom system in different frequency ranges. The so-called transonic-dip was found to differ for the aerodynamic methods used. Additionally effects were found which could be explained as probable two-dimensional effects. Author

N85-25187# National Aerospace Lab., Tokyo (Japan).
THE DEVELOPMENT OF UNSTEADY TRANSONIC 3-D FULL POTENTIAL CODE AND ITS AEROELASTIC APPLICATIONS
K. ISOGAI *In* AGARD Transonic Unsteady Aerodyn. and its Aeroelastic Appl. 25 p (SEE N85-25171 15-01) Jan. 1985 refs
Avail: NTIS HC A14/MF A01

The unsteady transonic 3-D full potential code (USTF3), which is based on a two-step semi-implicit time-marching finite difference technique, is outlined. To validate the code the unsteady pressure distributions on the oscillating horizontal tail model (NORA WING) and on the RAE swept tapered wing with oscillating part-span control surface are calculated and compared with the experimental results. The results of the aeroelastic applications of the code, including the static and dynamic aeroelastic response calculations of a high-aspect-ratio transport wing and the time domain numerical simulation of an active control system for a supercritical wing, are presented. Author

N85-25188# Advisory Group for Aerospace Research and Development, Paris (France).
SPECIAL COURSE ON V/STOL AERODYNAMICS: AN ASSESSMENT OF EUROPEAN JET LIFT AIRCRAFT
R. S. WILLIAMS (British Aerospace PLC, Surrey) Feb. 1985 25 p refs
(AGARD-R-710-ADDENDUM; AD-A155604) Avail: NTIS HC A02/MF A01

The European jet lift V/STOL was examined in order to illustrate the extent to which the power plant has affected aircraft layout and consequently the aerodynamic design. Direct comparisons of V/STOL with contemporary conventional layouts are made. The successful Harrier's aerodynamic progress is highlighted. Promised engine performance advances are shown to offer more aerodynamic freedoms to V/STOL design. Author

N85-26638# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
COST EFFECTIVE AND AFFORDABLE GUIDANCE AND CONTROL SYSTEMS
Loughton, England Feb. 1985 290 p refs In ENGLISH and FRENCH Proc. of the 39th symp., Izmir, Turkey, 16-19 Oct. 1984
(AGARD-CP-360; ISBN-92-835-0373-2; AD-A154327) Avail: NTIS HC A13/MFA01

This volume contains the Technical Evaluation Report, the Keynote address and 24 out of the 26 papers presented at the Guidance and Control Panel 39th Symposium. The papers covered the following topics: (1) cost effectiveness models/systems configuration and design tools; (2) low cost, high reliability guidance and control sensors; (3) computational techniques and data processing; (4) reduction of development and support costs; and (5) examples of cost-effective accomplishments and approaches. For individual titles see N85-26639 through N85-26662.

N85-26639# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Aircraft Div.
SOME ASPECTS OF HOW TO DESIGN COST-EFFECTIVE FLIGHT CONTROL SYSTEMS
U. BUTTER and L. BOTZLER *In* AGARD Cost Effective and Affordable Guidance and Control Systems 14 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The design of flight control systems for fighter aircraft is discussed with respect to areas which contribute to minimizing life-cycle costs. As life-cycle costs include all costs accumulating during the whole life of the system, all phases from the design to in-service use are considered. Any structural and technological design features that are introduced to save costs during system operation and maintenance require additional development effort. Therefore, the expected cost benefit has to be balanced against the development effort invested into the system to achieve a cost-effective design. Author

N85-26640# Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France).
COMBINATORIAL PERFORMANCE/COST ANALYSIS OF AN AUTONOMOUS NAVIGATION SYSTEM FOR AIRCRAFT [ANALYSE COMBINATOIRE PERFORMANCES/COUTS DUN SYSTEME AUTONOME DE NAVIGATION POUR AERONEFS]
P. LLORET and G. LAVOIPIERRE *In* AGARD Cost Effective and Affordable Guidance and Control Systems 12 p (SEE N85-26638 16-01) Feb. 1985 refs In FRENCH
Avail: NTIS HC A13/MF A01

A simple method is proposed for assisting the designer of autonomous navigation systems for aircraft in the choice of an optimal solution from the point of view of performance and cost. The proposed method is applied to a list of navigation system inertial navigation systems and on original rules uniting the price and the performance or the volume of the system considered. The combinatorial analysis proposed utilizes performance and cost data by comparing the cost of an inertial navigation system considered as a reference to the costs of solutions regarding a less effectively performing alternative inertial and one or more added sensors. The navigation of a combat helicopter is used to illustrate the method. Transl. by A.R.H.

N85-26641# Marconi Avionics Ltd., Rochester (England).
NAVIGATION: ACCOUNTING FOR COPY
D. J. HAMLIN *In* AGARD Cost Effective and Affordable Guidance and Control Systems 11 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The ideal navigation system, from the point of view of the supplier, is a saleable system. From the user's point of view, the ideal navigation system would support the operational functions of his vehicle with perfect precision at all times. That the matching of these aims has been challenging is evidenced by the staggering array of systems which have been marketed for the purpose since the 1940's, the range of principles employed, their characteristics and their costs. The contending technologies for the navigation element of various types of guidance and control applications are surveyed. The practical constraints on both supplier and user in attaining the ideals are illustrated. Examples are presented from both civil and military fields which are relevant to guidance and control, where improvements in cost effectiveness are being achieved. B.W.

N85-26642# Naval Air Systems Command, Washington, D. C.
DESIGN ADEQUACY: AN EFFECTIVENESS FACTOR
A. R. HABAYEB *In* AGARD Cost Effective and Affordable Guidance and Control Systems 16 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The concept of system effectiveness is reviewed and examined from the perspective of weapon systems consisting of launch platforms, targeting avionics, weapons, and targets. The application of system effectiveness to hardware systems is based on three effectiveness factors: (1) reliability (dependability), (2) readiness (availability); and (3) design adequacy (capability). Design adequacy is a measure of how well a system performs its functions. It is the most desired factor in the definintion, design, and early stages of system development. A design adequacy quantification methodology is presented and the relationship between design limitation and adequacy is discussed. The design adequacy methodology is based on the measures of adequacy, system parameters, subsystem parameters and the employment phases of the system. In a weapon system context, the performance parameters of a guidance and control subsystem, are interdependent with the parameters of the remaining subsystems. The paper deals with three employment phases of a weapon system. The three phases are: (1) prelaunch phase; (2) free flight phase; and (3) end-game phase. Examples based on air-to-air missiles are given to illustrate these relationships and concepts. B.W.

N85-26643# Politecnico di Milano (Italy).
THE EVOLUTIVE STATE: A NEW DEFINITION OF SYSTEM STATE TO INCLUDE SEQUENCING OF EVENTS
V. AMOIA and R. SOMMA (Selenia Spazio, Rome, Italy) *In* AGARD Cost Effective and Affordable Guidance and Control Systems 14 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The usual reliability modeling is based on the introduction of a system state (herewith referred to as macrostate) identified by the operating conditions (good, failed) of the system components. The inclusion of the information about the states sequencing, absent in the classical description, leads to the introduction of the concept of microstate. The peculiar properties of the microstate concept are discussed. A computing procedure was proposed, which shows that, despite the number of microstates, in general infinite, a truncated analysis can be performed to the desired degree of approximation. B.W.

N85-26644# Thomson-CSF, Issy les Moulineaux (France).
OPTMIZING THE SPECIFICATIONS FOR AN AIR-SURFACE LASER SYSTEM [OPTIMISATION DES SPECIFICATIONS DUN SYSTEME AIR-SURFACE LASER]
J. P. MURGUE and D. EVRARD (MATRA Service Aerodynamique, Velizy-Villacoublay, France) *In* AGARD Cost Effective and Affordable Guidance and Control Systems 7 p (SEE N85-26638 16-01) Feb. 1985 refs In FRENCH
Avail: NTIS HC A13/MF A01

Preliminary studies needed to specify a laser-guide air-to-surface attack system are presented as an example of meeting the

requirements for cost effectiveness in weapons systems. Emphasis is on attacking missile launching patrol boats. It is shown that bombing is an economic solution and that it is possible to cost effectively optimize the definition of the nacelle of the laser designator for bombing which demands look back angle optimization, as well as the guidance of the bomb which must remain at very low altitude to satisfy predicted meteorological conditions, and be sufficiently precise for the acquisition of small, rapid targets. B.W.

N85-26645# Singer Co., Wayne, N. J.
DESIGN-TO-COST (DTC) METHODOLOGY TO ACHIEVE AFFORDABLE AVIONICS
A. J. SHAPIRO *In* AGARD Cost Effective and Affordable Guidance and Control Systems 18 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

In response to the continual exponential growth in the complexity and cost of military weapon systems, especially the electronics portions, the United States Department of Defense has implemented a Design to Cost (DTC) procurement policy. The objective of this policy is to meet essential and desired operational requirements in the most cost effective manner by setting cost targets at the start of the procurement process. A methodology is described for developing electronic equipment to meet DTC requirements. Specific management action is required in establishing an appropriate organization as well as procedures and guidelines for the engineering development process and subsequent production to achieve the cost targets. The critical role of computer aided design in optimizing the electronic system design is highlighted. An example of a DTC program successfully applied to the Lightweight Doppler Navigation System (LDNS) AN/APN-128 is reviewed. Author

N85-26646# Societe d'Applications Generales d'Electricite et de Mecanique, Paris (France).
PREGUIDANCE AND PILOTING WITH THE AID OF COMPOSITE INERTIAL SENSORS [PREGUIDAGE ET PILOTAGE A LAIDE DE SENSURS INERTIELS COMPOSITES]
J. RESSEGUIER *In* AGARD Cost Effective and Affordable Guidance and Control Systems 15 p (SEE N85-26638 16-01) Feb. 1985 refs In FRENCH
Avail: NTIS HC A13/MF A01

To resolve the problem of preguiding small motors equipped with homing heads, SAGEM designed and built SIGAL (United integrated gyro-accelerometer system) equipment, compatible with constraints of volume, maintainability, and price. These sure measurement systems use: composite inertial sensors that are both rate gyros and accelerators; multiplexed loops; a strapdown arrangement; and an adapted electronic technology. The principle of the triazial measurement system is examined as well as the capabilities of SIGAL in meeting the needs of preguiding air-to-air, ground-to-air, and air-to-ground systems. Transl. by A.R.H.

N85-26647# Litton Guidance and Control Systems, Woodland Hills, Calif.
LASER GYROSCOPE RANDOM WALK DETERMINATION USING A FAST FILTERING TECHNIQUE
J. G. MARK and A. BROWN *In* AGARD Cost Effective and Affordable Guidance and Control Systems 17 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

In order to reduce the effect of quantization error on gyro test data, Litton has developed a high speed filter which outputs half second accumulated data samples. The quantization noise power in these samples is reduced by a factor greater than 512 while the random walk characteristics are virtually unaffected. High precision measurements of a gyro's random walk coefficient may therefore be obtained from a small data set. The operation of this fast filtering technique, is described, and its effect on gyro test data is analyzed, and laser gyro test results are presented which demonstrate the technique. Author

N85-26648# Smiths Industries Ltd., Bishops Cleeve (England).
THE SERIES 2000: A MINIATURE GAS BEARING DTG FOR LOW COST STRAPDOWN GUIDANCE AND CONTROL
G. BEARDMORE *In* AGARD Cost Effective and Affordable Guidance and Control Systems 14 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The development and status of a Dynamically Tuned Gyroscope (DTG) is described, with particular reference to the specialized technology employed to yield a cost effective design. Its configuration posesses a number of important advantages over those used in conventional tuned sensors, and allows, for the first time, a self acting gas bearing to be incorporated in a strapdown DTG. Other features of the design include the use of a capacitive pick off to replace the traditional inductive version, a high performance spin motor and a fully fabricated flexure hinge. this hinge overcomes many of the technical and commercial disadvantages of the now familiar carved from solid hinges. The problems that have hitherto prevented the application of gas bearing technology to tuned sensors are discussed. Current performance of the sensor is summarized and its advantages over contemporary rate sensors are compared with the requirements of future guidance and control applications. These include airborne, missile, underwater and surface systems where life, reliability, ready time and affordability are of prime importance. Author

N85-26649# Societe Francaise d'Equipements pour la Navigation Aerienne, Velizy-Villacoublay (France). Dept. Inertie et Optique.
GYROLASER GUIDANCE SYSTEM FOR MEDIUM RANGE MISSILES
B. DESALABERRY *In* AGARD Cost Effectiveness and Affordable Guidance and Control Systems 11 p (SEE N85-26638 16-01) Feb. 1985 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A13/MF A01

Laser gyro technology is now developed to the point where this type of inertial sensor can be used on medium range tactical missiles. After outlining the performances required for these sensors. The laser gyros and accelerometers chosen to construct an inertial system designed for the guidance and control of such a missile is described. The problems of filtering noise on the laser gyro readout signals is also be examined. Author

N85-26650# Societe Crouzet, Valence (France).
THE USE OF A SELF-COMPENSATED MAGNETOMETER IN AN ECONOMICAL NAVIGATION SYSTEM FOR THE HELICOPTER [UTILISATION DUN MAGNETOMETRE AUTOCOMPENSE DANS UN SYSTEME DE NAVIGATION ECONOMIQUE POUR HELICOPTERE]
J. L. ROCH, J. C. GOUDON, and P. CHAIX *In* AGARD Cost Effective and Affordable Guidance and Control Systems 10 p (SEE N85-26638 16-01) Feb. 1985 refs In FRENCH
Avail: NTIS HC A13/MF A01

Analysis of a mission of a military helicopter show the need for installing a navigation system, since to assure its safety and avoid detection by enemy systems, the helicopter must follow the terrain at a height less than or equal to 50m, and at a varying speed. It is difficult to take bearings during the so-called tactical phases of flight. Various autonomous navigation systems are examined. The advantages of using a magnetometer, the choice of magnetic sensor, and the principles of compensation are discussed. Results obtained using a system with a three-axis static magnetometer on the PUMA SA 330 and the GAZELLE SA 342 helicopter aare summarized and conform to operational requirements of the French army for the GV76 and RDN 80 B.
Transl. by A.R.H.

N85-26651# European Organisation for the Safety of Air Navigation, Brussells (Belgium).
A COST-EFFICIENT CONTROL PROCEDURE FOR THE BENEFIT OF ALL AIRSPACE USERS
A. BENOIT and S. SWIERSTRA *In* AGARD Cost Effective and Affordable Guidance and Control Systems (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

A control procedure for conducting time of arrival constrained flights in an economic manner is proposed. This procedure is intended to be compatible with present day voice communications (human or synthetic) although it is primarily designed to be used

in conjunction with future automated digital data communications. The procedure is applicable to the transit of flights through terminal areas such as are considered in connection with Zone-of-Convergence-type systems, and the final approach phase is accordingly integrated with the en route descent, cruise and (possibly) climb phases, or appropriate parts thereof. A detailed description of the procedure is presented together with brief summaries of the tests conducted in present and simulated future environments to assess its efficiency, and then sets out the results obtained to date and analyses them in terms of 4-d navigational accuracy and operational effectiveness. Author

N85-26652# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
WIND MODELLING FOR INCREASED AIRCRAFT OPERATIONAL EFFICIENCY
W. LECHNER and R. ONKEN *In* AGARD Cost Effective and Affordable Guidance and Control Systems 12 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

Accurate knowledge of the wind in magnitude and direction as a function of airspace position and time is an essential part for navigation and for fuel efficiency and efficient planning and control of air traffic. The demand for wind data in four dimensional guidance was examined. The calculation of the three dimensional flight path command subject to time-of-arrival constraints (fourth dimension) requires wind prediction along the complete flight path the aircraft is going to track. Since the flight path is calculated and updated on line wind information has to be available at any time for the respective three dimensional airspace. The wind data, currently available are not sufficient when used as single source. An actual wind situation can extremely deviate from what the MET service announces. Complementary or even quite different techniques emrge for wind estimation, in particular using modern aircraft sensor and computer equipment. Airborne wind estimation techniques were developed and implemented in the automatic digital flight control system of the DFVLR's test aircraft HFB 320. The efficiency of these techniques, is demonstrated. E.A.K.

N85-26653# British Aerospace Public Ltd. Co., Preston (England).
A METHOD OF ESTIMATING AIRCRAFT ATTITUDE FROM FLY BY WIRE FLIGHT CONTROL SYSTEM DATA
R. J. V. SNELL *In* AGARD Cost Effective and Affordable Guidance and Control Systems 9 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The use of active control technology (ACT) to control the aircraft flight both led to flight path sensors and associated computing. The use of these data to extract aircraft attitude was studied. This would avoid the requirement for supplementary hardware in the form of an attitude references system and Artificial horizon and could endow the source of attitude with the high integrity annd availability associated with flight control systems. An experimental application was flown on the ACT Fly-by-Wire Jaguar Demonstration aircraft using digital data originating in the Flight Control System. The flight results demonstrated good accuracy and stability in the general course of flying. If attitude can be established with sufficient accuracy, it is feasible to extract magnetic heading from a three axis magnetometer. Heading, together with attitude and air data information provides the basis for a dead reckoning navigation system. Such a basic system could be aided by a continuous terrain profile matching system to provide high accuracy navigation. The method offers a source of high integrity attitude and could serve as the basis for a low cost, highly accurate navigation system suitable for operation over digitally mapped terrain, either as a stand alone system or a back up for cross monitoring an inertial navigation system. E.A.K.

N85-26654# Marconi Avionics Ltd., Rochester (England). Airport Works.
THE IMPACT OF VLSI ON GUIDANCE AND CONTROL SYSTEM DESIGN
D. PRICE *In* AGARD Cost Effective and Affordable Guidance and Control Systems 4 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The potential of very large scale integrated circuit technology to reduce cost, including life cycle cost, of avionics systems was examined. Trends in methods of silicon realization and in system complexity are related to the necessary advances in methods of system design. A generic system design approach is outlined, which emphasis the discilines which are likely to enable cost-effective semicustom circuit design to become viable. E.A.K.

N85-26655# Air Force Armament Lab., Eglin AFB, Fla.
REUSABLE SOFTWARE: A CONCEPT FOR COST REDUCTION
C. M. ANDERSON and M. HENNE *In* AGARD Cost Effectiveness and Affordable Guidance and Control Systems 6 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The cost of military computer systems is increasing rapidly, and the percentage of the total cost attributed to software is also increasing. Several underlying causes for this increase are discussed. While the new United States (US) Department of Defense (DoD) standard high order language, Ada, will significantly help to reduce the software cost growth, other solutions must be sought. Reusable software component technology and associated parts composition sytems are presented as possible solutions. E.A.K.

N85-26656# Software Sciences Ltd., Farnborough (England).
MAINTAINING CONSISTENCY AND ACCOMMODATING NETWORK REPAIR IN A SELF-REGENERATIVE DISTRIBUTED DATABASE MANAGEMENT SYSTEM (A DISCUSSION OF THE MEANS AND COST)
M. REILLY, P. R. TILLMAN, R. CATT, and R. B. MOORE *In* AGARD Cost Effective and Affordable Guidance Control Systems 11 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The ADDAM is a data base management system that maintains a real-time data base which is partitioned and replicated amongst a number of computers connected in a local area network. With a centralized or quasidistributed data base, damage to particular components caused effective loss of the whole system due to loss of data. The ADDAM can tolerate substantial damage to the network with little degradation of performance or loss of data. Some of the protocols used by ADDAM to maintain data consistence are described. It is shown that it is possible to provide a very high degree of data reliability within a resilient real-time distributed data base. However, the cost is quite large, both in terms of the amount of computer resources consumed by the data base software and the number of internode message generated on the network. E.A.K.

N85-26657# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (West Germany). Missile Div.
SIMULATION: A TOOL FOR COST-EFFECTIVE SYSTEMS DESIGN AND LIVE TEST REDUCTION
R. GAUGETT *In* AGARD Cost Effective and Affordable Guidance and Control Systems 9 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

Taking advanced passive infrared guided missiles as an example of missile system simulation - both software and realtime hardware-in-the-loop including background - is a valuable tool to find cost-effective system designs and also to drastically reduce costs of field testing and live firing trials. The development of complex missile systems becomes questionable from a cost standpoint if the majority of the increased test efforts for this type of missiles is not substituted by missile system simulation. The author addresses Bodenseewrk's missile system simulation philosophy, simulation methods, high level programming language and the interfaces between the involved hardware and software. An in-depth discussion of the influence of simulation onto the

flight testing requirements of missile developments and the resultant cost savings conclude this paper. G.L.C.

N85-26658# Bodenseewerk Geraetetechnik G.m.b.H., Ueberlingen (West Germany).
A DESCRIPTION OF THE PROCESS OF ELABORATING MAN-MACHINE DIALOG IN AN AIRCRAFT EQUIPPED WITH CATHODE TUBES: ROLES AND SPECIFICATIONS OF PILOTED SIMULATION METHODS [DESCRIPTION DU PROCESSUS DELABORATION DU DIALOGUE HOMME MACHINE DANS LES AVIONS DARMES EQUIPES DE TUBES CATHODIQUES ROLE ET DESCRIPTION MOYENS SIMULATION PILOTEE]
P. HELIE *In* AGARD Cost Effective and Affordable Guidance and Control Systems 12 p (SEE N85-26638 16-01) Feb. 1985 refs In FRENCH
Avail: NTIS HC A13/MF A01

The use of cathode ray tubes (or systems permitting equivalent representations) on future military aircraft is envisioned as well as multiplexed commands implanted in joysticks and throttles, and a system of vocal dialog. Engineers studying man-machine dialog must reexamine established principles and develop other work methods. Documents developed for defining the different stages of development of such a system and tasks required for validating man-machine dialog are examined. The operational OASIS system developed for the Mirage 2000 aircraft for piloted simulation is described. Transl. by A.R.H.

N85-26659# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
TERRAIN FOLLOWING WITHOUT USE OF FORWARD LOOKING SENSORS
H. F. SCHWEGLER and B. SCHREINER *In* AGARD Cost Effective and Affordable Guidance and Control Systems 3 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

A system is presented which allows an aircraft to follow a preplanned vertical profile along a planned route. Using a simple representation of the planned vertical profile instead of terrain data the computational tasks to be performed in the aircraft in real time are minimized. This system may ease some operational problems of todays military aircraft when flying in hostile environment until the advent of more sophisticated systems likely to be based on the intelligent combination of forward looking sensor data and stored map derived information G.L.C.

N85-26660# Technische Univ., Brunswick (West Germany).
THE USE OF PRESSURE SENSING TAPS ON THE AIRCRAFT WING AS SENSOR FOR FLIGHT CONTROL SYSTEMS
D. BRUNNER *In* AGARD Cost Effective and Affordable Guidance and Control Systems 8 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

For the low speed operation of aircraft, during STOL-take off or STOL-landing and for windshear situations a precise measurement of the state of the aerodynamic flow is required. Normally the dynamic pressure is used to assess the state of flow, thus defining the stall margin in terms of a speed factor. However, flying at higher lift coefficients, a precise maintainence of a given lift coefficient by controlling the speed is no longer feasible. Instead, controlling the angle of attack or controlling the lift coefficient directly should be used. Some methods for the measurement and the control of the state of the aerodynamical flow including wing tap pressure measurements are discussed. Wind tunnel results are presented, that show the pressure distribution of a slotted STOL-wing and the typical relationship between the tap pressure, angle of attack and flap angle. Wing tape pressure measurements taken with the STOL-aircraft Do 28 aircraft are then discussed showing the feasibility of the method described to sense the state of flow. G.L.C.

N85-26661# Ferranti Defence Systems Ltd., Edinburgh (Scotland).
LOW COST TWO GIMBAL INERTIAL PLATFORM AND ITS SYSTEM INTEGRATION
R. N. PRIESTLEY and J. B. TOWLER *In* AGARD Cost Effective and Affordable Guidance and Control Systems 14 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The development of more accurate inertial systems has led to more expensive inertial instruments and complex electronics. Future navigation systems will require further improvements in accelerometer and gyro design in order to achieve the required performance. There are however doubts as to whether autonomous inertial systems will be sufficiently accurate. An alternative approach is to combine a second sensor with the inertial system to improve performance, for example doppler velocities or NAVSTAR/GPS positions and velocities. The inertial platform may then be simplified, retaining high accuracy only in the platform parameters having an impact on the integrated system performance. This simplification allows lower cost of ownership with an increase in reliability and a medium accuracy reversion capability. The inertial system computer may be programmed with the integration software so avoiding a separate dedicated integration computer with the consequent decrease in reliability. G.L.C.

N85-26662# Kongsberg Vapenfabrikk A/S (Norway).
COST-EFFECTIVE MISSILE GUIDANCE THROUGH DISTRIBUTED ARCHITECTURE AND STANDARD PROCESSES
H. GLOERUD *In* AGARD Cost Effective and Affordable Guidance and Control Systems 6 p (SEE N85-26638 16-01) Feb. 1985 refs
Avail: NTIS HC A13/MF A01

The development of the Penguin MK3 missile was initiated by the Royal Norwegian Air Force as a modern stand-off weapon for the F-16 aircraft. The guidance and control system of this missile is built upon the most modern principles using all digital electronics with distributed computational power. The system is separated in 6 main functions, each with its own powerful processor. High performance is achieved through the use of latest generation standard microprocessors and connected together by a high capacity data bus. Some of the results obtained from this development are described. G.L.C.

N85-28913# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
HELICOPTER AEROMECHANICS
Loughton, England Apr. 1985 329 p refs Lectures held in Brunswick, 2-3 May 1985, in Rome, 6-7 May 1985, and in St. Louis, 21-22 May 1985
(AGARD-LS-139; ISBN-92-835-1499-8; AD-A155946) Avail: NTIS HC A15/MF A01

A variety of information relevant to helicopters is presented. Topics range from actual aerodynamic studies to computerized simulation as employed in flight simulators. For individual titles see N85-28914 through N85-28920.

N85-28914# Technische Univ., Brunswick (West Germany). Inst. fuer Flugmechanik.
HELICOPTER AEROMECHANICS: INTRODUCTION AND HISTORICAL REVIEW
G. REICHERT *In* AGARD Helicopter Aeromech. 23 p (SEE N85-28913 18-01) Apr. 1985 refs
Avail: NTIS HC A15/MF A01

Although the current generation of civil and military helicopters have greatly improved upon the previous generations, rotorcraft technology still has the potential for decided improvements. As high-payoff technologies aeromechanics (aerodynamics/dynamics), structures/materials, avionics/flight controls, and engine drive system technology can be identified, of which aeromechanics will be discussed in more detail. The general role of aeromechanics in military and civilian applications to rotary wing aircraft will be summarized and an overview of the state of the art will be given. In addition to direct performance improvements, there is great opportunity to improve the operating characteristics to a degree that the full performance characteristics inherent in the designs may be realized. Some current systems fail in the utilization of their full performance as a result of dynamical limitations or high vibrational levels. G.L.C.

N85-28915# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
A SURVEY OF RECENT DEVELOPMENT IN HELICOPTER AERODYNAMICS
J. J. PHILIPPE, P. ROESCH, A. M. DEQUIN, and A. CLER *In* AGARD Helicopter Aeromech. 40 p (SEE N85-28913 18-01) Apr. 1985 refs Prepared in cooperation with Societe Nationale Industrielle Aerospatiale, Marignane, France
Avail: NTIS HC A15/MF A01

Various aspects of helicopter aerodynamics are addressed. The aerodynamics of isolated rotors and fuselages as well as some topics in interactional aerodynamics are dealt with. G.L.C.

N85-28916# Loughborough Univ. of Technology (England).
ROTORCRAFT NOISE
J. B. OLLERHEAD *In* AGARD Helicopter Aeromech. 38 p (SEE N85-28913 18-01) Apr. 1985 refs
Avail: NTIS HC A15/MF A01

The mechanisms of rotor noise generation are reviewed including methods for noise prediction and low noise design. Attention is focussed on the subjective effects of helicopter noise and the consequent requirements for statutory noise regulation. The economic and operational implications are discussed.
G.L.C.

N85-28917*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
RECENT DEVELOPMENTS IN THE DYNAMICS OF ADVANCED ROTOR SYSTEMS
W. JOHNSON *In* AGARD Helicopter Aeromech. 51 p (SEE N85-28913 18-01) Apr. 1985 refs
Avail: NTIS HC A15/MF A01 CSCL 01C

The problems that have been encountered in the dynamics of advanced rotor systems are described. The methods for analyzing these problems are discussed, as are past solutions of the problems. To begin, the basic dynamic problems of rotors are discussed: aeroelastic stability, rotor and airframe loads, and aircraft vibration. Next, advanced topics that are the subject of current research are described: vibration control, dynamic inflow, finite element analyses, and composite materials. Finally, the dynamics of various rotorcraft configurations are considered: hingeless rotors, bearingless rotors, rotors with circulation control, coupled rotor/engine dynamics, articulated rotors, and tilting proprotor aircraft.
G.L.C.

N85-28918# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugmechanik.
MISSION REQUIREMENTS AND HANDLING QUALITIES
B. GMELIN and H. J. PAUSDER *In* AGARD Helicopter Aeromech. 37 p (SEE N85-28913 18-01) Apr. 1985 refs
Avail: NTIS HC A15/MF A01

With the appearance of new missions for helicopters and with the development of a new generation of rotary-wing aircraft it has become obvious at the latest that future activities in the field of handling qualities must include the mission characteristics as well as the influences of the different subsystems implemented in the helicopter system. Therefore, mission analyses and consideration of system elements influencing mission performance are the basis for this work. The missions under consideration emphasize military missions but refer to civil missions, too. The system elements influencing mission performance include the basic helicopter, the pilot, the information system, the control system, interfaces, etc.
G.L.C.

N85-28919# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
THE ROLE OF SIMULATION
H. HUBER and P. KRAUSPE *In* AGARD Helicopter Aeromech. 35 p (SEE N85-28913 18-01) Apr. 1985 refs
Avail: NTIS HC A15/MF A01

The development of helicopter flight simulation has undoubtedly made considerable progress in the past decade. Due to the helicopter specific flight regime, which is essentially characterized by low altitude flying (NOE), low to moderate speeds, and distinct stability and control behavior, the simulation of rotorcraft sets high standards to the simulation quality. An overview about the various simulation techniques and their specific application during research and development work is presented. First, the details and capabilities of the round-based simulation are discussed. Stringent requirements for real-time simulation result in the use of comprehensive math models, representing the aerodynamic and dynamic complexities of rotary-wing aircraft. In addition, great effort has to be made to simulate the environmental scenario, such as visual and motional cues. Advances are especially made on the field of generating and displaying visual imagery. The technique of computer generated images (CGI) and the progress achieved, e.g., in the field-of-view and resolution, is demonstrated. G.L.C.

N85-28920# Royal Aircraft Establishment, Bedford (England). Helicopter Aeromechanics Section.
FLIGHT TESTING FOR PERFORMANCE AND FLYING QUALITIES
G. D. PADFIELD *In* AGARD Helicopter Aeromech. 51 p (SEE N85-28913 18-01) Apr. 1985 refs
Avail: NTIS HC A15/MF A01

A systematic review of flight test techniques and test data interpretation methods for helicopter performance and flying qualities is presented. The distinction is drawn between quasi-steady and dynamic testing and within these categories both clinical and role-related techniques are discussed. Performance topics covered include steady state performance in hover and forward flight, flight envelope boundaries, take-off and landing performance, and helicopter agility. Flying qualities topics begin with a treatment of static stability tests and progress to dynamic stability, control response, system identification and role-related evaluation techniques. Testing appropriate to certification and development phases and research activities are addressed. The exploratory nature of flight testing is evident throughout this work and safety aspects are emphasized when required. Results from recent and past test programs are used to illustrate the forms in which flight data can be presented, and data reduction and analysis methods established and under development are reviewed.
Author

N86-11147# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AERODYNAMICS AND ACOUSTICS OF PROPELLERS
Loughton, England Feb. 1985 458 p refs In ENGLISH and FRENCH Symp. held in Toronto, 1-4 Oct. 1984
(AGARD-CP-366; ISBN-92-835-0374-0; AD-A156047) Avail: NTIS HC A20/MF A01

A state of the art review of the aerodynamic design and testing of modern propellers, acoustic and vibration environmental problems and their solutions, and considerations in the integration of the propeller(s) and airframe is presented. Propellers have recently become a focus of attention after having been neglected for many years. The efficient use of propellers as a propulsion medium up to Mach 0.6 was realized at the expense of high noise and vibration. Since the mid-1970s there have been many developments, including the propfan, with an aerodynamic efficiency of 80% at Mach 0.8 now seriously challenges the fanjet. The advent of the supercritical airfoil is another significant development beginning to influence propeller design. For individual titles see N86-11148 through N86-11176.

N86-11148# Lockheed-Georgia Co., Marietta. Advanced Concepts Dept.
A REVIEW OF ADVANCED TURBOPROP TRANSPORT ACTIVITIES
R. H. LANGE *In* AGARD Aerodyn. and Acoustics of Propellers 16 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The application of advanced technologies shows the potential for significant improvement in the fuel efficiency and operating costs of future transport aircraft envisioned for operation in the 1990s time period. One advanced turboprop concept originated by Hamilton Standard and NASA is known as the propfan. The concept features a highly loaded, multibladed, variable pitch propeller geared to a high pressure ratio gas turbine engine. The blades have high sweepback and advanced airfoil sections to achieve 80 percent propulsive efficiency at M = 0.80 cruise speed. Aircraft system studies have shown improvements in fuel efficiency of 15 to 20 percent for propfan advanced transport aircraft as compared to equivalent turbofan transports. Beginning with the Lockheed C-130 and Electrica turboprop aircraft, an overview of

the evolution of propfan aircraft design concepts and system studies is presented. These system studies include possible civil and military transport applications and data on the performance, community and far field noise characteristics and operating costs of propfan aircraft design concepts. NASA Aircraft Energy Efficiency (ACEE) program propfan projects with industry are reviewed with respect to system studies of propfan aircraft and recommended flight development programs. Author

N86-11149# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
AERODYNAMIC METHOD USED IN FRANCE FOR ADVANCED FAST PROPELLER STUDY
J. M. BOUSQUET *In* AGARD Aerodyn. and Acoustics of Propellers 15 p (SEE N86-11147 02-01) Feb. 1985 refs In *FRENCH; ENGLISH summary Original language document* previously announced in IAA as A85-15840
Avail: NTIS HC A20/MF A01

Computational techniques and programs currently in use in the design analysis of aircraft propellers are surveyed and illustrated with diagrams and graphs of typical results. Methods examined include lifting line, incompressible lifting surface, three dimensional compressible, and three dimensional Euler; both classical and advanced propeller designs are considered. The Euler analysis of the experimental propeller HT1 being developed for ONERA is explored in detail, evaluating the effects of tip speed ratio, Mach number, number of blades, hub diameter, and a tapered diameter hub shroud. T.K.

N86-11150# Centre National de la Recherche Scientifique, Orsay (France).
DESIGN CONCEPT AND PERFORMANCE PREDICTION TECHNIQUE FOR POTENTIAL FLOWS AROUND ADVANCED PROPELLERS
T. S. LUU and R. COLLERCANDY *In* AGARD Aerodyn. and Acoustics of Propellers 12 p (SEE N86-11147 02-01) Feb 1985 refs
Avail: NTIS HC A20/MF A01

The design concept and performance prediction technique for potential flows around advanced propellers is presented. The design of propellers is based on the panel method, applied to the lifting surface theory in which the flow is supposed to be incompressible. A transonic performance prediction technique is developed where the resulting potential equation is solved by a finite difference approximate factorization method in a body fitted grid system. Both two and three dimensional results are presented. Author

N86-11151# Aircraft Research Association Ltd., Bedford (England).
A REVIEW OF ARA RESEARCH INTO PROPELLER AERODYNAMIC PREDICTION METHODS
A. J. BOCCI and J. I. MORRISON *In* AGARD Aerodyn. and Acoustics of Propellers 19 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

An improved wake method involving a numerical solution to Goldstein's wake flow model was developed and the effects of removing Goldstein's limiting assumptions are illustrated. The representation of ARA-D airfoil data for use with the wake methods is considered, covering the wide range of geometry and flow conditions likely to be encountered on operating blades. The importance of finite blade effects is discussed and a tip relief correction is shown to improve predictions of experimental blade pressures and loadings. A method was developed to calculate the flow induced by a prescribed wake vortex sheet and some of the issues arising in calculating the flow development from the propeller disc downstream are illustrated. A three dimensional method involving solution of the compressible potential flow equation was developed, capable of predicting the blade flow in some detail for general multiblade configurations. Comparisons with experiment are shown for two blade cases. Author

N86-11152# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
MODERN PROPELLER PROFILES
A. M. RODDE, J. J. CUNY (Societe Ratier Figeac, France), and J. J. THIBERT *In* AGARD Aerodyn. and Acoustics of Propellers 12 p (SEE N86-11147 02-01) Feb. 1985 refs In FRENCH Original language document previously announced in IAA as A85-15841
Avail: NTIS HC A20/MF A01

The design of a family of advanced profile composite aircraft propellers is presented, and the results of wind tunnel tests performed at the ONERA Modane S3 and CEATY S10 facilities are reported. The design specifications are outlined; the definition of profiles with relative thicknesses 4, 7, 12, and 20 percent is explained; and the test results are presented in graphs and diagrams. Significant performance improvements (relative to a NACA 16707 reference profile) are observed, including 43 and 8 percent better lift/drag ratios for cruising and ascent, respectively, 15 percent better Cz max, and equivalent critical Mach number at lower drag. The first planned application is to the Transall C160 two engine turboprop transport aircraft. T.K.

N86-11153# National Aerospace Lab., Amsterdam (Netherlands).
AERODYNAMICS OF WIDE-CHORD PROPELLERS IN NON-AXISYMMETRIC FLOW
J. B. H. M. SCHULTEN *In* AGARD Aerodyn. and Acoustics of Propellers 10 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

A lifting surface analysis is presented for propellers in nonaxisymmetric flow. In the analysis the Euler equations linearized about a uniform subsonic main flow are solved after separation of variables in cylindrical coordinates. This solution is obtained via an integral equation for the force distribution over the upper and lower surfaces of the blades which replaces the action of the propeller on the surrounding fluid. The boundary condition of vanishing normal velocity is applied at the actual blade surfaces, thus leading to a nonhelicoidal, unsteady lifting surface theory for propellers. Since the integral equation is solved most efficiently per circumferential Fourier component of the inflow distortion field, symmetric inflow is included naturally as the zeroth term of the Fourier series. General blade shapes can be handled as the blades may be swept both axially and azimuthally. There is no inherent limitation to the propeller tip Mach number. Apart from the calculation of the unsteady blade loading, expressions for the velocity and pressure fields are derived, in which the propeller slipstream appears explicitly as part of the complete velocity field in a form perfectly suited for wing interference calculations.
Author

N86-11154# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.
ON THE AERODYNAMICS OF INSTALLED PROPELLERS
M. E. ESHELBY *In* AGARD Aerodyn. and Acoustics of Propellers 15 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

When the propeller is installed on the aircraft there will be mutual influence between the airframe and the propeller and its slipstream, two sources of that interference are examined. First, as the aircraft angle of attack changes with forward speed the angle of attack of the propeller also changes giving rise to forces and moments other than thrust and torque. Second, the high energy slipstream may pass over the tailplane and so affect the tail lift force, and in consequence a pitching moment due to power may be produced. These two effects are considered separately and means are suggested to estimate their magnitude and their effect on the handling qualities of the aircraft. Author

N86-11155# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Entwurfsaerodynamik.
A UNIFIED APPROACH FOR THE AERODYNAMICS AND ACOUSTICS OF PROPELLERS IN FORWARD MOTION
A. DAS *In* AGARD Aerodyn. and Acoustics of Propellers 28 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The aerodynamics and the acoustics of moving bodies or surfaces follow the same basic laws of disturbance propagation

and hence can be treated in a unified way. Further advancements of the propeller theories have two objectives: attaining better propulsive efficiency and producing less noise at high forward speeds. A unified aerodynamic and acoustic theory of propeller in forward motion is formulated and analyzed in detail describing the aspect of disturbance propagation from singularities in arbitrary motion, derivation of the spatial and temporal dilatations concerned with the propagation process, generalized exposition of the solution method for aerodynamics and acoustics and an extended sweep technique to determine the inducing effect of moving surfaces. In view of the flow field of a propeller being not completely irrotational the use of pressure potential proves to be more suitable in the numerical methods. The results of the analysis are illustrated by diagrams. Author

N86-11156*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THEORETICAL ANALYSIS OF LINEARIZED ACOUSTICS AND AERODYNAMICS OF ADVANCED SUPERSONIC PROPELLERS
F. FARASSAT *In* AGARD Aerodyn. and Acoustics of Propellers 15 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01 CSCL 01A

The derivation of a formula for prediction of the noise of supersonic propellers using time domain analysis is presented. This formula is a solution of the Ffowcs Williams-Hawkings equation and does not have the Doppler singularity of some other formulations. The result presented involves some surface integrals over the blade and line integrals over the leading and trailing edges. The blade geometry, motion and surface pressure are needed for noise calculation. To obtain the blade surface pressure, the observer is moved onto the blade surface and a linear singular integral equation is derived which can be solved numerically. Two examples of acoustic calculations using a computer program are currently under development. Author

N86-11157# Lockheed-California Co., Burbank.
A GENERAL THEORY OF ARBITRARY MOTION AERODYNAMICS USING AN AEROACOUSTIC APPROACH
L. N. LONG and G. A. WATTS *In* AGARD Aerodyn. and Acoustics of Propellers 12 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The theoretical aspects of a new unsteady aerodynamics method that uses time domain aeroacoustic integral equations is described. Recent advances in theoretical aeroacoustics permit the development of general unsteady aerodynamics methods. The effects of thickness, compressibility, and arbitrary motions may be calculated for subsonic and supersonic flows. Most linearized unsteady aerodynamics methods today are limited to zero thickness effects and sinusoidal motion. The equations presented will make it possible to develop computer codes for complex three dimensional bodies, including not only complete aircraft configurations, but rotating propellers and helicopter blades as well. Panel methods for steady aerodynamics are widely used in the aircraft industry for such configurations, the present method should permit equally general configurations to be solved in unsteady motion, using a time stepping procedure. Author

N86-11158*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
SUMMARY OF RECENT NASA PROPELLER RESEARCH
D. C. MIKKELSON, G. A. MITCHELL, and L. J. BOBER *In* AGARD Aerodyn. and Acoustics of Propellers 24 p (SEE N86-11147 02-01) Feb. 1985 refs Previously announced as N84-32344
Avail: NTIS HC A20/MF A01 CSCL 01A

Advanced high speed propellers offer large performance improvements for aircraft that cruise in the Mach 0.7 to 0.8 speed regime. At these speeds, studies indicate that there is a 15 to near 40 percent block fuel savings and associated operating cost benefits for advanced turboprops compared to equivalent technology turbofan powered aircraft. Recent wind tunnel results for five eight to ten blade advanced models are compared with analytical predictions. Test results show that blade sweep was important in achieving net efficiencies near 80 percent at Mach 0.8 and reducing nearfield cruise noise about 6 dB. Lifting line and lifting surface aerodynamic analysis codes are under development and some results are compared with propeller force and probe data. Also, analytical predictions are compared with some initial laser velocimeter measurements of the flow field velocities of an eight bladed 45 swept propeller. Experimental aeroelastic results indicate that cascade effects and blade sweep strongly affect propeller aeroelastic characteristics. Comparisons of propeller nearfield noise data with linear acoustic theory indicate that the theory adequately predicts nearfield noise for subsonic tip speeds, but overpredicts the noise for supersonic tip speeds. B.W.

N86-11159# Societe Nationale Industrielle Aerospatiale, Marignane (France).
DYNAMIC BEHAVIOR OF A PROPFAN
J. M. BESSON and D. PETOT (ONERA, Paris) *In* AGARD Aerodyn. and Acoustics of Propellers 15 p (SEE N86-11147 02-01) Feb. 1985 refs In FRENCH Original language document previously announced in IAA as A85-15842
Avail: NTIS HC A20/MF A01

The dynamic behavior of a 1 m diameter 12 blade propfan model is investigated analytically and experimentally. Both the propfan and its individual blades are analyzed using two versions of a simplified beam model and the finite element codes ASTRONEFF and SAMCEF, considering blades of Dural alloy, CFRF, and foam filled CFRP. The modeling techniques are illustrated, and results are presented in graphs and tables. The single blade findings are compared with the results of wind tunnel tests performed at the ONERA Mondane S1 facility, and the errors of the models are found to be of the order 10 percent. The ASTRONEFF procedure is shown to be best adapted to the foam filled ribbed CFRP blade to be used in the actual propfan model. Preliminary computations of the aerodynamics and static deformation of the propfan are also presented. T.K.

N86-11160# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario).
PERFORMANCE EVALUATION OF FULL SCALE PROPELLERS BY WIND TUNNEL TEST
D. J. BARBER *In* AGARD Aerodyn. and Acoustics of Propellers 12 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

A large propeller test facility was developed for the nine meter wind tunnel. The facility is described along with the propeller test rig features and associated drive system. Propeller performance measurement philosophy, test procedures and calibrations are discussed. In cooperation with Dowty Rotol Ltd. and Hartzell Inc., two currently available propeller designs were tested. The two 8.5 foot diameter propeller suitable for a DHC Twin Otter size of aircraft provided an evaluation of alternative airfoil applications: the ARA-D series and NACA 16 series. Results have demonstrated propeller efficiencies close to manufacturers estimates for clean well finished blades. Forward and reverse thrust testing results are discussed with respect to aircraft application. Prediction methods tend to over estimate efficiencies due to hardware features encompassing blade finish, blade root/spinner juncture, spinner openings, erosion protection and deicer equipment. Typical results illustrating the influence on propeller performance of such features is given. Author

N86-11161# Institut de Mecanique des Fluides de Marseille (France).
STUDY OF THE 3D WAKE OF AN AERIAL PROPELLER [ETUDE DU SILLAGE 3D D'UNE HELICE AERIENNE]
D. FAVIER and C. MARESCA *In* AGARD Aerodyn. and Acoustics of Propellers 22 p (SEE N86-11147 02-01) Feb. 1985 refs In FRENCH
Avail: NTIS HC A20/MF A01

An analysis of the near and far wake of a four blade aerial propeller, operated under various working parameters and following various adjustments, was carried out with hot wire anemometry. Empirical laws were synthesized which provide the axial translation velocity of the tip vortices, the rate of wake radial contraction, in such a way that the stability limit of the vortex system is established as a function of azimuth rotation and as an extended range of the working parameters active in the range from null to maximum thrust. For a given functional regime, the determination of the three dimensional induced velocity field is effective in different sections downstream of the wake and conducted in a detailed characterization of the geometry and associated vortex intensity,

in the azimuth function and the axial distance to the downstream of the plane of rotation. E.A.K.

N86-11162# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
INVESTIGATIONS OF MODERN GENERAL AVIATION PROPELLERS
H. ZIMMER, R. HOFFMANN (Hoffmann-Propellers, Rosenheim, West Germany), and K. H. HORSTMANN (DFVLR, Brunswick) *In* AGARD Aerodyn. and Acoustics of Propellers 14 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

After a period of stagnation in the years following WW2 an accelerated movement towards propeller propulsion has taken place in recent years. Because of its inherent propulsive advantages the propeller propulsion has a considerable development potential. Initial analyses of the state of the art of propeller technology in the General Aviation field by means of flight and wind tunnel tests as well as by aerodynamic and acoustic calculations have shown possibilities for improvement, mainly in the lower and medium speed range. Improved propellers were designed and analyzed theoretically and experimentally. Newly designed supercritical airfoils with high lift to drag ratios at high lift were used. To find the optimum blade shapes associated with minimum supervelocities, also several tip shapes were analyzed. After wind tunnel tests the best of the propeller designs was selected for full scale flight test. A set of experimental propellers for the Do 228 Experimental aircraft was developed, constructed and tested. Improvements were achieved in the whole flight regime. The experience of this propeller development program was used to design a high performance high speed General Aviation propeller for M = 0.6 flight. Author

N86-11163# Dowty Rotol Ltd., Gloucester (England).
AERODYNAMIC AND STRUCTURAL ASPECTS OF PROPELLER AND DRIVE FOR A 1/5 SCALE WIND TUNNEL PROGRAMME
R. M. BASS, B. MUNNIKSMA (National Aerospace Lab., Amsterdam), and J. VANHENGST (Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost) *In* AGARD Aerodyn. and Acoustics of Propellers 18 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The paper describes the development of a model propeller and its calibration in association with an axisymmetric nacelle in the National Aerospace Laboratory low speed tunnel in Amsterdam before testing on a complete 1/5 scale model of the Fokker in the DNW (German-Dutch wind tunnel). The calibration so obtained, allowed the required operating propeller conditions to be set up on the complete F50 model. The influence of Reynolds number on correction for scale effects, between experimental model results and full scale prediction. A previously unsuspected and unavoidable vibration originating in the reduction gear train of the drive unit gave rise to high propeller blade stresses, ultimately leading to a blade failure. In order to continue running with minimum delay, new propeller blades with high internal damping were manufactured from composite materials, and the program was successfully concluded. Author

N86-11164# De Havilland Aircraft Co. of Canada Ltd., Downsview (Ontario).
SOME CONSIDERATIONS IN PROPELLER AND AIRFRAME INTEGRATION
B. EGGLESTON *In* AGARD Aerodyn. and Acoustics of Propellers 11 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The paper review elected items of R and D limited in support of propeller driven transport aircraft. The topics include the design of new propeller airfoils, two dimensional tests of selected airfoils, and estimates are presented of the resulting benefits in propeller performance. The application of numerical optimization to the aerodynamic design of propeller is also reviewed. Some results from wind tunnel tests of airframe/propeller installations are presented showing the benefits of alternative nacelle shape and the merits of high versus low wing locations on a transport aircraft. Author

N86-11165# Avions Marcel Dassault, Saint-Cloud (France). Div. des Etudes Avancees.
PROBLEMS OF THE INTEGRATION OF PROPELLERS IN AIRFRAMES, ESPECIALLY FOR HIGH PERFORMANCE TWIN-ENGINE AIRCRAFT [LES PROBLEMES D'INTEGRATION DE HELICES A LA CELLULE D'UN AVION ET, PLUS PARTICULIEREMENT, D'UN BIMOTEUR DE FORTE PUISSANCE]
R. TAISSERIE *In* AGARD Aerodyn. and Acoustics of Propellers 10 p (SEE N86-11147 02-01) Feb. 1985 In FRENCH
Avail: NTIS HC A20/MF A01

This report presents studies conducted on the integration of aircraft propellers with the airframe for general aircraft, as well as for high performance twin engine propeller aircraft. The effect of engine dimensions on the aerodynamic characteristics of the aircraft in all flight situations, including low speed flight, is presented. It is shown that detailed model tests will have to be conducted before accurate results can be obtained. The objective of these studies is to examine possible configurations for future maritime reconnaissance twin engine propeller aircraft. T.M.

N86-11166# Lockheed-Georgia Co., Marietta.
WIND TUNNEL INVESTIGATION OF THE INTERACTION OF PROPELLER SLIPSTREAM WITH NACELLE/WING/FLAP COMBINATIONS
A. S. ALJABRI and A. C. HUGHES *In* AGARD Aerodyn. and Acoustics of Propellers 10 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

Until recently it was sufficient to define the propeller slipstream by the average velocity induced across the propeller disk. With the advent of the highly loaded program and the accompanying concern for the effect of the slipstream and its interaction with aircraft components be known. This paper describes a series of wind tunnel tests performed to improve the understanding of this complex aerodynamic interaction. The tests were conducted using a conventional propeller operating at low subsonic speeds. Complementary theoretical and experimental studies were used to investigate the interaction effects. Results from wind tunnel tests on propeller/nacelle/wing, and propeller/nacelle/wing/flap combinations are presented here. Force, pressure, and wake survey data from the test allow the slipstream characteristics, including its distortion by the wing and flap, to be obtained. The important parameters which govern the slipstream shape and induced velocities are identified and techniques are developed for estimating slipstream drag and the torque absorbed by a wing immersed in the slipstream. An improved understanding of the effects of wind tunnel walls on propeller powered testing is also presented. Author

N86-11167*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
AN ASYMPTOTIC THEORY FOR THE INTERFERENCE OF LARGE ASPECT RATIO SWEPT WINGS AND MULTIPLE PROPELLER SLIPSTREAMS
R. K. PRABHU (Old Dominion Univ.), C. H. LIU, and S. N. TIWARI (Old Dominion Univ.) *In* AGARD Aerodyn. and Acoustics of Propellers 17 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01 CSCL 01A

This paper presents an asymptotic method for the analysis of the interference of multiple tractor propeller slipstream with large aspect ratio swept wings. It is assumed that the height of the slipstream is of the order of the wing chord and its spanwise extent is of the order of the wing span. Three different flow regions are identified by employing different stretching transformations. Asymptotic expansions are made in each of the three regions, using the chord to span ratio as the small expansion parameter. The details of the nonuniform flow in the slipstream enter into the wing sectional analysis. In the outer limit, the wing shrinks to a swept lifting line, and the slipstream reduces to a thin sheet of jet carrying the momentum gain from the propeller. The curvature of this jet sheet results in a pressure difference which is represented by a vortex sheet. The governing equations are solved by discretization. Several examples are considered for which experimental data are available. Comparison of the present results with the experimental data as well as other numerical solutions showed generally good agreement. Author

N86-11168# Carleton Univ., Ottawa (Ontario). Dept. of Mechanical and Aeronautical Engineering.
DEVELOPMENT OF MODERN TURBOPROP ENGINES
H. I. H. SARAVANAMUTTOO *In* AGARD Aerodyn. and Acoustics of Propellers 9 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

Proposals for propfan commercial aircraft operating at high cruise speeds pose requirements for advanced turboprops of high power. The history of turboprops for long range operation is briefly reviewed and the requirements for future engines are discussed. Considerable gains in the thermodynamic cycle can be realized, and the development of high performance gas generators should be a straightforward process. Transmission designs for high power engines may be extremely difficult and may result in novel engine configurations. It appears likely that a more modest goal of M = 0.7 cruise for shorter haul aircraft could be attained with much less risk while still achieving major gains. Author

N86-11169# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. for Experimental Fluid Mechanics.
AEROACOUSTIC WIND TUNNEL MEASUREMENTS ON PROPELLER NOISE
F. R. GROSCHE and H. STIEWITT *In* AGARD Aerodyn. and Acoustics of Propellers 9 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

Model tests were conducted in a low speed wind tunnel to determine the sound radiation of 5 propellers with different blade designs including variations of thickness ratios, blade profiles, blade planforms and blade tip configurations. The diameter of the propellers was 0.9 m, the propeller speed was kept constant. The tip Mach number was M sub I = 0.66 and the helical tip Mach number varied between 0.66 and 0.69. The main objectives were to investigate the effects of blade geometry on near field and far field noise and to locate the dominant sound sources in the propeller plane, radiating to the observer, by means of a highly directional microphone system. The results include: (1) comparisons of noise spectra of different propeller configurations; (2) near field sound pressures as function of axial distance from the propeller plane; and (3) directivity of sound radiation from the moving blades. Author

N86-11170# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
SOME AEROACOUSTIC WIND TUNNEL MEASUREMENTS, THEORETICAL PREDICTIONS, AND FLIGHT-TEST CORRELATIONS ON SUBSONIC AIRCRAFT PROPELLERS
W. J. G. TREBBLE, J. WILLIAMS (Southampton Univ., England), and R. P. DONNELLY (Dowty Rotol Ltd, Gloucester, England) *In* AGARD Aerodyn. and Acoustics of Propellers 21 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

Aeroacoustic experiments using the full scale propeller nacelle rig in the 24 ft anechoic tunnel were first made in 1979/80 on three alternative propellers also tested in flight on the Short's 330 aircraft. The Hartzell five bladed propeller of the production aircraft has conventional NACA 64 series sections and standard tips, the Hartzell Q-tip version of this has its tips bent as lower surface end plates in the direction of rotation, and the Dowty four bladed propeller has modern ARA-D sections and standard tips (D sub p = 2.8 m). Later complementary tunnel/flight experiments also included the Dowty four bladed R.212 propeller with classical NACA 16 series sections as fitted to the B.Ae. HS 748 aircraft (D sub p 3.7 m) Author

N86-11171# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).
AN INVESTIGATION OF IN-FLIGHT NEAR-FIELD PROPELLER NOISE GENERATION AND TRANSMISSION
H. BONNEAU, D. F. WILFORD, and L. K. WOOD *In* AGARD Aerodyn. and Acoustics of Propellers 12 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

In flight near field propeller noise measurements, made on a General Aviation turboprop aircraft, are reported for a range of propeller operating conditions, and are shown to be well defined and reproducible. Measurements have been made at 8 exterior microphones, 2 located on a wing mounted boom, and 6 embedded in, and flush with the aircraft fuselage. Interior noise levels are also presented. Measured propeller harmonic levels are compared to first principle calculations of near field noise, using a modified version of the Farassat computer program, in which the blade surface pressure is described using the known aerodynamic properties of the blade (NACA 16) airfoil sections. The first few; i.e., the dominant harmonic levels of propeller noise are shown to be well predicted, while higher harmonic levels are underpredicted. The transmission loss between exterior and interior noise levels is shown to be relatively constant for varying propeller operating conditions and at two different locations along the length of the fuselage. Interior noise levels are also shown for the aircraft in gliding flight at various forward velocities, with both engines at idle and propellers feathered. A method of interpolating these measurements is discussed, which allows the interior noise due only to the forward velocity of the aircraft, to be determined. The transmission loss for this component is also discussed. Finally, interior noise levels are presented for a series of ground static tests with engine mounts of various different stiffnessses. B.W.

N86-11172# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Entwurfsaerodynamik.
FULL-SCALE FLIGHT AND MODEL-SCALE WIND TUNNEL TESTS ON THE NEARFIELD NOISE CHARACTERISTICS OF AIRCRAFT PROPELLERS
H. HELLER, M. KALLERGIS, and B. GEHLHAR *In* AGARD Aerodyn. and Acoustics of Propellers 17 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

Flight noise tests employing a single engine Cessna T 207 aircraft with an array of wing mounted microphones were conducted to investigate nearfield acoustic characteristics of a 3 blade variable pitch propeller under different operational conditions, varying helical blade tip Mach number, propeller advance ratio, and blade loading. A special technique to minimize the engine exhaust influence on the propeller signature had been developed for this purpose. Supplementary, yet much more extensive tenth scale tests were performed in the DFVLR One Meter Acoustic Tunnel again in the acoustic nearfield of propellers with 2 to 6 blades over a substantial range or operational, partially interdependent, parameters, such as helical blade tip Mach number, blade pitch angle setting, blade incidence angle, rotational plane attitude, and ambient temperature. These data could also be compared to some third scale results for geometrically identical propellers. Especially the model tests allowed an exact quantification of the effect of the various parameters on the ensuing harmonic and subharmonic propeller noise spectra. Author

N86-11173# Aeritalia S.p.A., Pomigliano D'Arco (Italy).
CABIN NOISE REDUCTION FOR A NEW DEVELOPMENT TURBOPROP COMMUTER AIRCRAFT
A. CARBONE, A. PAONESSA, L. LECCE (Ist. Progetto Velivoli, Naples), and F. MARULO (Ist. Progetto Velivoli, Naples) *In* AGARD Aerodyn. and Acoustics of Propellers 14 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The program followed to attain an interior noise level similar to turbofan aircraft in a new design turboprop commuter is described. The need for an early consideration, in the definition phase of the aircraft, of the acoustic requirement for configuration development is stressed, along with some peculiar characteristics of this program. After a brief presentation of features of the aircraft related to interior noise control, the analytical and experimental models developed in the course of program are discussed. Some of the results of the studies are presented, clarifying the impact that they have had on the configuration of the aircraft. The output of three structural analysis theoretical procedures is compared to experiments. Two of these procedures, the panel stringer periodic model, and a simplified FEM analysis, are found adequate to represent experimental findings. The cylindrical shell - frame model is found not representative of test results. Sidewall treatment performance is discussed, with reference to theoretical and experimental results. The noise reductions measured in a furnished fuselage are compared to data obtained without interior treatment. Future developments and recommendations for additional work are discussed. Author

N86-11174# Lockheed-California Co., Burbank.
PROPELLER AIRCRAFT CABIN VIBRATION AND NOISE-EXCITATION, SOURCES, AND PATHS
R. E. DONHAM, F. J. BALENA, E. Z. BOCHARY, and O. K. LIEHR *In* AGARD Aerodyn. and Acoustics of Propellers 14 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The potential sources and paths by which the propeller produces structural responses resulting in vibration and noise in the cabin of a transport aircraft are discussed. New low cost, convenient experimental and analytical techniques are described for evaluating the excitations; propeller airborne pressures on the fuselage shells, slip stream induced forces on the wing and tail, and oscillatory forces on the propeller. The techniques described make use of ground determined structural signatures to relate forces with vibrations or noise, and of propeller signatures from flight which define the vibroacoustic contributions of individual propellers.
Author

N86-11175# Hamilton Standard, Windsor Locks, Conn.
THE STATE OF THE ART IN PROPFAN TURBOPROP NOISE
F. B. METZGER *In* AGARD Aerodyn. and Acoustics of Propellers 20 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The evolution of propeller noise research is summarized from 1919 to the present. The early experimental and analytical work to understand and predict propeller noise is discussed. Emphasis is placed on understanding source noise. However, the major advances in cabin comfort assessment and design of airplane fuselage and cabin trim to improve passenger comfort are briefly described. Emphasis is on the recent noise research work on the propfan, a many bladed relatively small diameter unshrouded motor with swept blades that will allow future transports to cruise efficiently at speeds equal to modern turbofan transports. The most recent propfan concept, a counter rotation version with even greater efficiency potential than the propfan with a single blade row is also discussed.
Author

N86-11176# Lockheed-Georgia Co., Marietta.
APPLICATION OF ACTIVE NOISE CONTROL TO MODEL PROPELLER NOISE
M. SALIKUDDIN, H. K. TANNA, R. H. BURRIN, and W. E. CARTER *In* AGARD Aerodyn. and Acoustics of Propellers 15 p (SEE N86-11147 02-01) Feb. 1985 refs
Avail: NTIS HC A20/MF A01

The applicability of active noise control to reduce cabin noise of turboprop aircraft is demonstrated by conducting several laboratory experiments. The principle of active noise control is to reduce the noise radiated from a primary source by superimposing a signal from a secondary source, which is made identical in amplitude but opposite in phase to the primary sound signal. A computer controlled algorithm was developed to implement this concept in a free field environment, in which, the noise from the primary source (eventually the propeller) and the noise measured at several locations on a representative surface (eventually the fuselage) were used to create the input for the secondary source. Experiments using a number of sinusoidal signals were conducted. An average noise reduction of 8 to 14 dB was achieved on the surface in the frequency range of 200 to 1000 Hz. Next the concept was applied to the propeller problem where the sound signal contains many discrete tones at harmonics of the blade passage frequency. For this purpose, a prerecorded time history of a 1/10th scale model propeller was used to drive the primary source. An average noise reduction of about 15 dB was observed at the first two blade passage frequencies, and 12 dB and 5 dB reductions were observed at the 3rd and 4th blade passage frequencies, respectively. Finally, the active noise control concept was applied to a 1/10th scale propeller, installed in an anechoic chamber with flight simulation facility. A substantial amount of noise reduction was achieved on the model fuselage surface.
Author

02

AERODYNAMICS

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

N83-25682# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SPECIALISTS' MEETING ON PREDICTION OF AERODYNAMIC LOADS ON ROTORCRAFT
H. R. VELKOFF (Ohio State Univ., Columbus) Feb. 1983 14 p refs Meeting held in London, 17-18 May 1982
(AGARD-AR-189; ISBN-92-835-1445-9; AD-A130486) Avail: NTIS HC A02/MF A01

While a broad overview of work being done on (1) rotor blade aerodynamic characteristics, (2) wakes and aerodynamic effects of rotorcraft and wind turbines; and (3) rotor airloads predictions programs was presented, a serious concern remains that the intent of the conferences was not fully met. Few papers evidenced experimental correlations of the aerodynamic forcing functions that were at a level similar to the extensive models and codes discussed. Most of the data used for evaluations were structural response data or were dependent on that response. Codes and analysis were not adequately verified. Adequate data bases for verification are not generally available and usually lack important such as flow velocities, pressures, or other measurements taken simultaneously. Experimental efforts were often run independently of the analytical programs and often do not meet the needs of the programs.
A.R.H.

N84-12099# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AERODYNAMICS OF VORTICAL TYPE FLOWS IN THREE DIMENSIONS
Loughton, England Jul. 1983 557 p refs In ENGLISH and FRENCH Symp. held in Rotterdam, Netherlands, 25-28 Apr. 1983
(AGARD-CP-342; ISBN-92-835-0334-1, AD-A135157) Avail: NTIS HC A24/MF A01

Separations which are frequently associated with vortical type flows are discussed. The trailing vortex system behind a lifting wing where the separation occurs at the trailing edge is noted. The use of large sweep angles with vortical flows is associated with separations forward of the trailing edge. A feature of such three dimensional flows are frequently well ordered with a defined stable structure and designers have increasingly sought to exploit them in meeting the growing speed and maneuver demands on modern aircraft. The following topics are discussed: (1) fundamentals, generation and structure of vortical flows; (2) interaction of vortical flows with surfaces; (3) modelling and computing; (4) stability and breakdown of vortical flows, (5) control and exploration of vortical flows. For individual titles, see N84-12100 through N84-12133

N84-12100*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.
ON ISSUES CONCERNING FLOW SEPARATION AND VORTICAL FLOWS IN THREE DIMENSIONS
D. J. PEAKE and M. TOBAK *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 31 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01 CSCL 01A

Vortical flows in three dimensional configurations that are of typical interest to aerodynamicists and researchers in fluid mechanics are reviewed. A list of 10 issues was compiled to understanding complex vortical flows
E.A.K.

N84-12101# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
THE VORTEX SKELETON MODEL FOR THREE-DIMENSIONAL STEADY FLOWS
H. G. HORNUNG *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 12 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

The essential concepts of two dimensional separation were extened to three dimensional steady flow, and the vortex skeleton model and electromagnetic analogy are introduced. The model gives a simple topological rule by which the vortex skeleton of a flow can be established from the structure of the wall streamline pattern. The important question of the occurrence of smoothly starting separation without zeros in the wall shear stress, is examined because of a new local solution of the Navier-Stokes and continuity equations. E.A.K.

N84-12102# Stanford Univ., Calif. Joint Inst. for Aeronautics and Acoustics.
ON THE STRUCTURE OF THE TURBULENT VORTEX
L. ROBERTS *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 11 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

The trailing vortex generated by a lifting surface, the structure of its turbulent core and the influence of axial flow within the vortex on its initial persistence and on its subsequent decay are described. Similarity solutions of the turbulent diffusion equation are given in closed form and results are expressed in sufficiently simple terms that the influence of the lifting surface parameters on the length of persistence and the rate of decay of the vortex can be evaluated. E.A.K.

N84-12103# Imperial Coll. of Science and Technology, London (England). Dept. of Aeronautics.
INSTABILITIES IN TRAILING VORTICES: FLOW VISUALIZATION USING HOT-WIRE ANEMOMETRY
C. STRANGE and J. K. HARVEY *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 11 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

Trailing vortices often break up after the formation of disc shaped disturbances. A flow visualization experiment was performed in which similar strongly dissipative disturbances were produced in the laboratory. Details of the origin and development of this instability are discussed. An experiment using hot wire anemometry and a conditional sampling technique was set up. Data are presented on a solitary wave like disturbance which was found on the outer edge of the core and convected downstream at about the same velocity as the ambient fluid. It is found that the perturbation flow field associated with this disturbance is not axisymmetric. E.A.K.

N84-12104# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
INTERACTION BETWEEN A SHOCK-WAVE AND A VORTEX FLOW
J. DELERY and E. HOROWITZ *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 19 p (SEE N84-12099 03-02) Jul. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A24/MF A01

The interaction between a vortex and a shock-wave normal to the streamwise axis of the vortex was studied both experimentally and theoretically. Measurements were made for four values of the upstream Mach number ranging from 1.6 to 2.28. They allowed the characterization of the shock effect on the vortical flow structure when breakdown does not occur. They also led to the definition of a breakdown limit function of the two parameters: normal shock strength - vortex swirl/ratio. Two flow configurations associated respectively with interaction without and with vortex bursting were carefully probed by using a two-color laser Doppler velocimeter system. When breakdown occurs, the mean meridian motion comprises a recirculating bubble near the axis of the structure. A flow model was developed in the framework of the Euler equations. As long as the vortex does not burst, the calculations give a faithfull description of flow phenomena. They also predict a limit for vortex breakdown which agrees satisfactorily with experiment. M.G.

N84-12105# Cranfield Inst. of Tech., Bedford (England). Div. of Aerodynamics.
ON THE GENERATION AND SUBSEQUENT DEVELOPMENT OF SPIRAL VORTEX FLOW OVER A SWEPT-BACK WING
D. I. A. POLL *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 14 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

An experimental investigation was performed to study the formation and development of spiral vortex flow over a swept-back wing. An aerofoil section with three alternative leading edge shapes was tested at sweep angles ranging from 0 to 56 deg for unit Reynolds number of 1,000,000/m and 2,000,000/m. The principal diagnostic tool was the surface oil-flow visualization technique supplemented by pressure distribution measurements in certain cases. No spiral vortex flow was observed for sweep angles of 0 and 15 deg but at higher sweep angles the oil-flows indicated that there were three different mechanisms for the formation of spiral vortices. The angle of incidence at the onset of vortex flow, and the mechanism responsible for its formation, were found to depend upon the sweep angle, the leading edge shape and the Reynolds number. It was also noted that the larger the leading edge radius the greater the dependence upon Reynolds number. However, comparison with other work suggests that Reynolds number, incidence and sweep angle alone are insufficient to determine the type of spiral vortex flow occurring on a given wing. M.G.

N84-12106# Technische Hogeschool, Delft (Netherlands). Dept. of Aerospace Engineering.
AN EXPERIMENTAL INVESTIGATION OF THE VORTEX FLOW OVER DELTA AND DOUBLE-DELTA WINGS AT LOW SPEED
N. G. VERHAAGEN *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 16 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

A wind tunnel investigation was performed to study, by employing a laserlight-sheet and oil-flow visualization technique, the flow above and behind a sharp-edged 76 deg delta wing and two sharp-edged double-delta wing models (76/60 and 76/40 deg, kink at midchord). In addition, balance measurements were performed to determine lift, drag and pitching moment. The tests were carried out for angles of attack from 5 to 25 deg and at a free-stream velocity of 30 m/sec, corresponding to a Reynolds number of 1,400,000, based on centerline chord. Above both double-delta wings a single-branched strake vortex is formed by vorticity from the strake leading edge. Downstream of the leading-edge kink a wing vortex is formed which is conjectured to be single-branched at about 5 deg angle of attack and double branched at angles of 10 deg, and beyond. The flow pattern downstream of the trailing edge of the 76/60 deg double-delta wing was observed to be similar to that behind the delta wing. Above the 76/40 deg double-delta wing breakdown of both the wing and strake vortices took place ahead of the trailing edge. M.G.

N84-12107# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
VISUALIZATION OF VORTICAL TYPE FLOWS IN THREE DIMENSIONS
H. WERLE *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 20 p (SEE N84-12099 03-02) Jul. 1983 refs In FRENCH; ENGLISH summary Previously announced as A83-44312
Avail: NTIS HC A24/MF A01

Turbulence structures that have been made visible by various means are outlined. Natural occurrences such as hurricanes, whirlpools, and island wakes have been photographed by satellite, from aircraft, and from the ground. Laboratory trials with wind and water tunnels have permitted photography of flows around helicopter blades, models, airfoils at various angles of attack, and around diversely shaped and oriented objects. Smoke streamlines have been generated with titanium tetrachloride wires, kerosene, and oil vapor, or by water condensed over liquid nitrogen. Colored dyes have been released from the surface of the model and

pressure distributions have been translated into lighted regions. Gases and liquids, colored or fluorescent, have served for visualizations in water channels. Spiral structures, point vortices on swept wings, bursting vortices, vortices shed from cylindrical and ellipsoidal bodies, as well as in unsteady flows have been visualized during trials in applied aerodynamics. Numerous photographic examples are provided. M.S.K. (IAA)

N84-12108# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
LASER VELOCIMETRY STUDY OF COMPRESSIBILITY EFFECTS ON THE FLOW FIELD OF A DELTA WING
G. VORROPOULOS and J. F. WENDT *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 13 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

Compressibility effects on the lee-side vortical flow field of a delta wing at incidence were studied using laser Doppler velocimetry. The tests covered the Mach number range from 0.18 to 0.80; both axial and circumferential velocity components were measured. It was found that the axial velocity excess observed at low Mach numbers became an axial velocity deficit at Mach numbers above 0.6. Strong asymmetry was observed in the circumferential velocity distribution at the higher Mach numbers. A flow picture including an embedded shock wave is proposed as physical explanation of observed compressibility effects. Author

N84-12109*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RECENT STUDIES AT NASA-LANGLEY OF VORTICAL FLOWS INTERACTING WITH NEIGHBORING SURFACES
J. E. LAMAR and J. F. CAMPBELL *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 32 p (SEE N84-12099 03-02) Jul. 1983 refs Previously announced as A83-33972
Avail: NTIS HC A24/MF A01 CSCL 01A

The importance of leading edge vortical flows, which occur near and interact with neighboring surfaces, is stressed. Research in this area conducted or sponsored by the NASA Langley Research Center since 1978 is surveyed. Particular attention is given to the cumulative results of a number of theoretical and experimental studies. It is noted that these studies have been carried out in order to understand and use this kind of flow. Much of the work has been devoted to improving the lift-to-drag ratio and pitch characteristics for wings in this flow, although work has also been done on examining the unsteady and lateral characteristics.
Author

N84-12110*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EXPERIMENTAL INVESTIGATION OF FOREBODY AND WING LEADING-EDGE VORTEX INTERACTIONS AT HIGH ANGLES OF ATTACK
G. E. ERICKSON (Northrop Corp.) and W. P. GILBERT *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 20 p (SEE N84-12099 03-02) Jul. 1983 refs
(Contract NAS1-16617)
Avail: NTIS HC A24/MF A01 CSCL 01A

An experimental investigation was conducted to assess the vortex flow-field interactions on an advanced, twin-jet fighter aircraft configuration at high angles of attack. Flow-field surveys were conducted on a small-scale model in the Northrop 0.41 - by 0.60-meter water tunnel and, where appropriate, the qualitative observations were correlated with low-speed wind tunnel data trends obtained on a large-scale model of the advanced fighter in the NASA Langley Research Center 30- by 60-foot (9.1- by 18.3-meter) facility. Emphasis was placed on understanding the interactions of the forebody and LEX-wing vortical flows, defining the effects on rolling moment variation with sideslip, and identifying modifications to control or regulate the vortex interactions at high angles of attack. The water tunnel flow visualization results and wind tunnel data trend analysis revealed the potential for strong interactions between the forebody and LEX vortices at high angles of attack. In particular, the forebody flow development near the nose could be controlled by means of carefully-positioned radome strakes. The resultant strake-induced flow-field changes were amplified downstream by the more powerful LEX vortical motions with subsequent large effects on wing flow separation characteristics. Author

N84-12111# Royal Aircraft Establishment, Bedford (England). Aerodynamics Dept.
SOME RESULTS FROM A PROGRAMME OF RESEARCH INTO THE STRUCTURE OF VORTEX FLOW FIELDS AROUND MISSILE SHAPES
T. R. BYRAM, A. PETERSEN (British Aerospace PLC), and S. T. KITSON *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 20 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

Wind tunnel tests were performed to measure the leeside flow field of a generalized missile model at an angle of attack of 14 degrees and freestream Mach numbers of 0.7 and 1.8. Flow field data are presented for a station towards the rear of the model showing the flow structure for the body alone and the effects of mounting a cruciform set of delta fins near to the nose and near to the base. The data presented include vector plots of the components of velocity in the cross flow plane, the distributions of local total pressure, local Mach number and vorticity. The presence of the set of forward mounted fins and its roll orientation was found to have a significant effect on the development of the body vortices. Fins mounted towards the rear of the body were found to disrupt the body vortex feeding region but had little effect on the vortex centers unless these lay in or very close to the plane of the fins. R.J.F.

N84-12112*# Analytical Methods, Inc., Bellevue, Wash.
PREDICTING AERODYNAMIC CHARACTERISTICS OF VORTICAL FLOWS ON THREE-DIMENSIONAL CONFIGURATIONS USING A SURFACE-SINGULARITY PANEL METHOD
B. MASKEW *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 12 p (SEE N84-12099 03-02) Jul. 1983 refs
(Contract NAS2-8788; N00014-78-C-0128; N00014-82-C-0354; DAAG29-81-C-0032)
Avail: NTIS HC A24/MF A01

A general low-order surface-singularity panel method is used to predict the aerodynamic characteristics of a problem where a wing-tip vortex from one wing closely interacts with an aft mounted wing in a low Reynolds Number flow; i.e., 125,000. Nonlinear effects due to wake roll-up and the influence of the wings on the vortex path are included in the calculation by using a coupled iterative wake relaxation scheme. The interaction also affects the wing pressures and boundary layer characteristics: these effects are also considered using coupled integral boundary layer codes and preliminary calculations using free vortex sheet separation modelling are included. Calculated results are compared with water tunnel experimental data with generally remarkably good agreement. Author

N84-12113# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. for Experimental Fluid Mechanics.
SEPARATION AND VORTICAL-TYPE FLOW AROUND A PROLATE SPHEROID: EVALUATION OF RELEVANT PARAMETERS
H. VOLLMERS, H. P. KREPLIN, and H. U. MEIER *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 14 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

The definition of some special lines in a flow field is discussed and a criterion for the identification of axes of local rotation is given. A preferred direction is introduced in space using the local direction of the velocity. A surface is constructed locally such that at any point the surface is normal to the velocity field. For a (normalized) direction field of the velocity, the components of the gradient tensor on this surface can be regarded as being equivalent to the curvature tensor of the surface. The behavior of the curvature is discussed. The surface is partitioned into hyperbolic and elliptic regions by the sign of the Gaussian curvature. It is found that the special points are associated with regions of extremely steep variations of the Gaussian curvature. Experimental evidence to this effect is provided by measurements of wall shear stress vectors and velocity vectors in the flow field around an inclined prolate spheroid. The above procedure is shown to be a tool for revealing some properties of the vortex skeleton of a flow field. Several other parameters of the measured flow field are also evaluated and presented. Author

N84-12114# Ministry of National Defence, Athens (Greece). Defence Industry Directorate.
ON THE GENERATION OF VORTICAL FLOW AT HYPERSONIC SPEEDS OVER ELLIPTICAL CONES
P. EVANGELOU *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 9 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

A method for calculating the hypersonic slip flow around slender elliptic cones at slight angle of attack is developed. The governing equations are derived from the Navier-Stokes equations and the energy equation by an order of magnitude analysis. There results a system of partial nonlinear parabolic differential equations for the flow variables of the shock formation regime. The system is integrated by means of an explicit finite-difference scheme and the results so obtained are compared with experimental data. Finally the influence of the elliptic cross section geometry as well as the influence of the angle of attack on the flow field properties with particular attention on the cross flow are investigated. Author

N84-12115# National Aeronautical Establishment, Ottawa (Ontario). Low Speed Aerodynamic Lab.
VISCOUS THREE-DIMENSIONAL FLOW SEPARATIONS FROM HIGH-WING PROPELLER-TURBINE NACELLE MODELS
R. H. WICKENS *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 29 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

This paper describes an investigation of viscous three dimensional flows on high-wing nacelle configurations which are typical of current commuter aircraft. Flow visualization on two nacelle configurations was used to depict the viscous vortex separations in the underwing junction, the nacelle afterbody, and the wing upper surface over the central region. The surface shear stress patterns, although complex, were composed of combinations of elementary three dimensional viscous flows and free vortices which stream downwind. A strong vortex flow was produced over the top of the wing by the use of leading edge extensions along the forward portion of the nacelle. Observations were also made of the effects of a propeller slip-stream and the distortion of this propulsive flow by the mutual interference of the wing and nacelle. Author

N84-12116# Royal Aircraft Establishment, Farnborough (England). Aerodynamics Dept.
THEORETICAL MODELLING OF THREE-DIMENSIONAL VORTEX FLOWS IN AERODYNAMICS
J. H. B. SMITH *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 21 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

A unified account is presented of the various inviscid models used to represent three dimensional vortex flows in aerodynamics; essentially those relying on vortex sheets and line-vortices. Recent developments in extending the scope, accuracy, and stability of these models are described. An evaluation of their relative strengths and weaknesses suggests that the different models all have continuing roles to play. It is claimed that vortex modelling has come of age, in the sense that we can now learn about the real world from the behavior of models, after decades of trying to make the models conform with reality. Author

N84-12117# National Aerospace Lab., Amsterdam (Netherlands). Fluid Dynamics Div.
COMPUTATIONAL VORTEX FLOW AERODYNAMICS
H. W. M. HOEIJMAKERS *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 35 p (SEE N84-12099 03-02) Jul. 1983 refs Sponsored in part by Royal Netherlands Air Force
Avail: NTIS HC A24/MF A01

A review is presented of computational methods for the determination of the characteristics of vortical type flows occurring in aircraft aerodynamics. The review covers primarily computational methods for computing the downstream development of vortex wakes and methods for computing the characteristics of configurations with leading-edge and strake vortices. The various computational methods in use at present are discussed in some detail. The possibilities and limitations of the methods are indicated and results of different methods are compared and discussed. Author

N84-12118# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
VORTEX FLOW SIMULATIONS PAST WINGS USING THE EULER-EQUATIONS
C. WEILAND *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 12 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

Flow fields with vortex separation play an important role in the aerodynamics of missiles and for airplanes. Investigations carried out recently have shown that such flow fields can be computed by means of solutions of the Euler-equations. In the present paper results are presented for flow fields around delta-wings with freestream Mach number larger than 1. The range of the angle of attack is up to alpha = 15 deg. The Euler-equations are integrated by using a space-marching finite-difference method. The delta-wings have got sharp and blunted leading edges. At the sharp leading edge a condition is prescribed which produces a tangential discontinuity by means of which vorticity is introduced into the flow field. The formulation of the governing equations, the boundary conditions and the initial data is discussed. The results shown are the contours of the bow shock, the isobars, the lines of constant total pressure and the velocity vectors of the cross flow. The wave drag is determined by evaluating the integral for the momentum in an adequate surface in the flow field. Author

N84-12119# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
SIMULATION OF TURBULENT FLOWS WITH A POINT VORTEX METHOD
S. HUBERSON *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 8 p (SEE N84-12099 03-02) Jul. 1983 refs Previously announced as A83-44313
Avail: NTIS HC A24/MF A01

Turbulent flows are modelled by the method defined by Rehbach (1977) for treating three dimensional, incompressible flows of a perfect fluid. The Helmholtz equation is used to calculate the temporal evolution of the vortices, the rotational velocity field, and the continuity equation. The velocity field is then obtained as a function of the Biot-Savart integral and the vortex field is discretized in terms of vortex particles, with the flow described by two fields of discrete vectors: vortices and temporal position. The formulation allows the use of a very fine mesh, with the number of grid points chosen limited by the amount of computing power and time available. A technique is defined for determining the magnitude of the error associated with the total number of grid points used. Examples are provided for turbulence in two dimensional flows. The technique is demonstrated to represent well deformation and elongation of the vortex eddies. M.S.K. (IAA)

N84-12120# Aeronautical Research Inst. of Sweden, Bromma.
NUMERICAL SOLUTIONS OF THE EULER EQUATIONS SIMULATING VORTEX FLOWS AROUND WINGS
A. RIZZI, L. E. ERIKSSON, W. SCHMIDT, and S. HITZEL *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 14 p (SEE N84-12099 03-02) Jul. 1983 refs Prepared in cooperation with Dornier G.m.b.H., Friedrichshafen, West Germany
Avail: NTIS HC A24/MF A01

The Euler equations was established as an appropriate model for inviscid vortex flow. The range of this model's applicability is demonstrated by presentation of flowfields computed around a number of different wings with either sharp or rounded edges and at subsonic, transonic, and supersonic speeds. The emphasis here is on the physics of the flow model rather than the numerical aspects of the solution method. The results display both expected as well as unexpected vortex phenomena and indicate the value of this computational tool. Particular attention is paid to the wake regions. Author

N84-12121*# Tennessee Univ. Space Inst., Tullahoma.
THE TREATMENT OF CONVECTED VORTICES IN COMPRESSIBLE POTENTIAL FLOW
J. STEINHOFF, K. RAMACHANDRAN, and K. SURYANARAYANAN *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 12 p (SEE N84-12099 03-02) Jul. 1983 refs Sponsored in part by NASA-Ames
Avail: NTIS HC A24/MF A01

A method is described for incorporating line vortices into the three dimensional compressible potential flow equation. A modified Biot-Savart law is used to compute a vortical velocity field, which is added to the gradient of the potential to form a total velocity. A rapidly converging approximate factorization (AFZ) scheme is then used to compute a potential such that the modified potential flow equation as well as the appropriate boundary conditions, based on total velocity, are satisfied. As part of a coupled iteration procedure, the positions of the line vortices are computed so that they convect with the total flow. The method is used to compute the field due to a single line vortex convecting past a wing. This represents an approximation of the effect of a canard or other lifting surface ahead of the wing, which sheds a tip vortex. It is seen that the flow field is substantially modified by the passage of the vortex. Unlike Euler equation schemes, which are also used to compute these flows, the solutions exhibit no numerical diffusion: The convected vortices retain their initial upstream width. Euler solutions, on the other hand, involve a vorticity which is numerically convected in an Eulerian frame and, unless extensive adaptive grid refinement is used they result in vortices with spread as they convect. Also, the potential flow method requires approximately two orders of magnitude less computing time and much less computer storage than the Euler methods. Author

N84-12122# Cornell Univ., Ithaca, N.Y. School of Mechanical and Aerospace Engineering.
VORTEX STABILITY AND BREAKDOWN
S. LEIBOVICH *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 22 p (SEE N84-12099 03-02) Jul. 1983 refs
(Contract NSF CME-79-19817)
Avail: NTIS HC A24/MF A01

Theoretical and experimental results, some quite recent, on the instability and breakdown of concentrated vortices at high Reynolds numbers are reviewed. Wave related theories of the vortex breakdown phenomenon are treated in some detail; these appear to provide a qualitative description of the response of vortex breakdown to variations in swirl or flow rate, and Benjamin's criticality classification, a wave-based concept, is consistent with experiment data. Known general criteria for the stability or instability of inviscid columnar vortices are reviewed, together with numerical studies of an inviscid vortex model that provides an excellent analytical fit to measured velocity profiles in vortices that experience breakdown. A new analysis of experimental data on vortex breakdown flows sheds light on the interplay between criticality and instability. The flows sufficiently far upstream of breakdowns to be unaffected by them are supercritical and stable, but they are generally closer to marginal instability than they are to criticality. The wakes are both subcritical and unstable. A conceptual framework for vortex breakdown, incorporating nonlinear wave theory and instability to three dimensional disturbances, is suggested based on information derived from the experimental studies. Author

N84-12123# Trondheim Univ. (Norway). Inst. for Mekanikk.
THE BREAK-UP MECHANISM OF A STREAMWISE DIRECTED VORTEX
L. N. PERSEN *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 5 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

The possible break-up mechanism of a vortex with its axis parallel to the direction of the mean flow is considered. Such streamwise directed vortices were considered first of all by G. I. Taylor in his investigation of the stability of the flow between two concentric cylinders. H. Gortler has made studies of streamwise directed vortices along a concave wall. In both these cases the vortices created seem to be very stable in the side-wise direction. However the G. I. Taylor vortices do not change in the direction of the mean flow, and thus do not exhibit any breakup mechanisms. In very many cases encountered under different flow conditions the breakup of a stream-wise directed vortex occurs after a certain distance downstream, and a possible mechanism whereby such a break-up can occur is presented. This mechanism is inherent in the basic equations of the flow, and as such is also exhibited on the equations of motion a non-viscous fluid. Author

N84-12124# Brown Boveri Research Center, Baden (Switzerland).
VORTEX BREAKDOWN: A TWO-STAGE TRANSITION
M. P. ESCUDIER and J. J. KELLER *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 8 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

It is demonstrated that a large-scale isentropic transition between conjugate swirling flow states can occur with no change in the flow force and that both flow states are supercritical. It is argued that such a transition represents the first stage of vortex breakdown in a tube, the second stage being a non-isentropic transition in the nature of a hydraulic jump to the downstream subcritical state. The intermediate (supercritical) state consists of a zone of stagnant fluid surrounded by a region of potential flow. These two zones are separated by a layer of rotational fluid originating in the upstream flow modelled as a Rankine vortex. It is found that for any ratio of core-to-tube radii, breakdown (i.e. the first transition) occurs for a unique value of the swirl number. In the limiting case of an infitesimally small core, the value is the square root of 2 compared with the critical value 2.405. It is argued that this limit cannot represent free breakdown, which in consequence must have a different character from the tube-flow breakdowns generally observed. Author

N84-12125# Technische Hochschule, Aachen (West Germany). Aeridynamisches Inst.
A CONTRIBUTION TO THE PROBLEM OF VORTEX BREAKDOWN
E. KRAUSE *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 4 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

Associated with the breakdown process is the formation of a stagnation point on the axis of the vortex. This requires the deceleration of the axial velocity component, which must be enforced by a positive axial pressure gradient. An analysis is presented which shows how the pressure gradient along the axis of the vortex is influenced by the radial and azimuthal velocity components. An explicit expression for delta p/delta $x(x,0)$ can be obtained by integration of the momentum equation for the radial velocity component with respect to the radial and subsequent differentiation of the integral with respect to the axial direction. In an order of magnitude analysis, it is then demonstrated that for large Reynolds numbers one component of the frictional force in the azimuthal direction cannot be neglected. In order to obtain an estimate for the pressure gradient rigid body rotation is assumed for the vortex core, and a distribution similar to that of a potential vortex, for the outer portion. The estimate shows that a positive axial pressure gradient can exist only, if the radial velocity component is positive and if the exponent is less than unity. It is also verified that a potential vortex cannot support an axial pressure gradient, that the pressure gradient in magnitude is directly proportional to the square of the maximum of the azimuthal velocity, referenced to the freestream velocity. Author

N84-12126# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
NUMERICAL SIMULATION OF VORTEX BREAKDOWN BY THE VORTEX-FILAMENT METHOD
Y. NAKAMURA, A. LEONARD, and P. R. SPALART *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 13 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01 CSCL 01A

The vortex-filament method was applied to the simulation of vortex breakdown. The principal vortex region was represented by multiple filaments, and an axial velocity component was induced by a spiral winding of the filaments. An accuracy check was performed for a cylindrical swirling flow with simple analytical expressions for the axial and theta velocities. The result suggests that the flow field can be simulated to any accuracy by increasing the number of filaments. An axisymmetric-type vortex breakdown was simulated, with experimental data serving as upstream

conditions. The calculated axial- and theta-velocity contours show the breakdown of the vortex, including a rapid change in the vortex core, followed axially by a recovery zone and then a second breakdown. When three dimensional initial data are used the second breakdown appears to be of the spiral type in correspondence with experimental observations. The present method can easily be used to simulate other types of vortex breakdown or other vortex flows with axial velocity. Author

N84-12127# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EXPERIMENTATION WITH TURBULENT FLOWS EXPERIENCING THE EFFECTS OF AN ADVERSE PRESSURE GRADIENT
J. L. SOLIGNAC and O. LEUCHTER *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 25 p (SEE N84-12099 03-02) Jul. 1983 refs In FRENCH; ENGLISH summary Previously announced as A83-44314
Avail: NTIS HC A24/MF A01

Experiments were performed to examine the effects on turbulent structures produced by the adverse pressure gradients around a delta wing and about symmetric wings. Laser tomoscopy visualized the flows, and measurements were taken of the static pressure distributions and the flow velocities (using LDV techniques). The flow velocities were 14.5 and 32 m/sec for the delta wing and winglets, respectively. Attention was focused on the leading edge vortex for the delta wing and the turbulence generated by the two NACA 0012 winglets, which were mounted at opposite angles of attack. The resulting turbulence differed mainly in velocity profiles. M.S.K. (IAA)

N84-12128# Grenoble Univ. (France). Inst. de Mecanique.
WAVES ON VORTEX CORES AND THEIR RELATION TO VORTEX BREAKDOWN
T. MAXWORTHY (Univ. of Southern California), M. MORY, and E. J. HOPFINGER *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 13 p (SEE N84-12099 03-02) Jul. 1983 refs
(Contract N00014-82-K-0084; DRET-82/468)
Avail: NTIS HC A24/MF A01

The conjective by Hopfinger, Browand and Gagne (1982) that travelling, large amplitude "kink" waves, observed in rotating, turbulent fluid might be at the origin of vortex breakdown and small scale turbulence production motivated a study of such waves on isolated vortices under controlled conditions. Their characteristics are interpreted in terms of theories based on the localized induction equation. It is found that these kink waves remain stable and exhibit soliton interaction properties. Axisymmetric travelling waves, on the contrary, cause breakdown when their amplitude exceeds a certain magnitude. Benjamin's (1967) theory was used to calculate the critical phase speed and the velocity perturbation inside a wave of finite amplitude. The theoretical results show that the axial velocity changes rapidly become large so that, according to instability considerations, growth of spiral disturbances is possible. Breakdown caused by axisymmetric waves and possibly by combined, axisymmetric and kink waves, is demonstrated experimentally. A.R.H.

N84-12129*# Vigyan Research Associates, Inc., Hampton, Va.
VORTICAL FLOW MANAGEMENT FOR IMPROVED CONFIGURATION AERODYNAMICS: RECENT EXPERIENCES
D. M. RAO *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 14 p (SEE N84-12099 03-02) Jul. 1983 refs Sponsored in part by NASA-Langley
Avail: NTIS HC A24/MF A01 CSCL 01A

Recent progress in vortex-control applications for alleviating the adverse consequences of three dimensional separation and vortical interactions on slender body/swept wing configurations is reported. Examples include helical separation trip to alleviate the side force due to forebody vortex asymmetry; hinged strakes to avoid vortex breakdown effects; compartmentation of swept leading edge separation to delay the pitch-up instability; under wing vortex trip and vortex trip and vortex flaps for drag reduction at high lift; and an apex-flap trimmer to fully utilize the lift capability of trailing-edge flaps for take off and landing of delta wings. Experimental results on generic wind-tunnel models are presented to illustrate the vortex-management concepts involved and to indicate their potential for enhancing the subsonic aerodynamics of supersonic-cruise type vehicles. Author

N84-12130# Cranfield Inst. of Tech., Bedford (England). Dept. of Applied Aerodynamics.
THE EFFECTS OF WING TIP DEVICES ON THE PERFORMANCE OF THE BAE JETSTREAM
M. J. FELL (British Aerospace PLC) and J. J. SPILLMAN *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 11 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

A measurable drag reduction for a Jetstream fitted with tip devices over the range of operational lift coefficients is demonstrated. The increase in wing root blending moment due to either device in order to compare their relative moments with simple tip extensions is estimated. N.W.

N84-12131# Cranfield Inst. of Tech., Bedford (England). Dept. of Applied Aerodynamics.
THE EFFECT OF WING TIP DEVICES ON THE FAR-FIELD WAKE OF A PARIS AIRCRAFT
J. J. SPILLMAN *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 9 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

Studies made of the flow about the wing-tip of a wind tunnel model showed that the vortex-type flow generally associated with the rolled-up vortex sheet well behind the tip existed just behind the trailing edge and seemed to be forming over the top of the wing-tip itself. As a result small cambered aerofoils were attached to the wing-tip to redirect the flow locally in such a way that each experienced a force with a significant thrust component. The effect is similar to that generated by the sail of a close-hauled yacht; consequently these small tip extensions were called sails. The original windtunnel and the preliminary flight tests of sails mounted from the tip tanks of the Paris aircraft of the Cranfield Institute of Technology are described. These initial tests showed that a considerable reduction in the lift-dependent drag resulted from fitting the sails but there was a marked scatter in the results which detracted from their credibility. Author

N84-12132# Politecnico di Milano (Italy). Dipt. di Ingegneria Aerospaziale.
BOUNDARY LAYER SEGMENTATION ON SHARP HIGHLY SWEPT LEADING EDGES AND ITS EFFECTS ON SECONDARY VORTICES
A. BARON and S. DEPONTE *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 7 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01

Pressure measurements were performed on an unslotted delta wing model, which enabled to determine the location of the secondary separation line, as a function of the angle of attack. A slotted delta wing model was then built and tests were carried on, showing a remarkable shift of the location of the secondary separation line. In addition, the secondary vortex flow was investigated by means of a tracing gas technique, based on the injection of Helium on the upper surface of the wing and measurements of its concentration in the flow downstream. Boundary layer segmentation appears to be a useful tool in preventing large secondary separations and allows higher lift coefficients to be obtained. It is reasonable to suppose that results similar to those reached for this delta wing could be expected also for conventional highly swept wings. Author

N84-12133*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
AUGMENTATION OF FIGHTER-AIRCRAFT PERFORMANCE BY SPANWISE BLOWING OVER THE WING LEADING EDGE
A. SEGINER (Technion-Israel Inst. of Technology) and M. SALOMON (SAL Engineering) *In* AGARD Aerodyn. of Vortical Type Flows in Three Dimensions 26 p (SEE N84-12099 03-02) Jul. 1983 refs
Avail: NTIS HC A24/MF A01 CSCL 01A

Spanwise blowing over the wing and canard of a 1:35 model of a close-coupled-canard fighter-airplane configuration (similar to the Kfir-C2) was investigated experimentally in low-speed flow. Tests were conducted at airspeeds of 30 m/sec (Reynolds number of 1.8 x 10 to the 5th power based on mean aerodynamic chord)

with angle-of-attack sweeps from -8 deg to 60 deg, and yaw-angle sweeps from -8 deg to 36 deg at fixed angles of attack 0 deg, 10 deg, 20 deg, 25 deg, 30 deg, and 35 deg. Significant improvement in lift-curve slope, maximum lift, drag polar and lateral/directional stability was found, enlarging the flight envelope beyond its previous low-speed/maximum-lift limit. In spite of the highly swept (60 deg) leading edge, the efficiency of the lift augmentation by blowing was relatively high and was found to increase with increasing blowing momentum on the close-coupled-canard configuration. Interesting possibilities of obtaining much higher efficiencies with swirling jets were indicated. Author

N84-20499# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TWO-DIMENSIONAL WIND TUNNEL WALL INTERFERENCE
M. MOKRY, Y. Y. CHAN, D. J. JONES, and L. H. OHMAN, ed. Nov. 1983 195 p
(AD-A138964; AGARD-AG-281; ISBN-92-835-1463-7) Avail: NTIS HC A09/MF A01 CSCL 01A

Developments in the understanding of the wall interference problem associated with two dimensional wind tunnel testing at subsonic and transonic speeds are described. Wall boundary conditions, asymptotic analysis of wall interference, classical and extended wall interference theories, wall interference corrections from boundary measurements, integral equation formulation of subcritical wall interference, and effects of side wall boundary layer on two dimensional tests are discussed. Unsteady wall interference at subsonic and supersonic flow conditions is reviewed. Advances in the adaptive wall technique, which actively reduces or eliminates wall interference, are described. E.A.K.

N85-10020# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
EXPERIMENTAL DATA BASE FOR COMPUTERS PROGRAM ASSESSMENT. REPORT OF THE FLUID DYNAMICS PANEL WORKING GROUP 04: ADDENDUM
Loughton, England Jul. 1984 148 p refs
(AGARD-AR-138-ADD; ISBN-92-835-1475-0) Avail: NTIS HC A07/MF A01

Data sets for high and low aspect radio wings in wing-alone and wing-body combination are presented to provide data for computer program assessment. For individual titles see N85-10021 through N85-10025.

N85-10021# Lockheed-Georgia Co., Marietta.
TRANSONIC WING AND FAR FIELD TEST DATA ON A HIGH ASPECT RATIO TRANSPORT WING FOR THREE DIMENSIONAL COMPUTATIONAL METHOD EVALUATION
K. P. BURDGES and B. L. HINSON *In* AGARD Exptl. Data Base for Computers Program Assessment p (SEE N85-10020 01-02) Jul. 1984 refs
Avail: NTIS HC A07/MF A01

Force and pressure data were obtained on a moderate aspect ratio transport wing that is representative of high performance supercritical technology. The pressure distributions on this wing exhibit recompression of the local supersonic flow over the front part of the wing, terminating the supersonic region with a moderate strength, swept shock wave. Far field boundary conditions were measured to provide a rigorous test case for theoretical models and eliminate uncertainties about wind tunnel wall effects. Tables show pressure coefficients with m = 0.62, 0.80, 0.82, and 0.84 for the upper and lower surfaces and the far field. Lift, pitching moments, and drag data are summarized in graphs. A.R.H.

N85-10022# Lockheed-Georgia Co., Marietta.
TRANSONIC WING AND FAR FIELD TEST DATA ON A MODERATE ASPECT RATIO WING FOR THREE DIMENSIONAL COMPUTATIONAL METHOD EVALUATION
K. P. BURDGES and B. L. HINSON *In* AGARD Exptl. Data Base for Computers Program Assessment 25 p (SEE N85-10020 01-02) Jul. 1984 refs
Avail: NTIS HC A07/MF A01

Force and pressure data were provided on a state-of-the-art supercritical moderate aspect ratio transport wing for evaluation of three-dimensional flow computation methods. The wing, though simply defined, is representative of high performance supercritical technology. The pressure distributions on this wing exhibit recompression of the local supersonic flow over the front part of the wing, terminating the supersonic region with a moderate strength, swept shock wave. The strength of the shock wave increases with free stream Mach number until a small region of trailing edge separation occurs in the 70% semispan pressure data for M = .84. The latter condition is an interesting test case for viscous modeling techniques. The accuracy of current computational methods causes concern over the influence of small differences between far field boundary conditions of wind tunnel experiments and the free air boundary condition applied at the edge of the mathematical computational zone. In an effort to improve the rigor of the code evaluation, a far field boundary condition was measured in the experiment to be included as a boundary condition when evaluating computational methods.
Author

N85-10023# Aircraft Research Association Ltd., Bedford (England).
PRESSURE DISTRIBUTIONS MEASURED ON RESEARCH WING M100 MOUNTED ON AN AXISYMMETRIC BODY
M. P. CARR and K. C. PALLISTER *In* AGARD Exptl. Data Base for Computer Program Assessment 36 p (SEE N85-10020 01-02) Jul. 1984 refs
Avail: NTIS HC A07/MF A01

Measurements of surface pressure distributions on a research wing in a transonic wind tunnel are presented. Tabulated data are given for an incidence range at constant Mach number and a Mach number range at approximately constant lift coefficient. Overall force measurements for the same test conditions as the presented pressures are also given. M.A.C.

N85-10024# Aircraft Research Association Ltd., Bedford (England).
PRESSURE DISTRIBUTIONS MEASURED ON RESEARCH WING M86 MOUNTED ON AN AXISYMMETRIC BODY
In AGARD Exptl. Data Base for Computers Program Assessment 25 p (SEE N85-10020 01-02) Jul. 1984 refs
Avail: NTIS HC A07/MF A01

Surface pressure distributions are measured on a research wind in a transonic wind tunnel. Tabulated data are given for seven conditions covering three Mach numbers. Force measurements for the same test conditions as the presented pressures are also given. M.A.C.

N85-10025# Aeronautical Research Inst. of Sweden, Bromma.
PRESSURE DISTRIBUTION ON A SWEPT WING AIRCRAFT IN FLIGHT
A. BERTELRUD *In* AGARD Exptl. Data Base for Computers Program Assessment 31 p (SEE N85-10020 01-02) Jul. 1984 refs
Avail: NTIS HC A07/MF A01

A comprehensive data base is developed for the flow on a swept wing aircraft under flight conditions. Four cases are presented. The data concerns pressure distributions, some skin friction information and very limited boundary layer results. The full data base contains several other types of data (including turbulence measurements), measurements taken under instationary conditions as well as particular investigations concerning drag reduction, junction flow, transition etc. The data structure obtained during a flight test differs from tunnel results in several respects. Ample and redundant data with elaborate checking of data validity and repeatability are required. Real life conditions, i.e., no wind tunnel walls, atmospheric turbulence (intensity and scale) vary with each flight and each altitude. For the present tests the following are observed: (1) natural transition, and (2) all data obtained are for trimmed conditions; i.e., the stabilizer/elevator has slightly different setting for each flight condition d-5. M.A.C.

N85-26666# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
LOW REYNOLDS NUMBER VEHICLES
T. J. MUELLER (Notre Dame Univ.) and E. RESHOTKO, ed. (Case Western Reserve Univ.) Feb. 1985 77 p refs
(AGARD-AG-288; ISBN-92-835-1486-6; AD-A153233) Avail: NTIS HC A05/MF A01

Recent interest in the subject of low Reynolds number configuration has entered on the design and evaluation of efficient airfoil sections at chord Reynolds numbers from about 100,000 to 1m. These configurations include remotely-piloted vehicles

operating at high altitudes, sailplanes, ultra-light man-carrying/man-powered aircraft, wind turbines and propellers. Serious problems still exist with respect to boundary layer separations and transition below R(c) = 500,000. Current design and analysis methods need improved criteria for laminar separation. Improved mathematical models for these complex phenomena require more experimental studies. For various reasons definitive experiments are difficult. The results of many experimental studies are presented to illustrate the type of difficulties encountered. Recommendations for future research are given. Author

N85-31028# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
COMPENDUM OF UNSTEADY AERODYNAMIC MEASUREMENTS, ADDENDUM 1
Loughton, England May 1985 127 p refs Supplement to AGARD-R-702; see N83-14065
(AGARD-R-702-ADD-1; ISBN-92-835-1495-5; AD-A157678)
Avail: NTIS HC A07/MF A01

Data sets of wind tunnel measurements made on aeroelastic configurations are given. Data are given on the ZKP wing with an oscillating aileron and on the LANN wing pitching oscillations. For individual titles see N85-31029 through N85-31030.

N85-31029# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany). Transport und Verkehrsfluegzeuge.
DATA SET 8: ZKP WING, OSCILLATING AILERON
K. DAU, S. VOGEL, and H. ZIMMERMANN *In* AGARD Compendium of Unsteady Aerodynamic Meas., Add. 1 44 p (SEE N85-31028 20-02) May 1985 refs
Avail: NTIS HC A07/MF A01

A data set containing pressure distributions measured on the ZKP wing for an oscillating aileron in the ONERA transonic S1 wind tunnel at Modane, France, in late 1982 is given. The purpose of the tests was to obtain steady and unsteady pressures due to fast-moving control surfaces in transonic flow, likely to be encountered in the operation of active control systems for transport aircraft. R.J.F.

N85-31030# National Aerospace Lab., Amsterdam (Netherlands). Aeroelasticity Dept.
DATA SET 9: LANN WING. PITCHING OSCILLATION
R. J. ZWAAN *In* AGARD Compendium of Unsteady Aerodynamic Meas., Add. 1 76 p (SEE N85-31028 20-02) May 1985 refs
Avail: NTIS HC A07/MF A01

This data set relates to a semi-span model of a transport-type wing with a supercritical aerofoil from root to tip. One of the objectives of this program was to create an experimental data base for steady and unsteady transonic computer code evaluation. The wing geometry was designed by Lockheed-Georgia, where the wing became known as wing A. A smaller scale model was already tested in steady flow. The mean test conditions are shown. In view of the intended correlations of experimental and calculated data, the greater part of the test runs was carried out with attached flow. Examples of the mean steady and the unsteady pressure distributions are given as well as spanwise load distributions. As all test runs were made at more or less different conditions, a modified set of CT cases is proposed in this data set. The modifications, however, leave the kind of parameter variations as foreseen in the original set of Ref 9.4 practically unchanged. From the correlation of experimental and calculated data, it appears that the correlation can be made most appropriately for the pressure distributions. The correlation of sectional coefficients is hampered by less accurate experimental values caused by a number of failing pressure tubes in regions of strong pressure gradients. R.J.F.

N86-15256# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel Working Group 07.
TEST CASES FOR INVISCID FLOW FIELD METHODS
Loughton, England May 1985 336 p refs
(AGARD-AR-211; ISBN-92-835-1497-1; AD-A162128) Avail: NTIS HC A15/MF A01

The escalating costs and the continuing limitations of wind tunnel testing together with the growing imperative to achieve the optimal design have rapidly increased the importance of computational fluid dynamics in the design of military aircraft. At relevant Reynolds numbers, inviscid flow methods continue to play an essential role in this design process. In recognition of this, the AGARD Fluid Dynamics panel established Working Group 07 to specify relevant reference test cases to serve as validation bases for those developing new methods with improved accuracy and cost-effectiveness. These cases further serve as check cases for those learning to use existing production codes. The recommendations of the Working Group are presented. For individual titles see N86-15257 through N86-15265.

N86-15257# Boeing Military Airplane Development, Seattle, Wash.
OBJECTIVES AND SCOPE OF THE WORKING GROUP 07
H. YOSHIHARA *In* AGARD Test Cases for Inviscid Flow Field Methods 3 p (SEE N86-15256 06-02) May 1985
Avail: NTIS HC A15/MF A01

The objectives and scope of the working group on test cases for inviscid flow field methods are defined. The types of solutions sort and their procedures are given. The membership of the group is given, both panel and nonpanel members. Also given is the meetings procedures. E.R.

N86-15258# Trondheim Univ. (Norway).
FORMULATION OF THE EULER BOUNDARY VALUE PROBLEM
H. NORSTRUD *In* AGARD Test Cases for Inviscid Flow Field Methods 56 p (SEE N86-15256 06-02) May 1985 refs
Avail: NTIS HC A15/MF A01

Most of the obtained solutions to fluid flow problems are based on irrotational motion and, hence, can be grouped together as potential flow solutions. In many practical cases such potential approximations yields satisfactory results as compared to a rotational flow solution. The Mach number contours around an airfoil at supersonic speed is shown. For flows with strong entropy variation in the flow field the situation, however, is changed. This is especially true for embedded shocks. The Mach number contour around a cylinder for M sub infinity less than 1, and the corresponding streamlines are illustrated. The major reason behind the discrepancy between a rotational and irrotational solution lies in the fact that the potential flow solution does not satisfy the Rankine-Hugoniot jump condition across a shock. As it can be seen, an irrotational solution like the full potential solution or the transonic small perturbation solution (TSP), will yield a larger Mach number jump across the shock as compared to the equivalent rotational or Euler solution. Furthermore, the shock location will differ between a rotational and irrotational solution. It must be stated that for flows with complex shock patterns and for flows with inherent vorticity the method of solution adopted must be based on the Euler equations. The flow field around a modern combat aircraft is well suited to serve as an example to this. The calculated pressure distribution around an aircraft forebody at M sub infinity is shown. Author

N86-15259# National Aerospace Lab., Amsterdam (Netherlands).
NUMERICAL METHODS
J. W. BOERSTOEL *In* AGARD Test Cases for Inviscid Flow Field Methods 7 p (SEE N86-15256 06-02) May 1985 refs
Avail: NTIS HC A15/MF A01

A survey of numerical techniques used in computational simulations of Euler flows is presented. The number of techniques reported in literature is so large that a detailed description of all of them is out of scope. Therefore, this survey is concentrated to sketching only the more important numerical topics, and pointing out differences in possible approaches. The general approach to the numerical solution of the initial boundary value problem of the Euler equations consists of two major steps. In the first step the flow equations, the boundary conditions, and the initial conditions of the continuum-model formulation of the problem are replaced by a large system of algebraic equations (discretization). In the second step the resulting system of algebraic equations is solved (solution). The discretization process reduces to splitting the (t,x,y,z)-space into small elementary volumes called cells (grid generation), and writing down, for each cell, algebraic approximations of the conservation equations, of the initial conditions, and of boundary conditions. The solution of the algebraic equation system is discussed, and the topic of well-posedness of the numerical problem is briefly discussed. Author

N86-15260# Politecnico di Milano (Italy)
EXACT SOLUTIONS TO TRANSONIC AND SUPERSONIC FLOWS
G. CHIOCCHIA *In* AGARD Test Cases for Inviscid Flow Field Methods 14 p (SEE N86-15256 06-02) May 1985 refs
Avail: NTIS HC A15/MF A01

A survey of the most important analytical solutions for transonic and supersonic flows is presented. Particular attention is paid to the transonic cases, where the presence of embedded supersonic regions of a priori unknown extension causes considerable difficulties to the numerical computations and raises the need for reference test cases. Exact analytical transonic solutions are rare and not always adequate for checking practical cases. For this reason some approximate analytical solutions are also presented; in this case, however, the approximations must be well known in advance and their numerical effects must be limited. As a general standard of judgement, solutions in which the approximation consists in the replacement of partial differential equations by finite difference equations are excluded. Closed form or series solutions for two or three cases of approximate equations whose validity fields are well established are accepted. Author

N86-15261# National Aeronautical Establishment, Ottawa (Ontario).
REFERENCE TEST CASES AND CONTRIBUTORS
D. J. JONES *In* AGARD Test Cases for Inviscid Flow Field Methods 24 p (SEE N86-15256 06-02) May 1985 refs
Avail: NTIS HC A15/MF A01

The reference test cases are divided into two sections. They are the two dimensional airfoils and cascades and three dimensional cases. Specifications, reference solutions, and contributors are given for the two dimensional cases. Specifications are divided into planform, profiles, root sections, and tip sections for the three dimensional cases. E.R.

N86-15262# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
NUMERICAL SOLUTIONS OF TWO-DIMENSIONAL REFERENCE TEST CASES
H. VIVIAND *In* AGARD Test Cases for Inviscid Flow Field Methods 68 p (SEE N86-15256 06-02) May 1985 refs
Avail: NTIS HC A15/MF A01

Selected numerical solutions of the two dimensional reference test cases are presented and the quality if not the absolute accuracy of these solutions are assessed. The numerical methods used to solve the Euler equations are not taken into consideration in the present discussion, and the numerical solutions available for a given test case are evaluated essentially through cross-comparisons of these solutions and by taking into account some known features of the exact (unknown) solution. The present evaluation has shown the importance of the outer boundary position in relation with the boundary conditions and the numerical treatment applied at this boundary. It seems that the minimum distance at which this boundary should be located in order to achieve a given accuracy can vary to a very large extent depending on the boundary treatment. This is an important question which requires detailed studies of all the factors involved. Whereas the trailing edge problem and the Zierep singularity problem change in nature when viscous effects are taken into account, the problem of the far field treatment (outside the viscous wake) remains exactly the same at high Reynolds numbers. Author

N86-15263# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
NUMERICAL SOLUTIONS FOR THREE-DIMENSIONAL CASES: SWEPT WINGS
P. SACHER *In* AGARD Test Cases for Inviscid Flow Field Methods 110 p (SEE N86-15256 06-02) May 1985 refs
Avail: NTIS HC A15/MF A01

The simplest swept wing geometry of practical interest was Test Case 11 and 12, ONERA M6, with constant section, moderate Aspect Ratio = 3.8 and only 30 deg leading edge sweep. But even this simple planform produced in TC11 with 3.06 deg angle of attack the rolling up of a Tip-Vortex which may contribute to induced drag. The numerical analysis of the nonlinear wake leaving the trailing edge of a lifting wing including the rolling up at the wing tips is one of the most promising aspects of the potential of solving the Euler equations at considerably higher cost in place of Full Potential equation. Consequently the complexity of a realistic transport type planform with twist, camber, variations of section profiles and breakpoints in leading and/or trailing edge sweep can be represented by Test Case 16, NASA AMES SWEPT WING. More or less, all additional problems in computation of the flow field are due to mesh-grid generation and the increase of the number of grid points which are necessary to simulate the flow sufficiently accurate. Only one contribution was obtained for this Test Case. Author

N86-15264# Royal Aircraft Establishment, Farnborough (England).
NUMERICAL SOLUTIONS FOR THREE-DIMENSIONAL CASES: DELTA WINGS
J. H. B. SMITH *In* AGARD Test Cases for Inviscid Flow Field Methods 94 p (SEE N86-15256 06-02) May 1985 refs
Avail: NTIS HC A15/MF A01

Wings of delta planform present the real problems of estimating wave drag and representing vortex flows in their simplest form. Any method of calculation aiming to contribute to these problems should be capable of performing well on such simple shapes. On the other hand, there is no evidence that reliable solutions for such simple shapes already exist. It was decided to seek solutions for wings of delta planform for conditions which are relevant to wave-drag estimation and vortex-flow prediction. For a shape which is reasonably slender, at a Mach number sufficiently greater than unity, the flow is supersonic everywhere, so that there is no upstream influence, and the flow can, in principle, be calculated by a space marching method. The final considerations affecting the choice of case are that the shape should be simple, and that experimental measurements should exist. The first makes it easy to ensure that the description of the shape is complete and unambiguous, and makes it possible for all potential computers to represent the shape in their programs. The second, while not strictly necessary and perhaps even irrelevant to the assessment of the accuracy of inviscid calculations, does provide an assurance that solutions judged to be mathematically accurate are not in serious conflict with physical reality. Author

N86-15265# Boeing Military Airplane Development, Seattle, Wash.
CONCLUDING REMARKS Abstract Only
H. YOSHARA *In* AGARD Test Cases for Inviscid Flow Field Methods 1 p (SEE N86-15256 06-02) May 1985
Avail: NTIS HC A15/MF A01

It may be recalled that the primary purpose of the WG07 was the generation of relevant Euler solutions, both planar and 3D, to serve as Reference Test Cases which developers of Euler methods could use to assess their codes. Since such Reference Test Cases in most cases must themselves be generated numerically, there was initial concern as to the meaningfulness of this objective. The quality of the results produced by the many dedicated contributors has largely dispelled this concern. Except for a few instances, the numerical algorithms used by the contributors within the flow field and at the boundaries were sound. The relative accuracies of the various contributions were due in large part to the density and extent of the mesh used, though the quality of the artificial viscosity used was also an important factor. The planar airfoil solutions recommended herein should serve as reliable Reference Test Cases. The 3D cases understandably are relatively less reliable and must at present be considered as interim Test Cases to serve as approximate guides. It is hoped that the latter cases can be upgraded by future improved calculations. To monitor such activities as well as possibly to extent the scope to viscous solutions, the AGARD Fluid Dynamics Panel has established a Computational Fluid Dynamics Subcommittee. Author

N86-15266# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AIRCRAFT DRAG PREDICTION AND REDUCTION
Loughton, England Jul. 1985 269 p refs Special course held in Rhode-Saint-Genese, Belgium, 20-23 May 1985 and in Hampton, Va., 5-8 Aug. 1985; sponsored by von Karman Inst. and AGARD
(AGARD-R-723; ISBN-92-835-1507-2; AD-A160718) Avail: NTIS HC A12/MF A01

Numerous topics relating to aircraft drag prediction and control are discussed. Laminar flow control with suction; parasitic and

interference drag prediction and reduction; and vortex drag reduction are among the topics discussed. For individual titles see N86-15267 through N86-15275.

N86-15267# Lockheed-Georgia Co., Marietta. Advanced Flight Sciences.
AIRCRAFT DRAG REDUCTION TECHNOLOGY: A SUMMARY
A. S. THOMAS *In* AGARD Aircraft Drag Prediction and Reduction 20 p (SEE N86-15266 06-02) Jul. 1985 refs Previously announced as N85-16782
Avail: NTIS HC A12/MF A01

The current techniques of aircraft viscous drag reduction and some of the more recent developments that have taken place in this technology are reviewed. The various sources and relative contributions of aircraft drag are described including skin friction drag, pressure drag, interference drag and lift induced drag. The physical processes that lead to these drag contributions are emphasized and methods of reducing the impact of these drag sources are discussed. It is shown how innovative and optimized aircraft configurations can lead to drag benefits. E.A.K. (IAA)

N86-15268# Arizona State Univ., Tempe. Mechanical and Aerospace Engineering.
BOUNDARY-LAYER TRANSITION: T-S WAVES AND CROSSFLOW MECHANISMS
W. S. SARIC *In* AGARD Aircraft Drag Prediction and Reduction 18 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01

The basic instability mechanisms are discussed from an elementary standpoint considering only boundary layers in external flows. The current state-of-the-art of boundary-layer transition prediction is reviewed and, by using recent results, it is shown that a number of unique transition mechanisms exist and each can play a different role in the breakdown to turbulence. The control of the stability and transition characteristics of a particular flow field requires thoroughly understanding the details of these breakdown mechanisms. Author

N86-15269# *Arizona State Univ., Tempe. Mechanical and* Aerospace Engineering.
LAMINAR FLOW CONTROL WITH SUCTION: THEORY AND EXPERIMENT
W. S. SARIC *In* AGARD Aircraft Drag Prediction and Reduction 11 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01

The concept of boundary-layer stabilization with weak wall suction is introduced at a basic level and the means for calculating the effects of suction are described. The historical development of this technique is reviewed and the state-of-the-art of theory and experiment is covered. Some problems associated with the implementation of suction into aircraft boundary layers are discussed. Author

N86-15270*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DESIGN CONSIDERATIONS FOR APPLICATION OF LAMINAR FLOW CONTROL SYSTEMS TO TRANSPORT AIRCRAFT
A. L. BRASLOW and M. C. FISCHER *In* AGARD Aircraft Drag Prediction and Reduction 27 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01 CSCL 01A

The current status of the laminar-flow control LFC technology is summarized. Factors that have previously inhibited the application of LFC are first reviewed. Involved are the effects of atmospheric ice crystals, surface irregularities, acoustical environment, and off-design operating conditions. Aircraft design trends that are different from turbulent aircraft are discussed as are various design requirements unique to the LFC systems. Current design approaches for the principal LFC systems are reviewed. These include the system for protection of the leading-edge region from surface contamination and icing and the system for removal of a portion of the boundary-layer air. The latter includes consideration of both multiple spanwise suction slots and distributed perforations and required differences between the wing-box and leading-edge box regions. Author

N86-15271*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TURBULENT DRAG REDUCTION FOR EXTERNAL FLOWS
D. M. BUSHNELL *In* AGARD Aircraft Drag Prediction and Reduction 26 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01

A summary of turbulent drag reduction approaches applicable to external flows is given. Because relatively recent and exhaustive reviews exist for laminar flow control and polymer (hydrodynamic) drag reduction, the focus here is upon the emerging areas of nonplanar geometry and large-eddy alteration. Turbulent control techniques for air generally result in modest (but technologically significant) drag reductions (order of 20 percent or less), whereas hydrodynamic approaches can yield drag reductions the order of 70 percent. Suggestions are included for alternative concepts and optimization of existing approaches. Author

N86-15272# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PARASITIC AND INTERFERENCE DRAG PREDICTION AND REDUCTION
P. POISSON-QUINTON *In* AGARD Aircraft Drag Prediction and Reduction 27 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01

Parasitic drag related to excrescences, leaks, etc., and to local flow separations, and interference drag related to wing/fuselage, propulsive nacelle/wing or fuselage, and external stores/wing or fuselage, etc., are discussed. Although a precise prediction of such drag terms is still difficult to obtain in wind-tunnel testing, a large number of typical trends are available to the designer to avoid too large penalties on transport or combat aircraft at the preliminary design stage; several examples are given to illustrate these trends, together with some optimization methods. Author

N86-15273# Lockheed-Georgia Co., Marietta.
RECENT DEVELOPMENTS IN THREE-DIMENSIONAL WAKE ANALYSIS
J. E. HACKETT and A. SUGAVANAM *In* AGARD Aircraft Drag Prediction and Reduction 19 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01

Significant advances in the determination of drag and its components (viscous, vortex, source, blockage, etc.) have been made in recent years. These were triggered by the reduction of the vortex drag integral to a wake integral by Maskell in the early 1970's. In 1979, Wu Hackett, and Lilley broadened the basis for Maskell's results and, in 1984, Hackett and Sugavanam devised methods which make it suitable for use in the near-wake of wind tunnel models. These advances are reviewed. A consistent derivation, starting from a simple form of the momentum equations, which include the best and least restrictive assumptions and procedures is provided. A practical example is discussed. Author

N86-15274# Royal Aircraft Establishment, Farnborough (England).
PREDICTION OF THE DRAG OF WINGS AT SUBSONIC SPEEDS BY VISCOUS/INVISCID INTERACTION TECHNIQUES
R. C. LOCK *In* AGARD Aircraft Drag Prediction and Reduction 71 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01

Alternative ways of calculating the drag of an aerofoil or wing are discussed, and it is concluded that, at the present time, the far field approach is both more accurate and more informative. In this approach, the total drag is split into three components, wave (C sub D sub W), vortex (C sub D sub i) and viscous (C sub D sub V), and it is shown how simple methods for estimating these components can be derived. A brief account is given of the modern technique of viscous-inviscid interaction, concentrating on methods in which an accurate inviscid code is coupled with an integral method for calculating the viscous shear layers (boundary layer and wake). Recent advances are described which should improve the overall accuracy and allow more difficult cases, where boundary layer separation is present, to be treated successfully. Some methods of this type for aerofoils in two dimensions are summarized, and their accuracy assessed by comparison with experiment, including examples where flow separation takes place. Finally, an experiment on a particular wing-body combination, typical of a modern transport aircraft design, is chosen to show how an

analysis of the drag can be performed by using the experimental pressure distribution as input to theoretical methods for calculating the separate wave, vortex and viscous components of drag.
Author

N86-15275# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Institut fuer Experimentelle Stroemungsmechnik.
TRANSONIC DRAG RISE AND DRAG REDUCTION BY ACTIVE/PASSIVE BOUNDARY LAYER CONTROL
E. STANEWSKY and F. KROGMANN *In* AGARD Aircraft Drag Prediction and Reduction 41 p (SEE N86-15266 06-02) Jul. 1985 refs
Avail: NTIS HC A12/MF A01

Accurate drag prediction and efficient drag reduction are, particularly in the transonic speed range, paramount to the future of economical aircraft design and operation. The prediction of drag based on high-speed wind tunnel results are discussed with emphasis placed on problems associated with testing at transonic speeds and the transfer of low Reynolds number wind tunnel results to full-scale aircraft conditions. A more general consideration of the drag development associated with compressibility and viscosity and the viscous-inviscid interaction of the flow on an aerodynamic configuration is given. Drag reduction methods which are mainly based on active and passive boundary layer control by means of slots and perforated strips utilized to either draw material from and/or add material to the boundary layer are discussed. It may be concluded that present transonic drag predicton methods need further improvement, especially at off-design conditions; and that some of the approaches to boundary layer control considered may be quite efficient in increasing aircraft aerodynamic performance.
Author

N86-19298# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SYMPOSIUM ON AERODYNAMICS AND ACOUSTICS OF PROPELLERS
P. POISSON-QUINTON (ONERA, Chatillon, France) Jul. 1985 43 p refs
(AGARD-AR-213; ISBN-92-835-1508-0; AD-A161886) Avail: NTIS HC A03/MF A01

The Advisory Report contains a review and evaluation of the material presented at the AGARD Fluid Dynamics Panel Symposium on Aerodynamics and Acoustics of Propellers held in Toronto, Canada, 1 to 4 October 1984. Also included are related information from other sources and an excellent discussion of the state of art of modern propeller design and performance is presented. This Advisory Report was produced at the request of the Fluid Dynamics Panel of AGARD.
Author

N86-19299# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TRANSONIC UNSTEADY AERODYNAMICS AND ITS AEROELASTIC APPLICATIONS
Jun. 1985 51 p Proceedings of the 59th Meeting of the Structures and Materials Panel, Toulouse, France, 2-7 Sep. 1984
(AGARD-CP-374-ADD-1; ISBN-92-835-1501-3; AD-A161953)
Avail: NTIS HC A04/MF A01

The 59th meeting of the AGARD Structures and Materials Panel (SMP) was held on 3 to 7 September 1984 in Toulouse, France. It included a specialists' conference to discuss the latest methods of predicting transonic unsteady airloads for oscillating surfaces and flutter. Also considered were aeroelastic applications, many of which were made to standard configurations selected for the SMP cooperative program. The 16 papers and the round table discussion are summarized in some detail for coordination with AGARD's Fluid Dynamics Panel and Fluid Mechanics Panel.
Author

N86-19300# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TWO-DIMENSIONAL TURBULENT SEPARATED FLOW
R. L. SIMPSON (Virginia Polytechnic Inst. and State Univ., Blacksburg) and A. D. YOUNG, ed. Jun. 1985 107 p refs
(AGARD-AG-287-VOL-1; AD-A160659) Avail: NTIS HC A02/MF A01

Many different flow cases with nominally two-dimensional turbulent separated flow regimes are discussed. Because of intermittent flow reversal and backflow near the wall, directionally sensitive measurement techniques such as hot-wire, pulsed-wire and laser anemometry are discussed. Experimentally-observed structure of detached flows on streamlined surfaces and around sharp-edged corners is discussed for steady and unsteady incompressible and compressible cases where large-scale structures dominate the flow behavior. A number of differential and integral calculation methods are discussed. Traditional attached flow turbulence models do not describe attached flows well and methods which include experimentally-observed features of detached flow parameters seem to perform best.
Author

N86-20376# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
IMPROVEMENT OF AERODYNAMIC PERFORMANCE THROUGH BOUNDARY LAYER CONTROL AND HIGH LIFT SYSTEMS
B. OSKAM (National Aerospace Lab., Amsterdam) and B. VANDENBERG (National Aerospace Lab., Amsterdam) May 1985 11 p
(AGARD-AR-210; ISBN-92-835-1498-X; AD-A160721) Avail: NTIS HC A02/MF A01

This report presents an overall survey and evaluation of the AGARD Symposium on Improvement of Aerodynamic Performance through Boundary Layer Control and High Lift Systems held in Brussel, Belgium, 21 to 23 May 1984. Emphasis of the presentations and discussion on lift augmentation was on mechanical highlift systems, while laminar flow control and boundary layer manipulation shared the session on drag reduction. Significant interest was also shown in control of shock wave boundary layer interactions to mitigate their adverse effects.
Author

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

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

N83-22177# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AIR TRAFFIC CONTROL IN FACE OF USERS' DEMAND AND ECONOMY CONSTRAINTS
Feb. 1983 111 p refs Conf. held in Lisbon, 15 Oct. 1982 *In* ENGLISH and FRENCH
(AD-A127146; ISBN-92-835-0326; AGARD-CP-340) Avail: NTIS HC A06/MF A01

The role of air traffic control in reduction of operating costs for aircraft is addressed, including fuel conservation, economic constraints, civilian military coordination aspects, management, and planning concepts. For individual titles, see N83-22178 through N83-22187.

N83-22178# Civil Aviation Authority, London (England).
A UK NATS VIEW OF THE AIR TRAFFIC MANAGEMENT REQUIREMENTS IN THE NEXT DECADE
P. H. HEMMING *In* AGARD Air Traffic Control in Face of Users' demand and Econ. Constraints 5 p (SEE N83-22177 12-04) Feb. 1983
Avail: NTIS HC A06/MF A01

The main categories of user demand in United Kingdom airspace at present and the Air Traffic Management infrastructure currently provided are discussed. Aspects of NATS plans for improvement and modernization of air traffic control and the relationship of these plans to improved economy and fuel conservation are outlined. The main focus of these plans is related to development

of ATC capability in the London and South East England area, therefore the redevelopment of the London Air Traffic Control Centre is described in the context of the theme of the Special Session. The relationship applicable to the United Kingdom between financial policy, implementation plans and the cost to system user is discussed in view of the constraints it places on the ability of the ATC system to meet commercial demand for the most economic service. Author

N83-22179# Civil Aviation Authority, London (England).
FUEL CONSERVATION AND ECONOMY CONSTRAINTS
D. BARBER and J. C. MORRALL *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 8 p (SEE N83-22177 12-04) Feb. 1983
Avail: NTIS HC A06/MF A01

Fuel conservation in civil aviation may be achieved by increasing the efficiency of the aircraft themselves, by operating the aircraft more efficiently, and by providing them with a more efficient air traffic environment. Three aspects are discussed briefly, and possible improvements in the air traffic management environment are examined in more detail. Finally, attention is drawn to the Research and Development program needed to achieve fuel conservation by improved air traffic management. Author

N83-22180# KLM Royal Dutch Airlines, Amsterdam (Netherlands). Aircraft Performance Dept.
THE AIRLINE FACING THE PRESENT CRISIS
J. H. WAGENMAKERS *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 7 p (SEE N83-22177 12-04) Feb. 1983
Avail: NTIS HC A06/MF A01

The impact of the drastic fuel price increase on airline operations is briefly discussed. Some measures that are being taken to contain the economic effect are reviewed. In particular air traffic control (ATC) criteria and military constraints are highlighted, which are known to have a direct influence on fuel burn. This is illustrated with examples and furthermore a specific comment is made in relation to the Portuguese ATC environment. Author

N83-22181# Allied Air Forces Central Europe, Ramstein AFB (West Germany).
MILITARY REQUIREMENTS [LES BESOINS MILITAIRES]
J. DEDONCKER *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 7 p (SEE N83-22177 12-04) Feb. 1983 In FRENCH
Avail: NTIS HC A06/MF A01

In view of the constraints affecting the military user, it is beneficial to question how much traffic control can contribute to solving actual problems which border largely on the matter of fuel costs. An outline of progress related to approval of the defense budget in member countries of the Atlantic Alliance illustrates how difficult it is in western democracies to obtain, in this crisis period, the credits needed to carry out the collective defense programs which were elaborated by NATO in consultation with member countries of the Alliance and approved by governmental authorities. Concrete results, obtained in recent years through the coordination of civilian and military partners responsible for space management provide a glimpse of models of action capable of contributing to a form of economy of costly fuel. These gains seem ridiculous when the question of means needed to realize a deliberately agreed upon policy is raised in all its seriousness. A.R.H.

N83-22182# Aeroportos e Navegacao Aerea E.P., Lisbon (Portugal).
AIR TRAFFIC SERVICES IN PORTUGAL
J. F. CARVALHO *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 3 p (SEE N83-22177 12-04) Feb. 1983
Avail: NTIS HC A06/MF A01

The Portuguese area of responsibility for the provision of Air Traffic Services; and the organization of services and authorities are described. An overview is given of development projects, for the Lisboa and Santa Maria FIR's, their objectives basic concepts, and implementation dates. Author

N83-22183# Portuguese Air Force, Alfragide.
AIR TRAFFIC SERVICES IN PORTUGAL: CIVIL-MILITARY COORDINATION ASPECTS
L. G. ROCHA *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 7 p (SEE N83-22177 12-04) Feb. 1983
Avail: NTIS HC A06/MF A01

The provision in Portugal of Air Traffic Services in civil and military aircraft and concurrent procedures is discussed. This assessment is based on a strictly military point of view having in account either its requirements or national and international involvements. All over the world the users of the airspace as well of the Air Traffic Control Systems are basically the General Aviation, Air Carriers with their trunk, regional and short haul categories and the military aviation. The effect that military activity has on ATC Systems is extremely inconstant depending on either air space structure or Air Traffic Services organization at each country. Author

N83-22184# Federal Aviation Administration, Washington, D.C.
OVERVIEW OF UNITED STATES PROGRAM FOR MODERNIZING AIR TRAFFIC CONTROL AND AIRWAY FACILITIES
R. W. WEDAN and P. R. DROUILHET (Lincoln Lab., Lexington, Mass.) *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 14 p (SEE N83-22177 12-04) Feb. 1983
Avail: NTIS HC A06/MF A01

The Federal Aviation Administration (FAA) recently completed a comprehensive plan for modernizing the United States (U.S.) Air Traffic Control and Airways Facilities over the period from now to the year 2000. An overview of this plan is provided and description of some of the recent technological developments that provide the foundation for significant improvements to the system are discussed. These improvements include a new discrete address surveillance and data communications system, an airborne collision avoidance system that operates independently from the ground based air traffic control system, the replacement of the air traffic control computer facilities with modern equipment, the inclusion of a higher level of automation to aid the controllers and to provide greater freedom of severe precision landing aids using microwave equipment, and enhanced dissemination of severe weather information to controllers and pilots. Other innovations are also planned in order to meet an increasing demand for air traffic control services but without incurring a proportionate increase in the cost of providing these services. Author

N83-22185# Ratcliffe (S.), Malvern (England).
MANAGEMENT AND PLANNING CONCEPTS
S. RATCLIFFE *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 6 p (SEE N83-22177 12-04) Feb. 1983
Avail: NTIS HC A06/MF A01

The processes used for management and control of air traffic are outlined. Some congestion in airspace or at airports is inevitable, the further ahead this congestion is foreseen, the more economically it can be resolved. A limit is set by the accuracy with which the future can be predicted. Existing ATC systems necessarily use human controllers, who often significantly outnumber the aircraft under their control. It is not easy to see how this situation might be improved. Control tasks must be divided up between numerous controllers who, at busy times, cannot discuss each others problems in any detail. Controllers therefore solve only subsets of the total problem, and their solutions are significantly less efficient than theory indicates is possible. The extent to which 'automation' might make possible cheaper or more efficient ATC is safety considerations and difficult 'human factors' problems. Author

N83-22186# Eurocontrol Agency, Brussels (Belgium).
DYNAMIC CONTROL OF INBOUND FLIGHTS FOR MINIMUM COST OPERATION
A. BENOIT and S. SWIERSTRA *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 32 p (SEE N83-22177 12-04) Feb. 1983 refs
Avail: NTIS HC A06/MF A01

The Zone of Convergence (ZOC) concept is proposed as an essential short term Air Traffic Control contribution to the economics of air transport. It is established that, when considering

traffic inbound to a medium to high density terminal, this approach could reduce fuel consumption by some ten to thirty percent, this value being referred to the total fuel burn in an extended area including and surrounding main terminal and extending over some 100, ideally 300, nautical miles. The selection of profiles tailored to the operators' criteria, whether constrained by ATC or not, is discussed in some detail. The compatibility of the techniques proposed with online operations is found to be satisfactory. This conclusion results from test conducted using ATC simulation facilities, airline flight simulators, and online exercises involving regular scheduled flights. Author

N83-22187# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
INVESTIGATIONS ON FOUR-DIMENSIONAL GUIDANCE IN THE TMA
V. ADAM and W. LECHNER *In* AGARD Air Traffic Control in Face of Users' Demand and Econ. Constraints 11 p (SEE N83-22177 12-04) Feb. 1983 refs
Avail: NTIS HC A06/MF A01

The four dimensional (4D) guidance of aircraft in the terminal area (TMA) allows for precise control of the minimum separation and thus efficient use of the available approach capacity of the respective airport. A concept for the 4D guidance of transport aircraft was developed and a corresponding control mode was integrated in an automatic flight control system for transport aircraft. The 4D mode is based on usual radar vector guidance technique of air traffic control and, therefore, is characterized by a succession of flight sections with constant values for indicated airspeed, heading and descent rate. The time of arrival is controlled by altering the path via a delay fan. The algorithm for the calculation of the commanded 4D flightpath takes into account suitable wind models updated by actual wind data. The 4D mode is described and first flight test results are discussed. Author

N84-25691# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ADVANCES IN STRAPDOWN INERTIAL SYSTEMS
Apr. 1984 225 p refs In ENGLISH and FRENCH Lecture held in Athens, 14-15 May 1984, in Rome, 17-18 May 1984, and in Copenhagen, 21-22 May 1984
(AGARD-LS-133; ISBN-92-835-0351; AD-A143244) Avail: NTIS HC A10/MF A01

Advances in strapdown inertial system technology during the last five years are addressed. Areas include advances in strapdown instruments, computational algorithms and the application to commercial aircraft, remotely. Piloted vehicles, flight controls, instrumentation, and navigation problems in general. For individual titles, see N84-25692 through N84-25699.

N84-25692# Draper (Charles Stark) Lab., Inc., Cambridge, Mass. G&N Advanced Programs Div.
ADVANCES IN STRAPDOWN INERTIAL SYSTEMS: INTRODUCTION AND OVERVIEW
G. T. SCHMIDT *In* AGARD Advan. in Strapdown Inertial Systems 4p (SEE N84-25691 16-04) Apr. 1984 refs
Avail: NTIS HC A10/MF A01

The significant advances in strapdown inertial system technology since the last Lecture Series (No. 95) in 1978 on the subject are presented. Areas that are addressed in the Lecture Series include advances in strapdown instruments and computational algorithms and the applications to commercial aircraft, remotely piloted vehicles, flight controls, instrumentation, and navigation problems in general. Author

N84-25693# Strapdown Associates, Inc., Minnetonka, Minn.
ADVANCES IN STRAPDOWN SENSORS
P. G. SAVAGE *In* AGARD Advan. in Strapdown Inertial Systems 24p (SEE N84-25691 16-04) Apr. 1984 refs
Avail: NTIS HC A10/MF A01

The advanced that have taken place in strapdown sensor technology since 1978 are reviewed. Principal areas addressed in strapdown gyro technology are the state of the art in mainstream floated rate-integrating and tuned-rotor strapdown gyros, performance advances in laser gyros, specical design considerations associated with mechanically dithered laser gyros, the state of the art in magnetic mirror and multioscillator laser gyros, present and projected application areas for laser gyros related to size, performance and cost, the theory of operation and state of the art in fiber optic rate sensor technology, and the fundamental distinctions between the laser gyro and fiber optic rate sensor. Basic areas addressed in strapdown accelerometer technology are performance advances in pendulous accelerometers, and the theory of operation and state of the art in vibrating beam accelerometer technology. Author

N84-25694# Strapdown Associates, Inc., Minnetonka, Minn.
STRAPDOWN SYSTEM ALGORITHMS
P. G. SAVAGE *In* AGARD Advan. in Strapdown Inertial Systems 30p (SEE N84-25691 16-04) Apr. 1984 refs
Avail: NTIS HC A10/MF A01

The attitude determination, acceleration transformation, and attitude/heading output computational operations performed in modern day strapdown inertial navigation systems are addressed. Contemporary algorithms are described for implementing these operations in real time computers. The attitude determination and acceleration transformation algorithm discussions are based on the two speed approach in which high frequency coning and sculling effects are calculated with simplified high speed algorithms, with results fed into lower speed higher order algorithms. This is the approach that is typically used in most modern day strapdown systems. Design equations are included for evaluating the performance of the strapdown computer algorithms as a function of computer execution speed and sensor assembly vibration amplitude/frequency/phase environment. Both direction cosine and quaternion based attitude algorithms are described and compared in light of modern day algorithm accuracy capabilities. Orthogonality and normalization operations are addressed for potential attitude algorithm accuracy enhancement. The section on attitude data output algorithms includes a discussion on roll/yaw Euler angle singularities near high/low pitch angle conditions. Author

N84-25695# Boeing Commercial Airplane Co., Seattle, Wash. Navigation Sensors/Displays Dept.
REQUIREMENTS, APPLICATIONS, AND RESULTS OF STRAPDOWN INERTIAL TECHNOLOGY TO COMMERCIAL AIRPLANES
P. J. FENNER *In* AGARD Advan. in Strapdown Inertial Systems 47p (SEE N84-25691 16-04) Apr. 1984 refs
Avail: NTIS HC A10/MF A01

The basis for selection of strapdown inertial system for short to medium range jet transports is discussed. Inertial data requirements and associated performance requirements are shown for commercial airplanes. Good performance at low cost and high reliability are key requirements of inertial technology application to commercial airplanes which do not have a long range navigation need. The Honeywell laser inertial reference system (IRS) selected by Boeing for the 757/767/737 airplanes is described, along with airplane installation and interface details. Test programs instituted to validate the design and reduce program risk are described. Performance and reliability experience data from Boeing flight tests, and over the first year of airline service, are shown to exceed expectations. Author

N84-25696# Societe de Fabrication d'Instruments de Mesure, Massy (France). Strapdown Systems Engineering Group.
STRAPDOWN INERTIAL SYSTEMS FOR TACTICAL MISSILES USING MASS UNBALANCED TWO-AXIS RATE GYROS
J. L. MICHELIN and P. MASSON (Lab. de Recherches Balistiques et Aerodynamiques.) *In* AGARD Advan. in Strapdown Inertial Systems 41p (SEE N84-25691 16-04) Apr. 1984
Avail: NTIS HC A10/MF A01

In 1979, SFIM began work on strapdown inertial systems using two axis dry tuned gyros (DTG). Since the first feasibility developments SFIM has worked on a large number of applications, the most important being for tactical missiles. All current developments are based on the same concepts - mass unbalanced gyros (M.U.G.) - fully digitized electronics - leading to a systems family - SIL 1 (Systmems Inertiels lies) - in which the cost and volume requirements are the essential points. The basic ideas, some examples of utilization and the test results obtained on some functional models and prototypes by SFIM and essentially by LRBA are presented. Author

N84-25697# Draper (Charles Stark) Lab., Inc., Cambridge, Mass. Inertial Subsystem Div.

MODULAR STRAPDOWN GUIDANCE UNIT WITH EMBEDDED MICROPROCESSORS

J. P. GILMORE *In* AGARD Advan. in Strapdown Inertial Systems 16p (SEE N84-25691 16-04) Apr. 1984 refs Previously announced as A80-18534

(Contract F08635-76-C-0306)

Avail: NTIS HC A10/MF A01

The Low-Cost Inertial Guidance System (LCIGS) is a modular strapdown implementation of attitude (gyro) and velocity (accelerometer) axes which permits the interchangeable use of different manufacturer's instruments without affecting the system's electronic or mechanical interfaces or processing software. This design flexibility is made possible by the use of microprocessors for processing and control. The microprocessors are embedded in each module and five are used: one per accelerometer triad, one each per gyro module, and one in the service module. The processors effect on-line digital torquing control of the gyros, active instrument error model compensation, including modeling for temperature sensitivity effects, temperature control, self-testing, etc. Adaptation of processing and calibration algorithms to accommodate for instrument changes or sensed environmental variations is achieved through the use of an alterable read-only data base that may be updated by the LCIGS support equipment as required at calibrations or upon an instrument replacement. This data base is accessed by the microprocessors and used to compute coefficient corrections for the processing algorithms. The system architecture is presented and the microprocessor software partitioning and functions are described. (Author) IAA

N84-25698# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Flight Dynamics Lab.

APPLICATION OF MULTIFUNCTION STRAPDOWN INERTIAL SYSTEM

D. L. SEBRING (McDonnell Douglas Corp., St. Louis), J. M. PERDZOCK, and J. T. YOUNG *In* AGARD Advan. in Strapdown Inertial Systems 20p (SEE N84-25691 16-04) Apr. 1984 refs

Avail: NTIS HC A10/MF A01

Reliability, redundancy, and survivability are key issues as integrated requirements for flight control, fire control, propulsion control and navigation are developed. These integrated systems require dependable sources of inertial measurement data. Current inertial sensors, however, are expensive to acquire and maintain, dedicated to specific systems, and are not designed to meet integrated reliability, redundancy, and survivability requirements. The Multifunction Strapdown Inertial System concept uses a minimum number of inertial sensors in a survivable configuration to provide inertial data for flight control, navigation, weapon delivery, cockpit displays, and sensor stabilization. Because of advantages in survivability, life cycle cost, maintainability and performance, the Multifunction Flight Control Reference System (MFCRS) program was initiated to verify, through flight test, on a McDonnell Douglas F-15 Eagle the key issues of redundancy management and flight control. A redundancy management system based on parity equations was designed. Author

N84-25699# Litton Technische Werke, Freiburg (West Germany). Systems Design Dept.

INITIAL ALIGNMENT AND AUGMENTATION OF THE ARINC 705 STRAPDOWN AHRS LTR-81

W. HASSENPFLUG and M. KLEINSCHMIDT *In* AGARD Advan. in Strapdown Inertial Systems 14p (SEE N84-25691 16-04) Apr. 1984 refs

Avail: NTIS HC A10/MF A01

After systems hardware description the attitude, heading and vertical loops are discussed. System simulation results are compared with flight test results achieved during A 300 B4 FFC flight certification and BMFT/LITEF sponsored flight tests. Techniques for further system improvements are shortly described. Author

N86-26316# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

GUIDANCE-CONTROL-NAVIGATION AUTOMATION FOR NIGHT ALL-WEATHER TACTICAL OPERATIONS

Loughton, England Oct. 1985 136 p refs In ENGLISH and FRENCH The 40th Guidance and Control Panel Symposium was held at The Hague, Netherlands, 21-24 May 1985

(AGARD-CP-387; ISBN-92-835-0381-3) Avail: NTIS HC A07/MF A01

The components, functions, and systems integration required to support the evolution of alternative guidance/control/navigation systems capable of enabling effective and routine night all-weather operations are discussed. Papers are organized under the following headings: operational requirements, systems concepts and integration issues, man-machine interface, terrain reference systems, and mission applications. For individual titles see N86-26317 through N86-26327.

N86-26317# Marconi Avionics Ltd., Rochester (England).

A COST-EFFECTIVE NIGHT ATTACK SYSTEM FOR GROUND ATTACK AIRCRAFT

J. F. FISHER and G. R. SLEIGHT *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 8 p (SEE N86-26316 17-04) Oct. 1985

Avail: NTIS HC A07/MF A01

Current ground attack fighters have a good day visual flight rule (VFR) capability. However, they are generally ineffective at night. GEC Avionics have developed a simple integrated night vision system which allows a pilot to operate effectively at high speed and low level. The system uses a fixed forward-looking FLIR sensor to display imagery to the pilot on a raster head-up display. This allows him to terrain-follow and acquire targets. He then uses a touch-sensitive head down display to designate targets to his weapon system for subsequent attack. The pilot is also equipped with night vision goggles to permit hard maneuvering, and with a digital map to enable him to navigate flexibly. By designing the entire system as an integrated whole, cockpit workload is minimized. A series of flight trials has clearly proved the concept. The US Marine Corps AV-8B and RAF Harrier GR5 will soon be equipped with just such a system. Author

N86-26318# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).

COCKPIT AUTOMATION REQUIREMENTS DERIVED FROM MISSION FUNCTIONS DATA

B. FAULKNER, R. SEIFERT, and K. D. RICHTER *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 7 p (SEE N86-26316 17-04) Oct. 1985 refs

Avail: NTIS HC A07/MF A01

Program activities directed towards the development of a system engineering concept for the design of the man-machine interface are summarized. The problem was approached from an operational and human task point of view. The first phase included the development of: (1) a mission task list for selected mission and weapon systems; (2) a method for rating the relative importance of each of the tasks related (a) to the frequency of occurrence, (b) to mission effectiveness, and (c) to flight safety; (3) criteria and/or categories for automation at the man-machine interface, against which the individual mission tasks could be rated; and (4) a method for rating the mission tasks in relation to the automation categories derived. Author

N86-26319# Ferranti Defence Systems Ltd., Edinburgh (Scotland).

AUTOMATION AND PILOT INTERACTIONS IN NIGHT OR ALL-WEATHER TACTICAL OPERATIONS

W. H. MCKINLAY *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 10 p (SEE N86-26316 17-04) Oct. 1985

Avail: NTIS HC A07/MF A01

Some of the areas in which automation could be used to reduce pilot workload when operating at night or in low visibility are examined. It is shown that in navigation the pilot's task extends from the planning stage before take off to the point at which tactical decisions are taken in the air. The role of the mission planning system and the features of a system developed for this

purpose are covered. The nature of the man-machine interface including its required features and the impact of the latter on the core avionic system including navigation and the MMI are addressed. Author

N86-26320# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio. Human Engineering Div.
SOME QUANTITATIVE METHODOLOGY FOR COCKPIT DESIGN
C. BATES, JR. and M. M. VIKMANIA *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 10 p (SEE N86-26316 17-04) Oct. 1985 refs
Avail: NTIS HC A07/MF A01

The rapidly developing technology in sensor systems, microprocessors, artificial intelligence and communication systems has blurred the traditional lines between avionics subsystems and offers new design options for integrating the aircrew into the weapon system. These developments, together with the stressful flight regimes imposed by advanced threat systems and the night-in-weather environment required for survival in air-to-ground attack/interdiction, require new approaches to crew station design. These new design opportunities are limited only by the design tools and data bases available for their execution. A simplified cockpit design process can be summarized as conceptual design, detailed design, and design verification. With the many tools needed to pursue this process the subset involving man/machine interface must provide a decision track quantifying and predicting the impact of design decisions on crew performance. To meet the objective of the full utilization of the weapon system crew, each technology option under consideration for incorporation in the cockpit must be judged with consideration of both mission and human performance. The cockpit design process must be embedded in an adequate human performance data base tailored for use by design personnel and must take full advantage of operational experience. The development of a family of cockpit design tools, together with the required data bases, has been one of the objectives of the Air Force Aerospace Medical Research Laboratory research program. From this program a select set of methods will be described and examples provided. Author

N86-26321# Thomson-CSF, Issy les Moulineaux (France).
SYNTHETIC REAL-TIME RELIEF DISPLAY ALL-WEATHER AIRBORNE MISSIONS
J. N. BOTELLA *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 4 p (SEE N86-26316 17-04) Oct. 1985
Avail: NTIS HC A07/MF A01

Within the context of all-weather airborne missions, it is necessary to provide the pilot with information on the external world, even, and particularly when information provided by radar or optronic sensors are failing. The development of altimetric digital data banks prompts investigations to examine the display of synthetic relief in a cockpit. The study of various mass storages shows that a color film has remarkable storage capacities. Altimetric data are stored on a film read by the MERCATOR reader (whose initial function is to read map images). Three-dimensional synthesis algorithms are used and they are provided with the exceptional possibilities enabled by the MERCATOR analysis. The philosophy of this study is to show how a unique product, the map reader MERCATOR, designed to display plane images, is used to perform tridimensional displays of relief. Author

N86-26322# Farrand Optical Co., Inc., Valhalla, N.Y.
THE WIDE FIELD HELMET MOUNTED DISPLAY
J. LARUSSA *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 7 p (SEE N86-26316 17-04) Oct. 1985 refs
Avail: NTIS HC A07/MF A01

The wide field helmet mounted display developed by the Farrand Optical Company, Inc. is described. This display provides the pilot with an instantaneous field of view of 60 deg vertically and 135 deg horizontally. The central field of view consists of an overlap field of 25 deg within which full stereopsis is available. It would appear that a new design which the Farrand Optical Company, Inc. is now in the process of designing for Aerospace Medical Research Laboratory (AMRK) would be applicable for night all weather operations where such data as flight path control, computed weapon projectories, synthetic outside world views, expected and unexpected threats and automatic terrain following paths would be displayed. The parameters that must be considered in designing a wide field helmet mounted display are discussed. Briefly, these parameters are size, weight and balance on the head, brightness of the display and see-through ability of the display. The discussion assumes the use of a one inch, high brightness, high resolution CRT input already developed and operational. Author

N86-26323# Marconi Avionics Ltd., Rochester (England). Aircraft and Missile Systems.
A SOLID-STATE MAP DISPLAY FOR RAPID RESPONSE OPERATION
D. J. POWELL and T. E. CRAYFORD *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 13 p (SEE N86-26316 17-04) Oct. 1985
Avail: NTIS HC A07/MF A01

A means to provide pilots with a presentation of a moving color map display on a standard color CRT is described. It uses solid-state techniques and derives the display from a digital database. The design criteria used in the development of the system are discussed and an overview of the system operation is presented. Finally, one of the many ways in which the system as a whole may be used in operation is addressed. Author

N86-26324# Harris Government Aerospace Systems Div., Melbourne, Fla. Digital Cartographic Programs.
APPLICATIONS OF DIGITAL TERRAIN DATA IN FLIGHT OPERATIONS
G. W. CANTRELL *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 24 p (SEE N86-26316 17-04) Oct. 1985
Avail: NTIS HC A07/MF A01

With the availability of a world-wide digital terrain data base becoming a reality, it is now possible to carry and display on a tactical aircraft all of the map information needed for a mission. Along with the map display on a color cathode-ray tube (CRT), current targets and mission-specific data can be shown. The limitations of today's commonly used film readers are eliminated by using a digital data base which contains elevation information; one such data base is the U.S. Defense Mapping Agency's Digital Land Mass System (DLMS). The terrain data can be digitally compressed and efficiently stored so that large area coverages may be achieved. With this information readily available, aircraft mission effectiveness and survivability can be enhanced. The system for accomplishing this task is called a digital map generator (DMG). The DMG architecture encompasses data storage, data access and reconstruction, data display processing, and data formatting for use by other aircraft subsystems. A DMG architecture was developed for application in low-level or nap-of-the-Earth tactical missions, as well as long range strategic missions. Mission capabilities are enhanced by using this DMG to support terrain following/terrain avoidance (TF/TA), autonomous navigation, threat avoidance, and weapons delivery. In addition, the same digital processing approach is usable for pre-flight mission planning. The ability to plan a flight using the actual mission data base gives the pilot the ability to see exactly where he will be at all times and to determine safe corridors for entry and departure, making maximum use of terrain shielding. Similarly, the terrain data may be used for reference during post-mission debriefing, in which the pilot can refer to in-flight annotations made through the DMG subsystem. Author

N86-26325# Theory and Applications Unlimited Corp., Los Gatos, Calif.
A NEW TECHNIQUE FOR TERRAIN FOLLOWING/TERRAIN AVOIDANCE GUIDANCE COMMAND GENERATION
R. V. DENTON, J. E. JONES, and P. L. FROEBERG *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 11 p (SEE N86-26316 17-04) Oct. 1985 refs
Avail: NTIS HC A07/MF A01

A real-time optimization technique that efficiently generates a robust, optimum terrain following/terrain avoidance (TF/TA) trajectory, and has the structural capability for adding threat avoidance is described. The TF/TA technique presented is based on definition of a performance measure that is systematically

optimized in real-time. The approach uses on-board Defense Mapping Agency digital terrain elevation data extensively, as updated by real-time sensor inputs. The optimization of the performance measure embodies the real-time trade-off of flying over (TF) versus flying around terrain features (TA). The performance measure is defined to generally penalize large excursions from the nominal (globally-defined) route, while rewarding a trajectory that achieves better terrain masking than contained in the nominal, mission-planned route. Direct incorporation of limits on the flight control variables (bank angle, roll rate, normal acceleration, etc.) is included within the procedure. The TF/TA technique also addresses additional considerations that apply when combining the TF/TA flight trajectory computation with maneuvers through mission waypoints. This involves several subtleties associated with the relative importance of the turning maneuver desired versus the normally applicable TF/TA performance measure. Finally, the relevance of this work to other advances in trajectory computation is described. This includes the relationship to global trajectory generation, and to integrated TF/TA with threat avoidance TF/(TA)2. Author

N86-26326# Societe Francaise d'Instruments de Mesure, Velizy-Villacoublay (France). Secteur Capteur Optronique.
USE OF A CO2 LASER LIDAR FOR FLIGHT AND PENETRATION AT VERY LOW ALTITUDES [UTILISATION D'UN LIDAR A LASER CO2 POUR LE VOL ET LA PENETRATION A TRES BASSE ALTITUDE]
B. STEPHAN *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 8 p (SEE N86-26316 17-04) Oct. 1985
Avail: NTIS HC A07/MF A01

A CO2 laser optical sensor system which allows the acquisition of accurate land distances for a large area is described. These values are obtained in a real-time mode with the use of a UMP 7800 computer, and allow the generation of a map of the terrain to determine geographic coordinates. This map makes it possible to determine the optimal navigation trajectory at very low altitudes, with optimization based on the terrain features. This sensor was tested at Villacoublay in 1984 and is currently under testing at C.E.V. The results of the experiments and the static and dynamic analysis tests are presented. Transl. by T.R.

N86-26327# Crouzet Aerospace and Systems, Valence (France). Div. Aerospatiale.
A MISSION NAVIGATION AND CONTROL SYSTEM FOR MODERN MILITARY HELICOPTERS [UN SYSTEME DE NAVIGATION ET DE GESTION DE LA MISSION POUR LES HELICOPTERS MILITAIRES MODERNES]
J. L. ROCH *In* AGARD Guidance-Control-Navigation Automation for Night All-Weather Tactical Operations 10 p (SEE N86-26316 17-04) Oct. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

The requirements of modern military helicopters have fostered the development of navigation systems which use position sensors as a part of a centralized mission control system. An overview of the requirements for modern operational helicopter systems is given, as well as current automatic navigation systems; this is followed by a report of the NADIR MK2 mission navigation and control system developed by the CROUZET Company. Transl. by T.R.

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

N83-34939# Southampton Univ. (England). Dept. of Aeronautics and Astronautics.
TECHNICAL EVALUATION REPORT ON THE FLIGHT MECHANICS PANEL SYMPOSIUM ON GROUND/FLIGHT TEST TECHNIQUES AND CORRELATION
J. WILLIAMS Jun. 1983 30 p refs
(AGARD-AR-191; ISBN-92-835-1454-8; AD-A132856) Avail: NTIS HC A03/MF A01

Twenty-four papers and the panel discussions are reviewed. Topics covered include: (1) aerodynamic performance prediction and correlation; (2) status of aerodynamic performance prediction; (3) flying qualities considerations; (4) aeroelastic effects; and (5) subsystem performance. A.R.H.

N84-20513# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
HELICOPTER FATIGUE DESIGN GUIDE
F. LIARD, ed. Nov. 1983 291 p
(AD-A138963; AGARD-AG-292; ISBN-92-835-0341-4) Avail: NTIS HC A13/MF A01 CSCL 01C

Fatigue problems about affecting helicopters are considered. Documents the experience of helicopter manufacturing member nations of NATO are reviewed. It is aimed expecially at design and test facilities who manufacture rotary wing aircrafts. Information on determination of fatigue strength and behavior is presented. E.A.K.

N85-10040# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THE INFLUENCE OF LARGE SCALE COMPUTING ON AIRCRAFT STRUCTURAL DESIGN
Loughton, England Aug. 1984 55 p refs Meeting held in Sienna, Italy, 2-6 Apr. 1984
(AGARD-R-706; ISBN-92-835-0364-3) Avail: NTIS HC A04/MF A01

Advances in large scale computing capacity and how they affect aeronautical design are reported. The use of vector processing to solve aircraft structural problems, the influence of new computing systems on computational mechanisms, and use of artificial intelligence in design processing is discussed. The role of AGARD and its response to the challenge is examined. For individual titles see N85-10041 through N85-10043.

N85-10041# Societe Nationale Industrielle Aerospatiale, Toulouse (France). Structural Methods Dept.
AEROSPATIALE'S EXPERIMENTATIONS OF VECTORIZATION ON SUPERCOMPUTERS FOR AIRCRAFT STRUCTURAL PROBLEMS
J. M. THOMAS and J. C. DUNYACH *In* AGARD The Influence of Large Scale Computing on Aircraft Struct. Design 14 p (SEE N85-10040 01-05) Aug. 1984
Avail: NTIS HC A04/MF A01

The vectorial and parallel performances of new computer architectures was tested. The experiment consisted of adapting existing structural stress routines to existing computers. The performance throughput gain expected from these computers within the context of industrial processing of large programs is estimated. The cost for adapting the programs to the computers is assessed, and basic rules which apply to the vectorization of most programs are established. E.A.K.

N85-10042*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
IMPACT OF NEW COMPUTING SYSTEMS ON COMPUTATIONAL MECHANICS AND FLIGHT-VEHICLE STRUCTURES TECHNOLOGY
A. K. NOOR, O. O. STORAASLI, and R. E. FULTON *In* AGARD The Influence of Large Scale Computing on Aircraft Struct. Design 29 p (SEE N85-10040 01-05) Aug. 1984 refs
Avail: NTIS HC A04/MF A01 CSCL 01C

Advances in computer technology which may have an impact on computational mechanics and flight vehicle structures technology were reviewed. The characteristics of supersystems, highly parallel systems, and small systems are summarized. The interrelations of numerical algorithms and software with parallel architectures are discussed. A scenario for future hardware/software environment and engineering analysis systems is presented. Research areas with potential for improving the effectiveness of analysis methods in the new environment are identified. E.A.K.

N85-10043# Cranfield Inst. of Tech., Bedford (England). College of Aeronautics.
LARGE SCALE COMPUTING IN AERONAUTICAL DESIGN
A. J. MORRIS *In* AGARD The Influence of Large Scale Computing on Aircraft Struct. Design 4 p (SEE N85-10040 01-05) Aug. 1984
Avail: NTIS HC A04/MF A01

The use of new advances in large scale computing and software techniques and how they create comprehensive design programs is outlined. The role of artificial intelligence in making large design programs accessible to the single user is emphasized. The AGARD response to the challenge posed by the new a situation is discussed and a series of tasks is proposed. E.A.K.

N85-21157# Advisory Group for Aerospace Research and Development, Paris (France).
TECHNICAL EVALUATION REPORT ON THE FDP SYMPOSIUM ON FLIGHT TEST TECHNIQUES
F. N. STOLIKER (Computer Sciences Corp., Camarillo, Calif.) Dec. 1984 24 p refs
(AGARD-AR-208; ISBN-92-835-1481-5; AD-A152532) Avail: NTIS HC A02/MF A01

The rapidly advancing technologies of integrated flight and fire control, all weather and night attack systems, digital multimode controls, wide field of view head-up displays, system/subsystem simulation, and rapidly increasing instrumentation acquisition, processing, and display capabilities led to the need for this symposium. The papers presented were concerned with three major subject areas: (1) Performance and flying qualities; (2) Systems testing; and (3) Instrumentation and facilities. Information on these topics in flight testing and instrumentation techniques was shared with the AGARD community. E.R.

N85-23754*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SIMULATION OF AIRCRAFT BEHAVIOUR ON AND CLOSE TO THE GROUND
A. G. BARNES (British Aerospace Plc, Preston, England) and T. J. YAGER Loughton, England AGARD Jan. 1985 66 p refs
(NASA-TM-87460; NAS 1.15:87460; AGARD-AG-285; ISBN-92-835-1490-4; AD-A153320) Avail: NTIS HC A04/MF A01 CSCL 01C

A guide to the current state of the technology of simulating fixed-wing aircraft handling qualities and performance on or close to the ground is presented and pitfalls which may prevent an adequate implementation are indicated. The scope of possible applications in both aircraft design work and pilot training is considered and the requirements for mathematical model definitions and implementations are discussed. The current requirements for visual and motion systems, cockpit cueing, and software modelling are also reviewed, and illustrated with specific examples in areas of aircraft research and development studies and pilot training uses. Needs for further improvements and additional data acquisition are identified. Author

N85-23765# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GEARS AND POWER TRANSMISSION SYSTEMS FOR HELICOPTERS AND TURBOPROPS
Loughton, England Jan. 1985 385 p refs In ENGLISH and FRENCH Conf. held in Lisbon, 8-12 Oct. 1984
(AGARD-CP-369; ISBN-92-835-0372-4; AD-A152673) Avail: NTIS HC A17/MF A01

The Symposium was arranged in seven sessions: Review of Current Transmission Technology (4); Helicopter and Turboprop Transmission Technology Needs and Design (4); Component Design Technology and Manufacturing Considerations (8); Tribological Aspects of Transmission Components (6); Diagnostics, Measurements, and Noise (5); Problems and Failures in Gearing Applications (3); and Qualification Standards and Specifications (2). The purpose of the Symposium was to exchange and disseminate information on reasearch and development conducted on gears and transmission systems in order to introduce new technologies for improvements in weight, performance, and life-cycle costs. For individual titles see N85-23766 through N85-23796.

N85-23766# Army Research and Technology Labs., Cleveland, Ohio. Propulsion Lab.
SUMMARY OF DRIVE-TRAIN COMPONENT TECHNOLOGY IN HELICOPTERS
G. J. WEDEN and J. J. COY *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 17 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

A review of current helicopters was conducted to determine the technology in the drive train systems. The design features including reliability, maintainability and survivability characteristics, in transmission systems for the OH-58, UH-1, CH-47 and UH-60 helicopters are highlighted. In addition, trade offs involving cost, reliability and life are discussed. B.W.

N85-23767# Societe Nationale Industrielle Aerospatiale, Marignane (France). Service D'Etude des Transmissions.
CURRENT TRANSMISSION SYSTEMS [SYSTEMES DE TRANSMISSION ACTUELS]
R. FRANCOIS *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 12 p (SEE N85-23765 14-05) Jan. 1985 In FRENCH
Avail: NTIS HC A17/MF A01

Transmissions on the new generation Ecureuil, Dauphin, and Super-Puma helicopters, produced in series by the National Industrial Aerospace Society, are described. The most significant technical options are comparatively analyzed showing progress made in the areas of safety, reliability, and the noise of reduction gears and gear boxes. The effective demonstration of safety margins is recalled as well as redundant systems for lubricating the main gear box. Simplicity of design, the use of steels, and heat treatments enhance the performance of gears and ball bearings. Consideration of the noise criteria when choosing the geometry of the gear teeth is discussed. A.R.H.

N85-23768# Imperial Coll. of Science and Technology, London (England). Tribology Section.
HELICOPTER TRANSMISSION LUBRICANTS
H. A. SPIKES *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 10 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

The problems associated with the lubrication of helicopter transmissions are outlined. Changes likely to occur over the next decade involving helicopter lubricants are discussed. For many years, helicopter reliability has suffered both in the UK and the USA from the requirement that the oil be common to both the transmission and the gas turbine. In practice, certainly in the UK, most helicopters do not, in fact, use a common oil. The UK helicopter industry is in sympathy with the logistic advantages of minimizing the number of oils stocked but feels that this could be more successfully achieved by adopting a single transmission oil for all NATO helicopters. It now appears that this is now being considered as a practical alternative on both sides of the Atlantic. In the UK, the MOD has funded the successful development of a helicopter transmission oil in anticipation of such a move. The

USA after many years of being antagonistic towards separate gearbox and engine lubricants is about to embark on a relevant oil development program. B.W.

N85-23769# Boeing Vertol Co., Philadelphia, Pa.
SPECIAL POWER TRAIN REQUIREMENTS FOR THE NEXT GENERATION OF ROTARY-WING AIRCRAFT
R. J. DRAGO and J. W. LENSKI, JR. *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 14 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

The omnipresent rotary wing drive system requirements for minimum weight with maximum reliability will be compounded in the future by additional restrictions on size, damage tolerance, cost, and east of assembly and maintenance. Possible approaches designed to improve the performance of rotary wing drive systems are discussed. Specific examples of extensions of current technology are given. B.W.

N85-23770# General Electric Co., Lynn, Mass. Gear Systems.
A STATE OF THE ART ASSESSMENT OF TURBOPROP TRANSMISSION TECHNOLOGY AND PROJECTED NEEDS FOR THE NEXT GENERATION
R. J. WILLIS, JR. *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 11 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

The major share of power transmission research and development during the past twenty years has been expended on the improvement of helicopter main rotor drives. Furtunately, most of the advanced technology features resulting from these efforts are directly applicable to turboprop transmission. The technology base is made up of a number of interacting disciplines whose application is tempered by economics as well as the engineering state of the art at any given time. Modern computers are playing an ever increasing role in the design process and promise to be the means of removing gear design from its empirical background. The utilization of state of the art technology as the framework for turboprop transmission design is discussed. B.W.

N85-23771# Pratt and Whitney Aircraft of Canada Ltd., Mississauga (Ontario).
ADVANCED GEARBOX TECHNOLOGY IN SMALL TURBO PROPELLER ENGINES
C. BROWNRIDGE and D. HOLLINGWORTH *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 14 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

Gearbox component analysis traditionally deals with the calculation of Hertzian stresses at gear contacting surfaces and the fillet stresses at the tooth bases caused by the meshing loads. Major assumptions are often made regarding the dynamic loads and the variation of loads across teeth due to misalignment. Little attention is paid to gear weight optimization, or stresses generated at complex interactions such as splines or fretting surfaces between flanges. Current 3D fe methods used to examine some of the more complex surface to surface interactions are discussed. The loading experienced between dynamically active teeth meshing at high speed is addressed. To successfully design a light weight and durable gearbox for aircraft applications complex computer modelling is necessary and new theories of failure are needed to deal with such aspects as fretting fatigue. B.W.

N85-23772# Bell Helicopter Co., Fort Worth, Tex. Transmission Design.
THE HELICOPTER TRANSMISSION DESIGN PROCESS
R. BATTLES *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 8 p (SEE N85-23765 14-05) Jan. 1985
Avail: NTIS HC A17/MF A01

An overview of helicopter transmission design and development is presented. Aspects from conceptualization to working production equipment are presented. They include the following six phases: (1) predesign; (2) design; (3) manufacturing coordination; (4) bench testing; (5) aircraft testing; and (6) field service support. G.L.C.

N85-23773# Centre Technique des Industries Mecaniques, Senlis (France).
SOFTWARE FOR DESIGNING TEETH FOR REDUCTION GEARS AND TRANSMISSIONS [LOGICIEL DE CONCEPTION DES DENTURES D'ENGRENAGES POUR REDUCTEURS ET BOITES DE VITESSES]
L. FAURE and A. BORRIEN *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 15 p (SEE N85-23765 14-05) Jan. 1985 In FRENCH
Avail: NTIS HC A17/MF A01

Capabilities offered by software developed by CETIM for the computer aided design of gear teeth (C.A.D.O.R.) are presented. The structure of the input program which permits the designer to rapidly obtain the optimal characteristics of a gear which must meet given specifications is presented. The combination of different programs in the software package to permit the user to assure proper gear sizing and set the tclerance for the desired precision and action is considered. Transl. by A.R.H.

N85-23774# *Westland Helicopters Ltd., Yeovil (England).* Tribology Research.
FINE FILTRATION: AN ATTRACTIVE ROUTE TOWARDS LOWER HELICOPTER OPERATING COSTS
P. B. MACPHERSON *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 10 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

Helicopter transmission mechanical reliability and longevity are considered and discussed in terms of filtration of the gearbox lubricating media. The background research and trails experience that led to the adoption of vine (3 micron) filtration are discussed. It is pointed out that in order to increase longevity, and therefore lower costs, the transmission unit must begin its life in the cleanest possible state. To achieve this end, standard production methods must be revised. G.L.C.

N85-23775# Ruhr Univ., Bochum (West Germany).
LOAD CAPACITY OF CAGES OF ROLLER BEARINGS FOR PLANET WHEELS
F. JARCHOW and P. G. HOCH *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 22 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

In planetary gears the rotation of the planet-carrier generates forces of inertia, which can cause fatigue failures of the cages in roller bearings of planet wheels. By means of computer routines forces on inertia and counter forces as well as stress resultants, nominal stresses, stress concentration factors and stress gradients are calculated for bearing cages of various design. Yield strength and fatigue strength of samples of cage material are determined experimentally, and fatigue stress diagrams for cases of different shape and material are worked out. Thus the calculated safety factors against fatigue failure are confirmed by test runs of bearings on a test bench. The results of the investigations are summed up in easily applicable charts. G.L.C.

N85-23776# Inspectorate International S.A., Neuchatel (Switzerland).
LOAD CARRYING CAPACITY OF DOUBLE CIRCULAR ARC GEARS
M. A. K. FAHMY and R. E. JONCKHEERE (Brussels Univ.) *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 12 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

An overview of some experimental and numerical investigations into several aspects of the load-carrying capacity of double circular arc (D.C.A.) gear teeth is presented. Tooth deflection and bending moment distribution were studied using three dimensional holographic interferometry, whereas rootstresses were determined by means of miniature strangers. The finite element method and finite difference method were used to determine deflections numerically. G.L.C.

N85-23777# United Technologies Corp., Stratford, Conn.
MANUFACTURING PERSPECTIVE IN THE DESIGN OF BEVEL GEARING
A. J. LEMANSKI, H. K. FRINT, and W. D. GLASOW *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 18 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

A manufacturing perspective of an advanced technique for the design and in-process inspection of spiral bevel gearing utilizing a computer controlled multi-axis coordinate measuring machine, is being developed. Both the designer and the gear manufacturing engineer will have more options in the analysis and manufacture of bevel gearing due to the positive control of the tooth profile geometry and related gear dimensions as permitted by the advanced technique. The Zeiss Model UMM 500 universal coordinate measuring machine in conjunction with an advanced Gleason G-Met software package provides for a unique interaction between the designer and the gear manufacturer that permits rapid optimization of spiral bevel tooth geometry during initial tooth form development. An advanced design/production technique for the in-process inspection and manufacture of aircraft quality spiral bevel gearing is described. The technique involves mapping of spiral teeth over their entire working surfaces and quantitatively comparing surface normals with the nominal master gear values at some 45 grid points. In addition, this technique features a means for rapidly calculating corrective grinding machine setting changes for controlling the tooth profile geometry within specified tolerance requirements. Author

N85-23778# Spar Aerospace Products Ltd., Toronto (Ontario). Manufacturing Dept.
MANUFACTURING CONSIDERATIONS RELATED TO AIRCRAFT GEARBOXES
J. N. MCDADE and G. B. COLLIN *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 10 p (SEE N85-23765 14-05) Jan. 1985
Avail: NTIS HC A17/MF A01

The technology used in aircraft gearbox manufacturing, covers a whole gamut of methods, types of machining and chemical processing. While an aircraft gearbox manufacturer must aggressively ensure efficient productivity, his efforts are frequently negated by the requirements of the designer. As aircraft gear systems are required to transmit more power at greater speeds, the trend is to provide this performance with a minimum of increase in size and weight. This necessitates better dynamic capability, resulting from improvements in metallurgy, manufacturing equipment, techniques, and metrology. These improvements can be costly, it is therefore, encumbent on the designer to carefully consider his designs, the terms of producibility. This can best be one in close liaison with the manufacturing engineer. G.L.C.

N85-23779# Fiat Aviazione S.p.A., Turin (Italy). Transmission Engineering Dept.
POSSIBLE TECHNOLOGICAL ANSWERS TO NEW DESIGN REQUIREMENTS FOR POWER TRANSMISSION SYSTEMS
L. BATTEZZATO and S. TURRA *In* AGARD Gears and Power Transmission S, .ems for Helicopters and Turboprops 13 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

In the new projects of gearboxes for aeronautical application, the specified requirements have become more and more severe asking for continuous technology advance. The most important points put out by these specs, such as fail safety, reliability, low vibration and low noise, high working temperature, invulnerability and maintainability, of course combined with a low weight characteristic are discussed. A detailed analysis is carried out to identify the guidelines for obtaining the best compromise among the above listed requirements, by applying a proven philosophy. The advantage of a reliable system capable of detecting failures in progress within the gearbox is also underlined as it can be a key point in defining the final design resulting from the optimization procedure. G.L.C.

N85-23780# Watteeuw (M. C.) N.V., Bruges (Belgium).
CASE DEPTH ON FLANKS OF GEARS FOR HELICOPTER GEARBOXES
A. WATTEEUW *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 12 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

One of the most difficult and delicate operations during the manufacturing process of gears for helicopter gearboxes and aircraft gears is the heat treatment. Case hardened alloy steel of high quality are mainly used for aircraft gears. not only a good structure in the case hardened tooth but also the surface hardness, the core hardness and case depth are very important for the load capacity of these gears. On the drawing and in the specifications belonging to it, values and tolerances have been provided for the above mentioned hardnesses. These, however, are not always adequate to guarantee a good manufacture. These and other factors such as load capacity, tensile stress and pitting of gears are treated. Author

N85-23781*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
TRANSMISSION EFFICIENCY MEASUREMENTS AND CORRELATIONS WITH PHYSICAL CHARACTERISTICS OF THE LUBRICANT
J. J. COY, A. M. MITCHELL, and B. J. HAMROCK *In* AGARD *Gears and Power Transmission Systems for Helicopters and* Turboprops 15 p (SEE N85-23765 14-05) Jan. 1985 refs Previously announced as N84-30293 Prepared in cooperation with Army Research and Technology Labs.
Avail: NTIS HC A17/MF A01 CSCL 11G

Data from helicopter transmission efficiency tests were compared to physical properties of the eleven lubricants used in those tests. The tests were conducted with the OH-58 helicopter main rotor transmission. Efficiencies ranged from 98.3 to 98.8 percent. The data was examined for correlation of physical properties with efficiency. There was a reasonable correlation of efficiency with absolute viscosity if the viscosity was first corrected for temperature and pressure in the lubricated contact. Between lubricants, efficiency did not correlate well with viscosity at atmospheric pressure. Between lubricants, efficiency did not correlate well with calculated lubricant film forming capacity. Bench type sliding friction and wear measurements could not be correlated to transmission efficiency and component wear. Author

N85-23782# Imperial Coll. of Science and Technology, London (England). Tribology Section.
THE CHARACTERISTICS OF SURFACE ROUGHNESS IMPORTANT TO GEAR AND ROLLING BEARING PROBLEMS
R. S. SAYLES and M. N. WEBSTER *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 14 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

The role of surface roughness in rolling and rolling and sliding contacts is examined in the light of present concepts and ideas. Examples of the influence of roughness, and the important characteristics of this roughness, are drawn from helicopter transmission and rolling bearing research. The important influence of geometry and roughness in tribological problems is accepted and only limited progress is made in understanding the exact mechanisms involved and incorporating this knowledge into surface finishing processes designed to improve performance. An approach to surface topography measurement and analysis which allows many of these problems to be examined in great detail is presented. Examples of the approach are presented for several tribological problems including dimensional tolerance, rolling contact noise, and fatigue life, and in each case the character of the important range and size of surface roughness features is identified in terms of its influence on the specific problem under examination. Author

N85-23783# Institut National des Sciences Appliquees de Lyon, Villeurbanne (France). Lab. de Mecanique des Contacts.
SIGNIFICANT PARAMETERS OF THE BEHAVIOR AND OF THE SURFACE DAMAGE OF THE LUBRICATED HERTZIAN CONTACT: AN APPLICATION TO GEARS [PARAMETRES SIGNIFICATIFS DU COMPORTEMENT ET DES AVARIES DE SURFACE DU CONTACT HERTZIEN LUBRIFIE, APPLICATION AUX ENGRENAGES]
D. BERTHE and L. FLAMAND *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 13 p (SEE N85-23765 14-05) Jan. 1985 refs In FRENCH
Avail: NTIS HC A17/MF A01

The life of a mechanism is often limited by surface damages. Some criteria are given for estimating the severity of the working of the lubricated Hertzian contact and the risk of surface damage. Three classes of surface damage in heavly loaded lubricated contacts are specified. Theoretical models used to analyze the mechanical behavior and the identify to parameters of contact operation are defined and the importance of the scale factor is noted. The application of the analysis method to problems of gear teeth surface damage is discussed. Transl. by A.R.H.

N85-23784# Pisa Univ. (Italy).
PROBLEMS OF ELASTIC HYDRODYNAMIC LUBRICATION OF HELICOPTER TRANSMISSION GEARS
D. DINI *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 9 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

The reduction gear box and its components, from the engine to the main and tail rotors, contain epicyclic and bevel reduction gears, as taper thrust and cylindrical roller bearing, subjected to elasto-hydro-dynamic lubrication whose operation needs a better understanding in order to improve present efficiency. Since the lubrication efficiency is depending upon the elastic deformation of the contact surfaces, a theory for a better physical interpretation of the mechanism is discussed as a design means to alleviate adverse stress conditions during operations. An attempt to solve the problem of computing the pressure distribution in the contact is made and, at the same time, of allowing for the effects that this pressure has on the properties of the fluid and on the geometry of the elastic solids. The solution also provides the shape of the lubricant film, particularly the minimum clearance between the solids. An experimental high performance equipment capable to simulate the behaviour of Hertzian contacts in elasto-hydro-dynamic lubrication is proposed. Author

N85-23785# Army Research Office, Research Triangle Park, N. C. Solid Mechanics Branch.
CHEMICAL-MECHANICAL INTERACTION IN GEARS
E. SAIBEL *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 8 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

A theory of chemo-mechanical interaction is developed to explain several disparate phenomena in the field of tribology on a quantitative basis. The important new quantity in this theory is the variation of the Gibbs chemical potential with stress, a quantity formulated and calculated explicitly using statistical thermodynamics and many-body theory, called the chemo-stress coefficient. The theory gives the basis for quantitative explanation of stress corrosion, fretting corrosion, the Rehbinder effect, and enhanced chemical activity on solid surfaces. In particular it suggests methods of arresting corrosion by controlling the charge distribution of electrolytes near the surface of the solid. A mechanism for pitting corrosion observed on lubricated load bearing surfaces of mechanical components such as gears is proposed. This theory emphasizes the importance of specific ions in the lubricant which migrate to the tips of cracks and diffuse through near-surface layers of the metal thereby causing volumetric changes leading to blistering or pitting. Author

N85-23786# Ecole Centrale de Lyon (France). Lab. de Technologie des Surfaces.
WEAR REDUCTION BY LUBRICANTS IN CONFINED CONTACTS [REDUCTION DE L'USURE PAR LES LUBRIFIANTS DANS LES CONTACTS ETROITE]
P. KAPSA and M. BELIN *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 11 p (SEE N85-23765 14-05) Jan. 1985 refs In FRENCH
Avail: NTIS HC A17/MF A01

The presence of a lubricant and its chemical activity are important parameters in the sliding friction behavior and wear of solids by relative displacement. In the case of transmission gears, the contact between the two solids is of the Hertzian type and friction is then produced in the absence of a thick oil film; the lubrication is mixed or limited elastohydrodynamic. In lubrication regimes where solid-solid contacts exist, wear reduction takes place by the formation of a thin solid film adhering to the sliding surface, created by a chemical reaction under the effect of sliding. Results of tests in the presence of anti-wear additives (dithiophosphate of zinc and tricresylphosphate) show the importance of wear on the kinetics of formation of these films. The apparent pressure of the contant and the sliding velocity not modify the elementary phenomena of war but do play a proponderant role in the total wear of surfaces. Transl. by A.R.H.

N85-23787# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ROOT STRESSES IN CONFORMAL GEARS-STRAIN GAUGE AND PHOTOELASTIC INVESTIGATIONS
D. G. ASTRIDGE, B. R. REASON, and D. BATHE *In its* Gears and Power Transmission Systems for Helicopters and Turboprops 15 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

The significant amount of analytical work on strong gear tooth forms carried out since the classical papers of Shotter et al are reviewed, and the results of a project which addresses a problem common to all three-dimensional photoelastic studies of root stresses in gears are presented an accurate delination of the contact conjunction geometry throughout the stress freezing cycle is the common problem. Photoelastic model results are compared with those measured by strain gauge methods on the definitive gears. Author

N85-23788# Kaman Aerospace Corp., Bloomfield, Conn.
TRANSMISSION OF GEAR NOISE TO AIRCRAFT INTERIORS PREDICTION METHODS
A. BERMAN *In* GARD Gears and Power Transmission Systems for Helicopters and Turboprops 7 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

Prediction of interior noise of helicopters due to drive train vibration ideally requires an analytical model of the entire dynamic system including airframe, transmission, and all attachments. The development of such a model is beset with numerous difficulties. The need for such model is addressed, as is certain of the critical issues involved: the inadequacy of finite element modeling in the acoustic frequency range; the costs associated with assessment of parametric variations; the difficulty of incorporating new technology into existing computer programs. Potential solutions to these problems are discussed: use of combined test and analysis (system identification) to obtain better models; component synthesis using frequency domain reduced models; a computer program known as DYSCO. This program has a general capability to modify and couple components in the time or frequency domain and can act as a repository for the latest analytical developments.
Author

N85-23789# Fiat Aviazione S.p.A., Turin (Italy). Direzione Progettazione.
EVOLUTION OF THE DESIGN TECHNIQUES FOR HELICOPTER MAIN TRANSMISSION GEARBOXES
G. BENSI and L. TARRICONE *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 14 p (SEE N85-23765 14-05) Jan. 1985
Avail: NTIS HC A17/MF A01

The evolution of the design techniques are shown which were adopted in FIAT AVIAZIONE for the helicopters main transmission gearboxes by means of the description of the mechanical units

designed for the AEROSPATIALE heliocopters: SA 321, SA 330, SA 360, SA 365. The technical solutions have followed a development strictly related to the customer required specifications. Considering the past and present evolution we can foresee the future development trend. As an explanatory example, an advanced main transmission gearbox for a medium twin engined helicopter is considered and some design solutions are shown. Evaluations of four gearbox configurations were carried out by assigning the right importance coefficient to three appreciation functions: reliability, cost and weight. Author

N85-23790# Naval Aircraft Materials Lab., Fleetlands (England).
CONDITION MONITORING OF HELICOPTER GEARBOXES USING AUTOMATIC VIBRATION ANALYSIS TECHNIQUES
P. GADD and P. J. MITHCELL (MOD Navy) *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 10 p (SEE N85-23765 14-05) Jan. 1985
Avail: NTIS HC A17/MF A01

Methods using enhanced signal averaging techniques were developed to give early warning of the onset of a variety of gearbox failures. Prototype analysis equipment was developed and tested which will permit the condition of components within helicopter dynamic systems (rotors, gearboxes, and powerplants) to be established. Arrangements for data collection in flight and during ground runs are described. The signal processing methods, including the automatic techniques for secondary analysis which enable defined features to be extracted from the basic signatures, are discussed. Examples are given of the extent to which damage or malfunction of various internal components can be discerned by the techniques employed. The question of application to the widely dispersed fleet of naval aircraft is considered, and the prospects for achieving full on-condition maintenance of in-service gearboxes is assessed. Author

N85-23791# Bolt, Beranek, and Newman, Inc., Cambridge, Mass.
GEAR NOISE ORIGINS
W. D. MARK *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 14 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

Each pair of meshing gears in a transmission gives rise to a source of vibratory excitation that can result in the radiation of sound. Each such source is most conveniently characterized as a displacement form of excitation generally referred to as the static transmission error of the gear pair. Contributions to the frequency spectrum of the static transmission error of spur and helical gears arising from tooth and gear body elastic deformations and from deviations of tooth surfaces from perfect involute surfaces are considered. Tooth surface deviations are decomposed into contributions giving rise to tooth meshing harmonic excitations and rotational harmonic or sideband excitations. Various types of gear tooth errors are defined and the contributions of these errors to different parts of the frequency spectrum are described. The attenuating effect on the static transmission error spectrum arising from the smoothing action of multiple tooth contact is explained. Author

N85-23792# Westland Helicopters Ltd., Yeovil (England). D.C.M.D. Transmissions.
THE OBSERVATION AND INTERPRETATION OF GEAR TOOTH FAILURES
B. A. SHOTTER *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 13 p (SEE N85-23765 14-05) Jan. 1985
Avail: NTIS HC A17/MF A01

Progress in transmission reliability can only come from a full understanding of what causes the limitation of tooth load carrying capacity. The many aspects of tooth failure, the significance of various initiation areas, possible approaches to improve the critical areas and other relevant factors are discussed. Author

N85-23793# CEMUL, Lisbon (Portugal).
PROBLEMS REGARDING THE PRACTICAL EVALUATION OF EFFICIENCY OF WORM GEARS
F. A. P. DASILVA *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 2 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

Worm gears are often used in industry or domestic application (lifts) when a high transmission is required in a limited space, which prevents the option for multiple gear trains. Negative aspects of these gears are the complex geometry and high values of sliding during contact leading to low values of efficiency. For the other types of gear, spur, bevel and conical ones values are usually higher than 90% but in this case practical values of 50% may result. It is possible according to the choosen geometry to forecast the efficiency theoretically. However the lubricant behavior is generally defined by a parameter, sometimes designated as lubricant factor, which is very difficult to ascertain with sufficient accuracy. Considerations regarding the practical determination of this factor and suggestions for testing are presented for discussion. Author

N85-23794# Cambridge Univ. (England). Dept. of Engineering.
TRANSMISSION ERROR MEASUREMENTS IN GEARBOX DEVELOPMENT
J. D. SMITH *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 5 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

There is a requirement to test gears for initial development, for production monitoring and for condition monitoring in service. Traditionally the first two were carried out by a combination of profile, helix, pitch and bedding checks and the third by measuring vibration at bearing housings. Gear drives in aircraft applications present difficulties in checking due to high distortions in the light weight gear cases. The use of transmission error (single flank) checking can give useful information on accuracy of alignment in gearboxes as well as fundamental noise generation information. Problems arise with attempts to use grating systems in turboprops but helicopters have tooth frequencies in a suitable range. Author

N85-23795# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Helicopter and Military Aircraft Group.
DO NEW AIRCRAFT NEED NEW TECHNOLOGIES AND CERTIFICATION RULES?
J. HARMANN and W. JONDA *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 7 p (SEE N85-23765 14-05) Jan. 1985
Avail: NTIS HC A17/MF A01

Using the example of development steps, a transmission usable for a 2 ton dual engined multipurpose helicopter demonstrates that technologies could drastically improve this product within approximately 15 years. Technologies which will influence the design are: improved manufacturing; use of computer calculation methods; testing procedure knowledge; diagnosis systems; and materials. The overall layout for the available engine power will change. To avoid unnecessary disadvantages the certification rules should be updated. The optimum benefits will be achieved when the certification rules are standardized for all counties in the Western World. B.G.

N85-23796# Federal Aviation Administration, Des Plaines, Ill. Propulsion Branch.
ESTABLISHMENT AND MAINTENANCE OF CERTIFICATION STANDARDS FOR HELICOPTER AND TURBOPROP POWER TRANSMISSION SYSTEMS
H. W. FERRIS *In* AGARD Gears and Power Transmission Systems for Helicopters and Turboprops 7 p (SEE N85-23765 14-05) Jan. 1985 refs
Avail: NTIS HC A17/MF A01

The procedures used by the Federal Aviation Administration (FAA) to develop qualification/certification safety standards for helicopter and engine turboprop drive systems are discussed. The rules are always generated in coordination with industry for a minimum of economic impact, and are worded to promote design innovation while maintaining adequate safety. The rules are periodically updated to account for service experience and

advancements in the state-of-the-art. A survey of the applicable Federal Aviation Regulations (FAR's) explains how all safety aspects of a new drive system are covered during the initial certification program. The FAR's also provide for continued airworthiness, as service experience is accumulated, such that inspection intervals may be increased to on condition, or decreased, if service diffulties indicate that an area of re esign is required. As further testing continues, initial limitations on component replacement times are relaxed until operating costs decrease to a minimum as the design reaches maturity. The FAA role is to assist industry in the promotion of aviation without compromising safety. Author

N85-25249# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
IDENTIFICATION OF DYNAMIC SYSTEMS
R. K. MAINE, K. W. ILIFF, and R. K. BOGUE, ed. Jan. 1985 147 p refs
(AGARD-AG-300-VOL-2; ISBN-92-835-1488-2; AD-A154031)
Avail: NTIS HC A07/MF A01

The problem of estimating parameters of dynamic systems is addressed. The theoretical basis of system identification and parameter estimations is presented in a manner that is complete and rigorous, yet understandable with minimum prerequisites. Emphasis is on maximum likelihood and related knowledge of stochastic processes or functional analysis. No previous background in statistics is assumed. The treatment emphasizes unification of the various areas in estimation theory and practice. For example, the theory of estimation in dynamic systems is treated as a direct outgrowth of the static system theory. Topics covered include: basic concept and definitions, numerical optimization methods; probability; statistical estimators; estimation in static systems; stochastic processes; state estimation in dynamic systems; output error, filter error, and equation error methods of parameter estimation in dynamic systems; and the accuracy of the estimates. Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

N83-30414# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
MODERN DISPLAY TECHNOLOGIES FOR AIRBORNE APPLICATIONS
Apr. 1983 239 p refs Lecture series presented at London, 6-7 Jun. 1983, Rome, 9-10 Jun. 1983, and Fort Monmouth, N.J., 16-17 1983
(AD-A129876; ISBN-92-835-1449-1; AGARD-LS-126) Avail: NTIS HC A11/MF A01

Electronic displays for airborne application was discussed. Changes in display technology and applications which are evident in many fields, and result from the increasing use of digital data processors and the need to efficiently interface them to human operations are outlined. Topics discussed include: human factors aspect of diplays, cockpit environment, cathode ray tubes, image generation on matrix displays, light emitting diodes, liquid crystal displays, electroluminescent displays, vacuum fluorescent tubes, large area gas discharge displays or plasma displays and optical techniques for airborne displays. For individual titles, see N83-30415 through N83-30426.

N83-30415# Technische Hogeschool, Twente (Netherlands).
HUMAN FACTORS ASPECTS OF DISPLAYS
D. BOSMAN *In* AGARD Mod. Display Technol. for Airborne Appl. 28 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

A total display system is a window, which permits the operator (pilot) to perceive the state and the dynamics of all the parameters which are relevant to this task is discussed. The performance of the visual interface between machine and brain is determined by technical and ergonomic factors. A basis for better interpretation of such data in assessing display performance specifications is described. E.A.K.

N83-30416# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
COCKPIT ENVIRONMENT
W. M. HOLLISTER *In* AGARD Mod. Display Technol. for Airborne Appl. 16 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

The cockpit environment where modern display technology is applied is described. Six display devices are discussed. Applications are classified according to their visualization format. E.A.K.

N83-30417# Thomson-CSF, Boulogne-Billancourt (France). Div. des Tubes Electroniques.
CATHODE RAY TUBES
J. P. MICHEL *In* AGARD Mod. Display Technol. for Airborne Appl. 36 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

The cathode ray tube (CRT) is one of the earliest electro-optical devices. The basic CRT is divided into four electro-optical regions, plus the screen itself: the electron beam formation region, the beam focusing region, and the drift region. The physical and visual characteristics are described. B.G.

N83-30418# Technische Hogeschool, Twente (Netherlands).
IMAGE GENERATION ON MATRIX DISPLAYS
D. BOSMAN *In* AGARD Mod. Display Technol. for Airborne Appl. 17 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

Images are two dimensional distributions of luminance L(x,y) wherein x and y are the spatial (distance) coordinates of the local luminance L. The spatial resolution required for faithful reproduction of the image is determined by very steep luminance gradients and small radii curvature of contours, (at viewing distance seen at a solid angle of 0.5 minute) and by just noticeable L-differences (JND's) in low gradients. The required luminance resolution is determined by discernible luminance contrasts (3%). The performance and its limits of the CRT as used in both the recreational sector (television) and professional applications (such as aircraft displays), were extensively researched and described. The new generation of flat panel display devices have image generation properties which are sufficiently different from those of the CRT to require additional ergonomic investigations. In particular, the structural information (spatial domain) does not allow such operations as analogue low pass filtering based on partial overlap of pixels: the image remains tesselated because of the display technologies involved, wherein pixels are formed by reticulation of the light modulating or emitting display surface. Author

N83-30419# Marconi Avionics Ltd., Boreham Wood (England).
LIGHT EMITTING DIODES
D. PRICE and K. T. BURNETTE (Bunker Ramo Corp.) *In* AGARD Mod. Display Technol. for Airborne Appl. 24 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

The evolution of Light Emitting Diodes (LEDs) as a result of the initial search for materials suitable for the formation of improved quality diodes and transistors are reviewed. Any semiconductor having an energy band gap wide enough to support a visible radiative recombination process is a potential candidate for the fabrication of LEDs. Materials used successfully for the formation of light emitting diodes include SiC, a compound of Chemical Group 4 elements, several Group 3-5 compounds and several Group 2-6 compounds. Extreme difficulties experienced in forming pn diode junctions within Group 2-6 compounds resulted in the development of a metal-insulator-semiconductor electron injection structure that to data was in general characterized by relatively low light emission efficiencies. Light emitting diodes are being successfully applied to airborne numeric and alphanumeric display tasks with more sophisticated graphics displays designed for aircraft installation nearing completion. Author

N83-30420# Royal Signals and Radar Establishment, Malvern (England).
LIQUID CRYSTAL DISPLAYS
A. J. HUGHES *In* AGARD Mod. Display Technol. for Airborne Appl. 17 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

Although liquid crystalline materials were recognized for over 100 years, their potential in display devices has become apparent only during the last 15 years. In this time many different effects were dicovered and assessed in laboratories, commercial exploitation was rapid and extensive, and a few displays were already fully developed for military use. The physical properties of liquid crystal materials and a selection of the more significant effects exploited in displays, pointing out their relative advantages and limitations is described. The present state of the art is summarized and some tentative predictions for future performance are made. Author

N83-30421# Army Avionics Research and Development Activity, Fort Monmouth, N. J.
ELECTROLUMINESCENT DISPLAYS
B. GURMAN *In* AGARD Mod. Display Technol. for Airborne Appl. 31 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

The principles of operation and physical/visual characteristics of electroluminescent displays are reviewed. The state-of-the-art in ac and dc, powder and thin film electroluminescent devices is described. M.G.

N83-30422# Thomson-CSF, Boulogne-Billancourt (France). Div. des Tubes Electroniques.
VACUUM FLUORESCENT TUBES
J. P. MICHEL *In* AGARD Mod. Display Technol. for Airborne Appl. 8 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

The historical development and current state-of-the-art of vacuum fluorescent tubes is reviewed. The principles of operation, physical/visual characteristics, addressing/driving, and system interface are discussed. M.G.

N83-30423# Thomson-CSF, Boulogne-Billancourt (France). Div. des Tubes Electroniques.
LARGE AREA GAS DISCHARGE DISPLAYS OR PLASMA DISPLAYS
J. P. MICHEL *In* AGARD Mod. Display Technol. for Airborne Appl. 17 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

Operating principles, physical and visual characteristics, addressing and driving, and system interface of both ac and dc plasma displays are discussed. The state of development and primary applications are also reviewed. M.G.

N83-30424# Royal Signals and Radar Establishment, Malvern (England).
OTHER TYPES OF DISPLAY
A. J. HUGHES *In* AGARD Mod. Display Technol. for Airborne Appl. 12 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

A selection of newer and less well advanced display technologies that need further development before commercial or military acceptance are discussed are all non-emissive and include magnetooptic, magnetic particle, electrochemical, and various electro-mechanical displays. The properties and limitations of these various techniques are reviewed and compared with those of more established liquid crystal displays. R.J.F.

N83-30425# Royal Aircraft Establishment, Farnborough (England).
OPTICAL TECHNIQUES FOR AIRBORNE DISPLAYS
G. H. HUNT *In* AGARD Mod. Display Technol. for Airborne Appl. 12 p (SEE N83-30414 19-06) Apr. 1983 refs
Avail: NTIS HC A11/MF A01

Different types of optical designs used in airborne electronic displays are discussed in broad terms. The design constraints of each are noted. Optical filters, biocular magnifying displays, head-up displays, diffractive-optic displays, and multicolor displays are discussed. R.J.F.

N83-30426# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
APPLICATIONS
W. M. HOLLISTER *In* AGARD Mod. Display Technol. for Airborne Appl. 9 p (SEE N83-30414 19-06) Apr. 1983
Avail: NTIS HC A11/MF A01

Relative comparisons are made among various competing display technologies. Performance measures selected for comparison are summarized. Comparisons are made with regard to luminous intensity, reflectance, contrast, color, and resolution. Advantages and disadvantages are listed. An assessment of the potential of each technology for each application is summarized. R.J.F.

N85-18988# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TECHNICAL EVALUATION REPORT ON THE 46TH SYMPOSIUM OF THE AVIONICS PANEL ON SPACE SYSTEM APPLICATIONS TO TACTICAL OPERATIONS
J. STATSINGER (Aerospace Corp., El Segundo, Calif.) Loughton, England Sep. 1984 16 p Symp. held in Hampton, Va., 17-20 Oct. 1983
(AGARD-AR-203; ISBN-92-835-1478-5; AD-A148374) Avail: NTIS HC A02/MF A01

The highlights are presented of the NATO Secret AGARD Avionics Panel Symposium on space system applications to tactical operations, which convened in order to accomplish the following: (1) provide an overview of tactical needs which are effectively addressed by space systems; (2) characterize the various existing and potential space systems with emphasis on those attributes which are most related to tactical needs; (3) assess the advantages and limitations of space systems in supporting combat operations; (4) investigate the interaction of space assets with ground and mobile resources and the consequent operational issues; and (5) discuss future trends in space technology and their relationship to evolving combat needs. R.S.F.

N85-23798# Advisory Group for Aerospace Research and Development, Paris (France). Avionics Panel.
DESIGN FOR TACTICAL AVIONICS MAINTAINABILITY, TECHNICAL EVALUATION REPORT
B. L. DOVE, ed. and J. B. CLARY, ed. Oct. 1984 13 p
(AGARD-AR-204; AD-A150576) Avail: NTIS HC A02/MF A01

The inherent logical makeup of digital systems presents the opportunity for improving the maintainability of complex avionic systems. While there was limited success in the early use of Built-In-Self-Test and Built-In-Test (BIST/BIT), higher levels of circuit integration now offer even greater opportunities and challenges to avionic systems designers. However, while past and current digital systems designs have BIST/BIT as an add-on feature, future avionic system designs must be designed for maintainability. Recently, improved techniques and tools to support design for maintainability have become available to avionics systems designers. If used appropriately, these new approaches can lead to dramatic improvements in avionic systems maintainability. Advanced methods and tools to support design for avionic maintainability are discussed. Since modern avionic systems consist of programmable processors, both hardware and software design for maintainability issues and approaches were discussed. B.W.

07

AIRCRAFT PROPULSION AND POWER

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

N83-34953# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PROPULSION AND ENERGETICS PANEL WORKING GROUP 14 ON SUITABLE AVERAGING TECHNIQUES IN NONUNIFORM INTERNAL FLOWS
M. PIANKO, ed. (ONERA, Chatillon, France) and F. WAZELT, ed. (Technische Hochschule Darmstadt, West Germany) 1982 172 p
(AGARD-AR-182(ENG.); AD-A133968) Avail: NTIS HC A08/MF A01

Numerous investigations were made into how the average properties across a nonuniform or unsteady flow to characterize it for the purpose of one dimensional performance of a gas turbine powerplant. Collection and review of existing practice or proposal for averaging nonuniform and or unsteady flows; identification of averaging techniques to calculate heat, power, thrust, and efficiency; qualification where applicable of uncertainty levels of different averaging methods, recommendation of methods for adoption, and recommendation of futher research activities to resolve uncertainties were studied. Author

N84-12168# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AUXILIARY POWER SYSTEMS
Loughton, England Sep. 1983 228 p refs In ENGLISH and FRENCH Meeting held in Copenhagen, 30-31 May 1983
(AGARD-CP-352; ISBN-92-835-0339-2; AD-A136220) Avail: NTIS HC A11/MF A01

The state-of-the-art of aircraft auxiliary power systems for electrical, hydraulic, and pneumatic subsystems is reviewed. The advantages and problems associated with such systems are defined and future design improvements are identified. For individual titles, see N84-12169 through N84-12186.

N84-12169# Bundesministerium der Verteidigung, Bonn (West Germany).
AUXILIARY POWER REQUIREMENTS: THEIR ROLE IN AIRCRAFT PERFORMANCE
E. W. ECKERT *In* AGARD Auxiliary Power Systems 17 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

Based on the historical development and the actual status of requirements, the trends of essential parameters are analyzed, physical and technical possibilities are assessed and a prognosis is offered. Increasing demands for secondary power for subsystems and more powerful engines have led to stronger secondary power components, thus creating a mass problem. Energy losses add a thermal problem. Complexity rises rapidly with the number of inputs and outputs. All of this, together with such aspects as redundancy, reliability, safety, maintainability and life cycle cost, composes today's auxiliary power system. The future system, in response to high performance requirements and budgetary and personnel restrictions, should aim at less complexity and more efficiency.
Author

N84-12170# Societe Microturbo, Toulouse (France).
AUXILLIARY POWER SYSTEMS WITH GAS TURBINES [GROUPES AUXILIAIRES A TURBINE A GAZ]
A. ROMIER and P. CALMELS *In* AGARD Auxiliary Power Systems 8 p (SEE N84-12168 03-07) Sep. 1983 In FRENCH
Avail: NTIS HC A11/MF A01

Gas turbine auxilliary power systems were developed to meet the demand for aircraft autonomy during their use for checklist, conditioning from the ground, and main engine starting. Solutions developed in the military and civil domains for a short operational pure start system are examined as well as an auxilliary system with continued operation. Present trends on modern aircraft where the starting system is capable of continued operation are considered. Future needs that can be predicted as a function of the growing complexity of onboard weapons systems which require ground conditioning, the development of principal reactors imposing ever more important starting power, and operation as a help in the flight domain with extremely reduced time of use are explored. Transl. by A.R.H.

N84-12171# KHD Luftfahrttechnik G.m.b.H., Oberursel (West Germany).
SECONDARY POWER SYSTEMS FOR FIGHTER AIRCRAFT EXPERIENCES TODAY AND REQUIREMENTS FOR A NEXT GENERATION
W. HAUSMANN, M. PUCHER, and T. WEBER *In* AGARD Auxiliary Power Systems 15 p (SEE N84-12168 03-07) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

The necessary of a continuous increase of fighting efficiency of weapon systems sets forth a number of new requirements for the next generation of military aircraft in particular regarding the distribution and use of the onboard auxiliary power. Energy conversion methods have to be applied which are readily adaptable to operation requirements and also favour the thermal balance of the aircraft. As an example of the pneumatic energy conversion the efficiency of an auxiliary system is presented together with a listing of those factors which play a role in its optimization. Design concepts and options available for future systems are presented Experience derived from a modern fighter aircraft system serves as a basis for discussion of advanced requirements and design features. Author

N84-12172# Solar Turbines International, San Diego, Calif. Turbomach.
SMALL AUXILIARY POWER UNIT DESIGN CONSTRAINTS
C. RODGERS *In* AGARD Auxiliary Power Systems 19 p (SEE N84-12168 03-07) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

Self-sufficiency for military aircraft operating from remote advanced bases can be attained with small on-board air breathing gas turbine auxiliary power units (APUs) supplying main engine start and aircraft secondary power. The small, fixed shaft, gas turbine configuration comprising the single-stage radial compressor and radial inflow turbine, mounted back-to-back, and overhung from a cold end bearing capsule has found favor in providing this duty due to inherent attributes of low costs, simplicity and high power-to-weight ratio. Extensive experience with these APUs has led to the formulation of several major design constraints, within the objective of minimum life cycle costs, that enhance development of both modified and derivative versions. Some of these design constraints are discussed and advantageous areas of research and development for future APUs are identified.
Author

N84-12173# KLM Royal Dutch Airlines, Amsterdam (Netherlands).
APU IN COMMERCIAL AIRLINE OPERATION
H. W. C. L. SCHOEVERS and A. BOOY *In* AGARD Auxiliary Power Systems 9 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

Advantages and disadvantages of incorporating auxiliary power units in commercial aircraft are discussed. Reliability, maintenance and weight costs, and fuel savings are specifically addressed. The auxiliary power unit (APU) provides pneumatic and electrical power on the ground for operation of the air conditioning and electrical systems and for starting the main engines. Operation and control are fully automatic after start initiation, making a better use of the manpower available. Since the airplane's air packs are run, the APU can provide a cooler aircraft at boarding time on hot days than ground equipment. Moreover, individual temperature control of the cabin sections is possible. The APU reduces dependence on ground equipment availability and reliability, thus enhancing on-time performance. It reduces the quantity of required ramp equipment, thus reducing ramp congestion and consequently turn-around time. Even a water system may fall in this category. On some aircraft availability of the APU may be used to replace a failing engine generator during specific flight phases. M.G.

N84-12174# ABG-Semca S.A., Toulouse (France).
AUXILIARY POWER UNITS FOR WIDE-BODY AIRCRAFT
S. RIAZUELO, M. CENIVAL (Turbomeca, Bizanos, France), and M. EGLEM *In* AGARD Auxiliary Power Systems 14 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

Existing auxiliary power units for wide body aircraft are described with individual consideration given to the power section, accessory gear box, load compressor, and digital electronic regulation modules. Requirements for future designs of such systems are identified. M.G.

N84-12175# British Aerospace Aircraft Group, Brough (England).
SECONDARY POWER SUPPLIES FOR A SMALL SINGLE ENGINE COMBAT AIRCRAFT
G. JONES *In* AGARD Auxiliary Power Systems 7 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

A possible secondary power supply system for a small single engined combat aircraft is described along with the way in which reliability, survivability and installation problems influence the type of system which is proposed for such an aircraft. The particular constraints imposed by the use of a Pegasus vectored thrust engine in a short take off vertical landing (STOVL) aircraft are also discussed. The proposed system consists of a conventional engine driven accessory gearbox to provide hydraulic and electrical power in flight. A remotely mounted auxiliary power unit (APU) is used to start the engine by means of a pneumatic link from a load compressor. The APU drives a separate standby hydraulic pump and generator for ground operation and emergency power in flight. Possible areas of future research and development which would lead to improved efficiency and reduced weight are also discussed M.G.

N84-12176# Avions Marcel Dassault, Saint-Cloud (France). Dept. au Bureau d'Etudes Serie.
HYDRAULIC GENERATION OF AUXILLIARY POWER FOR THE MIRAGE 2000 AIRCRAFT [GENERATION HYDRAULIQUE DE SECOURS DU MIRAGE 2000]
P. ATLAN *In* AGARD Auxiliary Power Systems 6 p (SEE N84-12168 03-07) Sep. 1983 In FRENCH
Avail: NTIS HC A11/MF A01

The auxiliary hydraulic power system of the Mirage 2000 aircraft is described and justified. The system was designed to respond to a particular problem that is specific to that aircraft. A source of energy was found and a means of putting it to work to assure the operation of the aircraft flight control hydraulic servocommand in the case of a dead engine and in the tail slide maneuver flight phase was developed. Transl. by A.R.H

N84-12177# British Aerospace Aircraft Group, Preston (England).
OPTIMIZATION OF ENGINE POWER OFFTAKE BY SECONDARY POWER SYSTEM DESIGN
J. R. HOPKINS *In* AGARD Auxiliary Power Systems 15 p (SEE N84-12168 03-07) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

The configuration constraints presented to a systems engineer when designing a secondary power system are examined with particular reference to the minimizing of engine power offtake. The effects of power offtake on the engine and current solutions available to the systems designer are discussed. A secondary power system which is optimized for a twin engined, agile, combat aircraft is defined. M.G.

N84-12178# Rocket Research Corp., Redmond, Wash.
HOT GAS APU STARTER FOR ADVANCED AIRCRAFT APPLICATIONS
B. W. SCHMITZ, L. D. GALBRAITH, W. E. JORGENSON, and D. A. PAHL *In* AGARD Auxiliary Power Systems 14 p (SEE N84-12168 03-07) Sep. 1983 refs
(Contract F33615-76-C-2148)
Avail: NTIS HC A11/MF A01

A hot gas rotary vane motor for aircraft APU starting over the environmental temperature range of -65 F to + 130 F was tested. Problems with excessive gas consumption and binding of parts due to differential expansion are indicated. The effect of friction coefficient, vane weight, venting, and blade linking on overall internal friction are shown. Design approaches evolved to minimize overall friction and loads on the vanes. A motor successfully demonstrated operation at environmental temperatures down to -65 F and as repeated restart capability are solved. Design criteria allow application of the rotary vane motor to specific aircraft starting requirements. E.A.K.

N84-12179# Teledyne CAE, Toledo, Ohio Advanced Development and Technical Planning.
A JET FUEL STARTER FOR LOWEST SYSTEM LIFE CYCLE COST
R. SMITH *In* AGARD Auxiliary Power Systems 11 p (SEE N84-12168 03-07) Sep. 1983 refs
(Contract F33657-76-C-2055)
Avail: NTIS HC A11/MF A01

A modular Jet Fuel Starter design employing an Expendable Gasifier (EG) concept indicates a substantial life cycle cost savings over a conventional overhauled unit. To achieve these savings, a low cost gasifier is a mandatory requirement. The EG does this by maximizing cast to hear net shape components, using aluminum cold end castings and by minimizing the use of expensive high temperature alloys. Gasifier performance parameters, specific power, compressor pressure ratio, cycle temperature and fuel consumption, were selected to minimize component stress and sensitivity to refined dimensions. The gasifier interfaces were established to fit optional JFS and auxilarily power unit installations, and include turbojets and turbofans suitable for unmaned vehicles. E.A.K.

N84-12180# Lufthansa G.m.b.H., Hamburg (West Germany).
COST EFFICIENT ON BOARD POWER FOR AIRLINE OPERATION
K. MOSE *In* AGARD Auxiliary Power Systems 12 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

Airline experience with auxiliary power units (APU), influenced by the fuel crisis was reviewed. Typical APU design features and performance outputs, supplying bleed air and/or electrical power on board the airplane are presented. It is suggested that the economical impact on APU operation are tue to fuel cost increase and high level of APU maintenance cost. Remedy actions are proposed by: incorporation of fuel saving modification programs and reduction of APU operating time which will effect the operating procedures. The utilization of alternative power sources on the ground, providing on board power, by mobile or stationary systems for electrical and pneumatic supply with respect to: system compatibility with on board power requirements and availability and necessary cost investments are proposed. E.A.K.

N84-12181# Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany).
APU OPERATIONAL EFFICIENCY
W. HOOSE *In* AGARD Auxiliary Power Systems 15 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

Exprience with a new generation on Auxiliary Power Unit (APU) installed in a commercial transport aircraft is presented. Operational requirements and efficiency of the APU in the Various operating modes are outlined. The factors determining the APU performance characteristics with respect to a cost effective are emphasized. Future development trends seen from the point of view of the aircraft manufacturer is considered. E.A.K.

N84-12182# Vereinigte Flugtechnische Werke G.m.b.H., Bremen (West Germany).
GROUND AND INFLIGHT OPERATIONAL EFFECTS OF APU'S
J. H. RENKEN *In* AGARD Auxiliary Power Systems 17 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

The Airbus APU which has a deliver well defined quantities of bleed air and electrical power under two very different conditions on ground and inflight was examined. The on ground operation is essentially governed by problems like noise generation and emission, and ingestion of hot gas, constraining the possible range of intake and exhaust position. The infight operation is dominated by the external fuselage flow conditions intake and exhaust are exposed to and which may effect significantly the installation

pressure-ratio and with that the infight restart envelope and infight performance. Depending on fuselage surface pressures and boundary layer conditions, intake and exhaust geometries and ducting have to be designed so that a favourable IPR is provided during APU starting as well as APU operation, keeping at the same time negative effects on the aircraft as for instance drag increase at a minimum. The effect of these environmental conditions on the APU performance is discussed. E.A.K.

N84-12183# Rockwell International Corp., Canoga Park, Calif.
SUPER INTEGRATED POWER UNIT FOR FIGHTER AIRCRAFT
A. D. LUCCI, J. A. WILLIAMS, E. C. BEDER, and B. L. MCFADDEN (AFAPL, Wright-Patterson AFB, Ohio) *In* AGARD Auxiliary Power Systems 6 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

The SIPU concept the designs of the demonstrator, and each of its subsystems are described. An SIPU is a multifunctional aircraft power unit capable of providing (1) electrical, pneumatic, and hydraulic power for ground maintenance and standby operations, (2) normal and emergency main engine start power, and (3) emergency electrical and hydraulic power. Power is obtained either from jet fuel combustion with air for ground operations and normal engine starts, from a gas generator system using onboard stored propellants for emergency functions, or from the aircraft main engine compressor air for the emergency electrical and hydraulic power function. The benefits resulting from the use of an SIPU are pesented. E.A.K.

N84-12184# Rolls-Royce Ltd., Bristol (England).
ALL-ELECTRIC ACCESSORY DRIVE SYSTEMS: IMPLICATIONS ON ENGINE DESIGN AND PERFORMANCE
G. B. TOYNE and G. S. HODGES *In* AGARD Auxiliary Power Systems 8 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

All-electric accessory power systems were studied. The effects on engine design and performance are outlined. In the all-electric proposal, all accessory power requirements are generated and distributed electrically. Air bleeds for environmental control systems are replaced by increased shaft power offtake. The concept which is considered for a large subsonic offers the prospect of simplification and weight reduction in the engines. For supersonic combat aircraft, the concept is not recommended; with relatively higher levels of shaft power offtake, additional handing problems will be created. The effects on the engine and aircraft weight and systems as a whole consideration. E.A.K.

N84-12185# Sundstrand Advanced Technology Group, Rockford, Ill.
IMPLEMENTING MICROPROCESSOR TECHNOLOGY IN AIRCRAFT ELECTRICAL POWER GENERATING SYSTEM CONTROL
G. RUFFNER, B. MENL, and S. LORENZ *In* AGARD Auxiliary Power Systems 15 p (SEE N84-12168 03-07) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

The implementation of microprocessor technology of most control protection and build on test functions, the aircraft electrical power generating systems is described. The design implementation process used in current system is highlighted. With the adaptation of advanced microprocessor systems in the next generation of aircraft electric systems, additional functions can be implemented. Microprocessor control of generator paralleling and voltage regulation coupled with more effective builtin test capabilities will result in significant improvements in system performance. E.A.K.

N84-12186# Auxilec S.A., Colombus (France). Electro-Technics Dept.
THE 400 HZ GENERATORS EVOLUTION, EFFECTS ON INSTALLATION ARRANGEMENTS
C. JACQUES *In* AGARD Auxiliary Power Systems 11 p (SEE N84-12168 03-07) Sep. 1983
Avail: NTIS HC A11/MF A01

The need for 400 Hz electric power which keeps on increasing on airplanes is discussed. Up to now the way to obtain constant frequency from variable speed drive is either hydro or electro mechanical. New conversion systems are arising: they take benefits from the most recent improvements and developments in high speed electrotechnics and power electronics. Rotational speeds running at more than 2400 r.p.m. are accessible to the onboard generator and a significant improvement of power to weight ratio is obtained. The installation of such a generator on aircraft entails an high speed gear whic can be combined with it or, installed in the accessory gearbox. The cooling of the whole system is realized by air or, by oil, electronic components included. Optimum design leads to share the oil circuit of the gearbox with the generator cooling system. E.A.K.

N84-16188# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
VISCOUS EFFECTS IN TURBOMACHINES
Loughton, England Sep. 1983 380 p refs In ENGLISH and FRENCH Conf. held in Copenhagen, 1-3 Jun. 1983
(AGARD-CP-351; ISBN-92-835-0340-6; AD-A139749) Avail: NTIS HC A17/MF A01

Experts and specialists from industry, research institutes, and universities establish the latest state-of-the-art regarding: viscous-inviscid interactions, viscous flow computations, end-wall boundary layers, and experimental measurements from multistage turbomachines. For individual titles, see N84-16189 through N84-16211.

N84-16189# Office National d'Etudes et de Recherches Aerospatiales, Leclerc (France).
PROGRESS IN COMPUTATION OF VISCOUS INVISCID INTERACTION
J. C. LEBALLEUR *In* AGARD Viscous Effects in Turbomachines 26 p (SEE N84-16188 07-07) Sep. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

The numerical techniques based on viscous-inviscid interaction are surveyed with a very global view, to get the main developments areas, the capacities and constraints. Then restricting to the integral methods interacted with a defect formulation, typical examples are presented for the calculation of separated flows in external aerodynamics, using the approximation of a potential inviscid flow. Results achieved in internal aerodynamics, using a defect integral method interacted with the full Euler equations are presented. The calculated flow is a choked transonic channel flow, with a turbulent shock wave-boundary layer interaction which generates a very small separation. The coupling is converged with the previously suggested zonal relaxation technique, direct or semi-inverse, including a local and automatic control of the numerical stability. Author

N84-16190# National Gas Turbine Establishment, Farnborough (England). Turbomachinery and Installations Dept.
APPLICATION OF AN INVISCID-VISCOUS INTERACTION METHOD TO TRANSONIC COMPRESSOR CASCADES
W. J. CALVERT *In* AGARD Viscous Effects in Turbomachines 13 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

Results obtained using an inviscid-viscous interaction method to predict the blade-to-blade flow in axial compressors are compared with experimental data from a number to transonic linear cascades. The cascades cover a wide range of duties, with inlet Mach numbers varying from 0.8 to 1.46 and flow deflections from 70 deg to 50 deg. Generally the predictions are in good agreement with the test data. Author

N84-16191# Vrije Universiteit, Brussels (Belgium). Dept. of Fluid Mechanics.
A VISCID INVISCID INTERACTION PROCEDURE FOR TWO DIMENSIONAL CASCADES
P. JANSSENS and C. HIRSCH *In* AGARD Viscous Effects in Turbomachines 18 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

A viscous inviscid interaction scheme was developed in order to predict fluid turning and loss coefficients for arbitrary cascade bladings of axial and centrifugal turbomachines. The effects of the blade surface boundary layers, separation of these boundary layers and the wake downstream of the trailing edge are taken into account by the wake displacement body method. The effective separation line between the inviscid outer flow, separated boundary layers and the wake is iteratively searched using a free streamline method. A Kutta Joukowsky condition at the trailing edge corrects the outlet flow angle and ensures zero loading on the wake. The outer potential flow is solved in a finite element Galerkin

approximation and the boundary layer development is predicted with an integral method. Corrections based on Richardson numbers are included for streamline curvature and Coriolis effects on turbulence. Author

N84-16192# Hochschule der Bundeswehr, Munich (West Germany).
DESIGN OF TRANSONIC COMPRESSOR CASCADES FOR MINIMAL SHOCK LOSSES AND COMPARISON WITH TEST RESULTS
L. FOTTNER and H. J. LICHTFUSS (Motoren- und Turbinen-Union) *In* AGARD Viscous Effects in Turbomachines 22 p (SEE N84-16188 07-07) Sep. 1983 refs Sponsored in part by Bundesministerium der Verteidigung
Avail: NTIS HC A17/MF A01

Blading concepts with respect to optimal profile shape take into account the close interdependence between the pressure distribution on profile suction and pressure side and the boundary-layer development (i.e. the losses) on these surfaces. For transonic compressor bladings with minimal losses, the shock and shock/boundary-layer interaction losses have to be carefully considered. For supersonic inlet conditions these losses were reduced by using wedge-type profile shapes in the supersonic part of the profile (wedge-type). On the other hand the diffusion losses in the subsonic region (rear part of the blade) can be reduced by reducing subsonic deflection of a given vector triangle, resulting in a limited supersonic expansion (MCA-type). Thus, a careful optimization process must be done for the partition of supersonic and subsonic deflection. Cascade tests were carried out for the mid section of a rotor blade of a three-stage transonic compressor. The analysis of these tests and additional laser anemometry measurements within the compressor showed good agreement between design and test and proved the low loss design of the special profile types. Author

N84-16193# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
FLOW TRAJECTORIES, MIXING AND ENTROPY FLUXES IN A TURBINE CASCADE
J. MOORE *In* AGARD Viscous Effects in Turbomachines 14 p (SEE N84-16188 07-07) Sep. 1983 refs Sponsored in part by Rolls Royce, Ltd.
Avail: NTIS HC A17/MF A01

Flow in a turbine cascade with a 281 mm axial chord and a one million exit Reynolds number studied by Langston, et al. at United Technologies Research Center is considered. Measurements were made in a geometrically similar cascade with an axial chord of 235. mm and the same span/chord and pitch/chord ratios. The present five-blade cascade has an exit Reynolds number based on axial chord of 580,000. Measurements of total pressure and flow direction downstream of the cascade complement the results of Langston et al. which showed the flow development only within the cascade. The downstream flow is important, however, as approximately 50% of the losses occur downstream of the trailing edge. Regions of high-loss fluid are found and the origin of fluid in these regions is traced using the ethylene injection technique with a flame ionization detector. From a computational standpoint, there is interest not only in the location of the ethylene at the downstream plane, but also in the concentration levels and the diffusion rates. From a practical standpoint, the most significant result from the present tests is that the highest entropy fluxes downstream of this cascade (at x/c = 1.4) occur near midspan in a high-loss core and not near the end walls. Author

N84-16194# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
A COUPLING METHOD FOR THE INVERSE MODE CALCULATION OF TRANSONIC INTERNAL FLOWS WITH A SHOCK WAVE [METHODE DECOUPLAGE POUR LE CALCUL EN MODE INVERSE DES ECOULEMENTS INTERNES TRANSSONIQUES AVEC ONDE DE CHOC]
G. MEAUZE and J. DELERY *In* AGARD Viscous Effects in Turbomachines 15 p (SEE N84-16188 07-07) Sep. 1983 refs Original language document announced as A83-48183
Avail: NTIS HC A17/MF A01

A coupling method for modeling internal transonic flows with shock waves is presented, based on the a priori selection of the positions of the interaction zones. Nonviscous flow is calculated using the Euler equations, the Prandtl equations are employed for the dissipative layers (with solutions obtained by the finite difference technique), and an integral method is used for the boundary layers. Control surfaces are defined at the boundary of the viscous layer, along the displacement surface, and along the surface of the body itself. Coupling on the displacement surface is stressed, and account is taken of the pressure gradients and the shape of the streamlines on the displacement surface. Comparisons of the model predictions with data from ONERA S8Ch transonic channel (two dimensional) demonstrate that velocity profiles can be accurately generated, even with multiple separation zones. An inverse-inverse mode is appropriate in a symmetric channel, such as a nozzle, where a generalized depiction of turbulence can be obtained.
M.S.K. (IAA)

N84-16195# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
AN EXPERIMENTAL METHOD FOR ANALYZING SHOCK-BOUNDARY LAYER INTERACTIONS IN CASCADES [METHODE D'ANALYSE EXPERIMENTALE DE L'INTERACTION CHOC-COUCHE LIMITE EN GRILLES D'AUBES]
A. FOURMAUX *In* AGARD Viscous Effects in Turbomachines 9 p (SEE N84-16188 07-07) Sep. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

The small physical thickness of cascades boundary layers, due to the usually small dimensions of the test models, makes it difficult to measure the characteristic parameters of the viscous layer. In order to estimate the displacement effect and to evaluate the importance of the shock-boundary layer interactions, a time-marching computation method is used in inverse mode to reconstitute the flow in the channel from static pressure plot on the blade. The principle and the limits of this method of analysis are presented, as well as comparisons between the calculation results and detailed measurements carried out within the channel. Furthermore, the purely experimental aspect is considered: techniques used to adjust and control the flow, and measurement techniques. Author

N84-16196# United Technologies Research Center, East Hartford, Conn. Gas Dynamics and Thermophysics Dept.
COMPRESSOR AND TURBINE BLADE BOUNDARY LAYER SEPARATION
M. J. WERLE *In* AGARD Viscous Effects in Turbomachines 13 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

Numerous sites on compressor and turbine blades are susceptible to the phenomenon of boundary layer separation. In such situations it is found that the boundary layer is incapable of negotiating a local adverse pressure gradient, which is subsequently relieved as it breaks away from the surface and induces a strong interaction with the inviscid stream. Since losses and heating due to such occurrences can be significant, a need continues to exist for efficient, and reliable prediction techniques for this class of problems. A multiyear, multiphase program aimed at developing and assessing finite difference techniques for a wide range of separation induced problems is reviewed. Results are given for leading edge bubbles, transonic shock induced seperations, cove aide bubbles, and trailing edge induced wake bubbles. Both the analytical technique and collaborating experimental studies are discussed and directions for future research are identified.
Author

N84-16197# Cambridge Univ. (England). Dept. of Engineering.
THE DEVELOPMENT OF UNSTEADY BOUNDARY LAYERS ON THE ROTOR OF AN AXIAL-FLOW TURBINE
H. P. HODSON *In* AGARD Viscous Effects in Turbomachines 18 p (SEE N84-16188 07-07) Sep. 1983 refs Sponsored in part by the Central Electricity Generating Board and the Science and Engineering Research Council
Avail: NTIS HC A17/MF A01

The effects of rotor-stator interactions upon the efficiency of a large scale, low speed turbine were investigated. A comparison is made between the performance of the mid-span section of the rotor blades and of a rectilinear cascade of identical geometry. Wind tunnels were operated at a Reynolds number of 3.15 x 10(5). Measurements of the blade surface boundary layers and

their associated profile losses are presented. The profile loss of the turbine rotor at mid-span was approximately 50 percent higher than that of the rectilinear cascade. The mean velocity profiles of the boundary layers indicate that this difference is mainly due to the higher growth rate of the suction surface boundary layer on the turbine rotor. The time-resolved boundary layer measurements indicate that the increased growth rate is caused by the interaction of the wakes of the upstream nozzle row with the blade surface boundary layers. This results in a localized transition of the otherwise laminar boundary layers. The boundary layers thus alternate between characteristically laminar and turbulent states during one wake passing cycle. M.G.

N84-16198# Pisa Univ. (Italy). Ist. di Macchine.
AERODYNAMIC COMPUTATION METHOD OF AIRFOIL CASCADES SUBJECTED TO VISCOUS FLOW
P. PSARUDAKIS *In* AGARD Viscous Effects in Turbomachines 17 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

A computational method for the determination of aerodynamic characteristics of airfoil cascades subjected to viscous flow is presented. The method is based on the determination of the flux perturbation directly due to the local continuous stream velocity over every single cascade airfoil. Particular attention is given to the development of a method suitable to decrease computation time and, at the same time, to make possible versatile application to physical phenomena simulation. Various comparisons with theoretical and experimental values carried out by other authors confirm the validity of the present method. Author

N84-16199# Newcastle-upon-Tyne Univ. (England). Lab. for Fluid Mechanics and Thermodynamics.
NUMERICAL SIMULATION OF STALLING FLOWS BY AN INTEGRAL EQUATION METHOD
R. I. LEWIS and D. T. C. PORTHOUSE *In* AGARD Viscous Effects in Turbomachines 17 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

An integral equation method is presented for the solution of the Navier Stokes equations for stalling aerofoil, cascade or bluff body flows. Vorticity created at the aerofoil or body surface at each time step of a numerical procedure, is diffused into the main stream and convected by the local velocity vector. Viscous diffusion is simulated by a model akin to Brownian motion whereby all shed vorticity elements are given random displacements at each time step. Solutions are shown for boundary layers, bluff bodies, aerofoils and a first attempt at a cascade. M.G.

N84-16200# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
COMPUTING THE THREE DIMENSIONAL BOUNDARY LAYER IN A COMPRESSOR [CALCULS DE COUCHE LIMITE TRIDIMENSIONNELLE DANS UN COMPRESSEUR]
B. AUPOIX and J. COUSTEIX *In* AGARD Viscous Effects in Turbomachines 13 p (SEE N84-16188 07-07) Sep. 1983 refs In FRENCH; In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

The study of transport equations for turbulent stress on a turning reference mark or on a curved wall revealed two types of effects. There was a stabilization or destabilization of the turbulence due to the longitudinal curvature with the component of the rotation vector parallel to the wall, and a three dimensional effect when the component of the rotation vector is normal at the wall. The stabilizing or destabilizing effect, as well as that of the exterior turbulence was introduced into a mixing length scheme which was then used to construct families of profiles of the speed of the boundary layer by similitude. The analysis of these families of profiles supplied closure relations for an integral method of calculating three dimensional boundary layers. Transl. by A.R.H.

N84-16201# Stuttgart Univ. (West Germany). Inst. fuer Luftfahrt-Antriebe.
VISCOUS EFFECTS AND HEAT TRANSFER IN A CALCULATION METHOD FOR AXIALSYMMETRIC FLOW IN MULTISTAGE TURBOMACHINES USING THE STREAM FUNCTION
W. SANDEL *In* AGARD Viscous Effects in Turbomachines 10 p (SEE N84-16188 07-07) Sep. 1983 refs Sponsored in part by Deutsche Forschungsgemeinschaft
Avail: NTIS HC A17/MF A01

A method is described for including viscous effects and heat transfer in a through-flow computation procedure based on the stream function approach for steady axialsymmetric flow. Viscous shear stress and heat conduction relations are used within a coarse grid resolution due to storage and computation time limitations in multistage applications. Near the end walls an analytic function is used to model the dissipation rate. The approach allows for energy transport across streamlines. M.G.

N84-16202# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
EFFECTS OF A SKEWED INLET END WALL BOUNDARY LAYER ON THE 3-D FLOW FIELD IN AN ANNULAR TURBINE CASCADE
E. BOLETIS, C. H. SIEVERDING, and W. VANHOVE *In* AGARD Viscous Effects in Turbomachines 16 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

The results of an experimental investigation on the effect of a skewed inlet boundary layer on the flow field in a low speed, low speed, low aspect ratio, high turning annular turbine nozzle guide vane are presented. Three test series differing by their degree of inlet skew were performed. The flow was explored by means of double head four hole pressure probes in five axial planes from upstream to far downstream of the blade row. The results are presented in the form the contour plots and spanwise pitch-averaged distributions. The axial evolution of the measured pitch-averaged spanwise flow angle distribution is compared with a three dimensional, inviscid, rotational flow calculation. M.G.

N84-16203# Durham Univ. (England). Dept. of Engineering.
SECONDARY FLOWS AND LOSSES IN A TURBINE CASCADE
D. G. GREGORY-SMITH and C. P. GRAVES (Gilbert Gildes and Gordon, Ltd.) *In* AGARD Viscous Effects in Turbomachines 24 p (SEE N84-16188 07-07) Sep. 1983 refs Sponsored in part by Rolls Royce, Ltd. and the U.K. Ministry of Defence
Avail: NTIS HC A17/MF A01

An investigation was made of the flow in a cascade of large scale rotor blades of some 110 deg of turning. The aspect ratio (span/chord) was 1.77, and the inlet boundary layer on the end walls was varied around 0.2 of the span. The flow was traversed in great detail on ten planes using cobra type probes with a computerized data recording and analysis system. The results are presented graphically using contour and vector plots on various planes through the flow field. The horse-shoe vortex and passage vortex development are clearly seen, with the upstream boundary layer being shed downstream as a loss core. Another region of high loss is related to a counter vortex in the corner between the suction surface and the end wall. The results were also pitch averaged, and compared with predictions of angle and loss distribution. Some traversing was also carried out using hot wire anemometry. Regions of high turbulence intensity and shear stress were identified, associated with the regions of high loss. Some indication is given of the mechanisms of loss production within the cascade. M.G.

N84-16204# National Technical Univ., Athens (Greece). Lab. of Thermal Turbomachines.
BOUNDARY LAYER DEVELOPMENT ON ROTATING BODIES OF REVOLUTION
L. LAMBROPOULOS, P. KTENIDIS, and K. PAPAILIOU *In* AGARD Viscous Effects in Turbomachines 7 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

Existing experimental data concerning rotating viscous flows are analyzed. It is demonstrated how one may describe such cases in the rotational frame of reference, using simple boundary layer notions. Boundary layer calculations are then performed in order

to predict these flows. The theoretical and experimental results are found to be in a very good agreement. M.G.

N84-16205# Vrije Universiteit, Brussels (Belgium). Dept. of Fluid Mechanics.

END-WALL BOUNDARY LAYER CALCULATIONS IN MULTISTAGE AXIAL COMPRESSORS

J. DERUYCK and C. HIRSCH *In* AGARD Viscous Effects in Turbomachines 16 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

A previously developed theory for the calculation of a three dimensional boundary layer along any curved axisymmetric wall surface is summarized. In addition, new defect force correlations take into account the interactions between blades and end-wall boundary layer flows, in particular tip clearance effects, relative motion and secondary losses are included. Velocity profiles are reconstructed from the integral boundary layer thicknesses by use of velocity profile models defined in the meridional and angular directions. The different aspects of the theory are tested systematically on various configurations. It is shown that the overall behavior of axial compressor boundary layers can be simulated with the present method and that the defect force correlations are able to simulate all the secondary flow effects. M.G.

N84-16206# Ecole Centrale de Lyon (France). Lab. de Mecanique des Fluides.

EXPERIMENTAL AND THEORETICAL STUDIES OF PARIETAL VISCOUS BOUNDARIES IN A SINGLE STAGE TRANSONIC COMPRESSOR [ETUDES EXPERIMENTALES ET THEORIQUES DES COUCHES VISQUEUSES PARIETALES DANS UN COMPRESSEUR MONO-ETAGE TRANSSONIQUE]

F. LEBOEUF and H. NAVIERE *In* AGARD Viscous Effects in Turbomachines 10 p (SEE N84-16188 07-07) Sep. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

Experimental results obtained in a one-stage transonic axial flow compressor, which is a typical stage of an aeronautical motor are presented. Emphasis is placed on the velocity vector in front of and downstream of the blades, near the hub and the tip of the machine. These flows are studied theoretically. The main characteristics of the method are that the transfer of information is properly realized while changing a frame of reference. Also a very good computational stability is obtained. In this method, two equations for the transport of two vorticity components are used in parallel with the equations which describe, in an integral form, the 3D viscous layer, and with an equation which describes the inviscid flow at the wall. Comparison between the experimental and theoretical results attests to the validity of the method.
Author

N84-16207*# Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.

ANNULUS WALL BOUNDARY LAYER DEVELOPMENT IN A COMPRESSOR STAGE, INCLUDING THE EFFECTS OF TIP CLEARANCE

B. LAKSHMINARAYANA, K. N. S. MURTHY, M. POUAGARE, and T. R. GOVINDAN *In* AGARD Viscous Effects in Turbomachines 17 p (SEE N84-16188 07-07) Sep. 1983 refs
(Contract NSG-3212)
Avail: NTIS HC A17/MF A01

The end-wall boundary layer development in a compressor stage, including the inlet guide vane (IGV) passage and the rotor passage, was measured. The measurement upstream of the rotor and inside the IGV passage were carried out with a five-hole probe. The data (blade-to-blade) inside the IGV passage were carried out with a five-hole probe. The data (blade-to-blade) inside the rotor passage were measured using a three-sensor rotating hot-wire below the tip clearance region and 'V' configuration probe inside the clearance region. The rotor exit measurements (blade-to-blade) were acquired with a laser Doppler velocimeter. The velocity profiles and the integral properties are presented and interpreted. The boundary layer is comparatively well behaved up to the leading edge of the rotor, beyond which complex interactions result in very unconventional profiles. The momentum thicknesses decrease in the leakage flow region of the rotor. The momentum thicknesses and the limiting streamline angles predicted from a momentum integral technique agree well with the data up to the leading edge of the rotor. M.G.

N84-16208*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

END-WALL BOUNDARY LAYER MEASUREMENTS IN A TWO-STAGE FAN

C. L. BALL, L. REID, and J. F. SCHMIDT *In* AGARD Viscous Effects in Turbomachines 23 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01 CSCL 21E

Detailed flow measurements made in the casing boundary layer of a two-stage transonic fan are summarized. These measurements were taken at stations upstream of the fan, between all blade rows, and downstream of the last blade row. At the design tip speed of 429 m/sec the fan achieved a peak efficiency of 0.846 at a pressure ratio of 2.471. The boundary layer data were obtained at three weight flows at the design speed: one near choke flow, one near peak efficiency, and one near stall. Conventional boundary layer parameters were calculated from the data measured at each measuring station for each of the three flows. A classical two dimensional casing boundary layer was measured at the fan inlet and extended inward to approximately 15 percent of span. A highly three dimensional boundary layer was measured at the exit of each blade row and extended inward to approximately 10 percent of span. The steep radial gradient of axial velocity noted at the exit of the rotors was reduced substantially as the flow passed through the stators. This reduced gradient is attributed to flow mixing. The amount of flow mixing was reflected in the radial redistribution of total temperature as the flow passed through the stators. The data also show overturning of the tip flow at the stator exits that is consistent with the expected effect of the secondary flow field. The blockage factors calculated from the measured data show an increase in blockage across the rotors and a decrease across the stators. M.G.

N84-16209# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Antriebstechnik.

FLOW MEASUREMENTS IN THE STATOR ROW OF A SINGLE-STAGE TRANSONIC AXIAL-FLOW COMPRESSOR WITH CONTROLLED DIFFUSION STATOR BLADES

R. J. DUNKER *In* AGARD Viscous Effects in Turbomachines 13 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

The time-dependent three dimensional viscous flow downstream of the rotor in a single-stage transonic axial-flow compressor without inlet guide vanes was measured and analyzed at design and off-design operating conditions. Measurements were made between the blade rows and within the stator row which had been recently redesigned using a controlled diffusion blade design method. Detailed measurements of the blade surface pressure distributions were performed in order to investigate whether the favorable behavior of controlled diffusion blades can be obtained under the real flow conditions within a turbomachine, and not only under those conditions in a cascade. These data, as well as laser-velocimetry data, indicate blade boundary layer separation under some operating conditions. The optical measurements were taken at different instantaneous rotor positions relative to the stator. These results give some insight into the unsteady flow within the stator, e.g. the development of the fluctuating velocity vectors, of the turbulence intensity, of the rotor blade wakes, and of the stator blade boundary layers. M.G.

N84-16210# United Technologies Research Center, East Hartford, Conn. Gas Turbine Technology Div.

COMPRESSOR ROTOR AERODYNAMICS

R. P. DRING, H. D. JOSLYN, and J. H. WAGNER *In* AGARD Viscous Effects in Turbomachines 16 p (SEE N84-16188 07-07) Sep. 1983 refs
(Contract NAS3-23157; F33615-77-C-2083)
Avail: NTIS HC A17/MF A01 CSCL 20E

Although the numerical sophistication of multi-stage turbomachinery through-flow calculations has evolved to a very high level, the aerodynamic inputs of total pressure loss, deviation and blockage are subject to a high degree of empiricism. There is a need for detailed flow field data in a multi-stage environment in order to bring some discipline to this important aspect of turbomachinery design. A survey of some of the initial results of an in-depth investigation of the aerodynamics of the second stage of a large scale two stage axial compressor is presented. The

second stage rotor data are compared with data obtained on an isolated rotor with very thin and then very thick inlet hub and tip boundary layers. The single and multi-stage rotor data presented include surface flow visualization and rotating frame radial/circumferential traverse measurements presented in the form of fullspan contour plots of rotary total pressure. Also presented are the spanwise distributions of loss, deviation and blockage. Some implications of these results for through-flow analyses are discussed. M.G.

N84-16211# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
EXPERIMENTAL VERIFICATION OF AN ENDWALL BOUNDARY LAYER PREDICTION METHOD
C. W. ELROD and J. L. BETTNER (Detroit Diesel Allison Div.) *In* AGARD Viscous Effects in Turbomachines 21 p (SEE N84-16188 07-07) Sep. 1983 refs
Avail: NTIS HC A17/MF A01

An endwall boundary layer code was verified in a low speed compressor facility and used to compute casing blockage and efficiency penalty in a full-scale engine. Detailed endwall boundary layer measurements and overall compressor performance measurements were obtained for various conditions of surface roughness, porosity and tip clearance in the low speed compressor facility. Stage pressure ratio and stall margin were determined for the single-stage compressor at three corrected speeds. Shroud roughness did not markely reduce overall compressor performance at design conditions, but did result in some loss of stall margin. Shroud wall porosity, on the other hand, did reduce design point performance, but also substantially increased stall margin. The shroud endwall boundary layer code exhibited overall satisfactory agreement with solid smooth/rough endwall experimental results, but was not as effective for the T56-A-100 experimental results. The code was effective in predicting tip clearance effects.
Author

N85-15733# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ENGINE CYCLIC DURABILITY BY ANALYSIS AND TESTING
Loughton, England Sep. 1984 271 p refs In ENGLISH and FRENCH Conf. held in Lisse, Netherlands, 30 May - 1 Jun. 1984
(AGARD-CP-368; ISBN-92-835-0362-7; AD-A149028) Avail: NTIS HC A12/MF A01

Engine utilization and accelerated mission testing development; critical material characterization; life assessment methodologies; and component and engine cyclic testing are discussed. The current state-of-the-art in technolgical areas is related to improving engine life. The technical and economical problems of advanced cyclic testing in the development of engines are considered with focus on relationships between engine utilization and failure modes, accelerated mission testing development, critical material characteristics, component life assessment methods, recent results of component and engine cyclic testing, and future requirements. For individual titles see N85-15734 through N85-15751.

N85-15734# Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
IN-FLIGHT EVALUTION OF LCF LIFE CONSUMPTION OF CRITICAL ROTOR COMPONENTS SUBJECTED TO HIGH TRANSIENT THERMAL STRESS
G. E. BREITKOPF and T. M. SPEER *In* AGARD Eng. Cyclic Durability by Analysis and Testing 15 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

The calculation procedure under review offers the opportunity of a rapid approximation of transient temperatures and thermal stresses in the rotor structure of a gas turbine engine. The method can be implemented with the aid of a microprocessor system, permitting the Low Cycle Fatigue (LCF) life consumption of components subject to considerable thermal stresses, such as HP turbine and compressor stages, also to be calculated with good accuracy in flight. In view of the large scatter in the life consumption per hour flown and the large number of influencing parameters, concerning the hot section components, calculation of the life actually consumed per flight on completion of the flight would seem to be the only method that is simultaneously simple to handle and sufficiently accurate to enable the cyclic strength of the components to be used to the full. Author

N85-15735# Rolls-Royce Ltd., Bristol (England).
MONITORING ENGINE THERMAL STRESSES
T. M. EDMUNDS and R. A. LAWRENCE *In* AGARD Eng. Cyclic Durability by Analysis and Testing 20 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

The high performance and rapid response of modern military engines means that transient thermal stresses make a significant contribution to the fatigue life utilization of critical rotating components. This, coupled with the variability of actual usage, raises a requirement for calculating transient thermal stresses from flight recorded data. A computationally efficient procedure for meeting this requirement is described. The analysis is based on a simplified model of the heat transfer and mechanics of the engine that is tuned with results of more sophisticated finite difference and finite element computations. Applications to a engine disc are described using data collected by on-board recordings. The results are validated by comparisons with more detailed theoretical analyses - practical constraints preventing a direct measurement of in-flight stresses. The integration of the results into the overall lifting procedure is also briefly described. Author

N85-15736# Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
ACCELERATED MISSION ENDURANCE TESTING (AMET)
W. R. TAYLOR *In* AGARD Eng. Cyclic Durability by Analysis and Testing 5 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

The cost of ownership of gas turbine aircraft engines today makes it imperative that the development process produce a production engine that will minimize life cycle cost. This problem was recognized and one of the most significant changes that was made in the last 10 years is the incorporation of AMET into the development programs. In the past, engine designs were qualified for production release when it successfully completed a 150 hour model test. However, as these engines accumulated service time, problems arose that were not discovered in factory test. It was apparent that the durability of these engines were not well understood. In 1973, the US Air Force, Navy, and Detroit Diesel Allison incorporated a new test cycle in their TF41 engine development program that was representative of the ircraft usage. The success of this effort encouraged the incorporation test method into other engine development programs. Today, the US Air Force uses factory test cycles for design verification and qualification that were derived from known or projected aircraft usages. The background of mission related testing, test cycle derivation, data sources, key parameters, limitations and benefits will be discussed. Author

N85-15737# Turbomeca S. A. - Brevets Szydlowski, Bordes (France).
DESIGN AND TEST REQUIREMENTS FOR DEVELOPMENT OF TODAY'S ENGINES [EXIGENCES DE CONCEPTION ET D'ESSAI POUR DEVELOPPER LES MOTEURS D'AUJOURD'HUI]
J. FRESCO *In* AGARD Eng. Cyclic Durability by Analysis and Testing 14 p (SEE N85-15733 07-07) Sep. 1984 In FRENCH Original language doc. previously announced as N82-17205
Avail: NTIS HC A12/MF A01

To adapt to the ever greater safety and profitability requirements for transport aircraft, the engine must fulfill two functions which are often of an opposite nature: performance and durability The combination of these two lines of force: performance (translated in terms of fuel consumption or power) and durability, lead to the final objective which is cost reduction. Today, from the beginning of a new engine, it is necessary to quarantee potentials that are of the same order, if not superior, to those of engines which have already accumulated thousands of flight hours. The different methods that permit achieving the durability objective are analyzed including how they are involved in engine design. Tests which best reproduce the damage phenomena are described, and some examples are given which relate particularly to small engines.
Transl. by A.R.H.

N85-15738# National Aerospace Lab., Amsterdam (Netherlands).
OVERVIEW OF THE AGARD SMP ACTIVITIES ON TURBINE ENGINE MATERIALS TECHNOLOGY IN THE 1972 - 1982 PERIOD
A. J. A. MOM *In* AGARD Eng. Cyclic Durability by Analysis and Testing 34 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

An overview of research on turbine engine technology over the last 10 years is given. These activities cover most of the material related aspects in gas turbine technology from the initial design stage up to the final retirement of components. The development and application of advanced materials; material properties and behavior; material processing and fabrication techniques; maintenance and repair; and life prediction methods are discussed. With respect to the advanced materials and fabrication techiques, attention is given to the directionally solidified in-situ composites, the ceramic materials and the powder metallurgy materials, and their different processing aspects. New fabrication techniques like hot isostatic pressing, superplastic forming and surface treatments are included. Furthermore the corrosion behavior and low cycle fatigue characteristics of engine materials, including methods to predict creep and fatigue behavior, e.g., the strain range partitioning method, are discussed. Finally, attention is given to maintenance, repair and life prediction of engine components. Emphasis is directed to the introduction of damage tolerance concepts to make a more economic use of inherently available component life than is presently done by the safe life philosphy. R.J.F.

N85-15739# Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany). Materials Lab.
COMPARISON BETWEEN THE PROPERTIES OF CONVENTIONAL WROUGHT AND POWDER METALLURGICAL ALLOYS FOR TURBINE DISC APPLICATIONS
G. W. KOENIG *In* AGARD Eng. Cyclic Durability by Analysis and Testing 11 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

Mechanical properties of powder-metallurgical nickel-base superalloys (e.g., U700PM; Rene 95) were evaluated in order to predict the behavior of advanced aero-engine discs in comparison with conventional wrought nickel-base (e.g., Waspaloy; IN 718) discs. The assessment includes tensile strength, crack initiation and propagation fatigue life as well as the influence of mean stress. Special emphasis was put on the question about the scatter in fatigue lives resulting from defects in the material (e.g., oxide inclusions) and on the surface (e.g., grooves). The tolerance with respect to these defects was estimated on the basis of fracture mechanics methods. The potential of advanced nickel-base superalloys with respect to static strength and fatigue life is superior to that of currently used conventional wrought disc materials. It is shown that the most important requirement for the use of this fatigue potential is a high quality standard which limits the maximum size of defects both in the material and on the surface. The now available knowledge of the variable influencing the reliability of disc materials enables an optimization to obtain improved service behavior. Furthermore, the strength and quality of materials as well as the manufacturing process can be fitted to the requirements of each type of component. R.J.F.

N85-15740# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry Cedex (France). Lab. des Materiaux et Procedes.
INCONEL 718 ALLOY RESISTANCE TO CRACK PROPAGATION [RESISTANCE A LA PROPAGATION DE FISSURES DE L'ALLIAGE INCONEL 718]
L. PORET, J. Y. GEUDOU, and A. PINEAU (Ecole des Mines de Paris) *In* AGARD Eng. Cyclic Durability by Analysis and Testing 11 p (SEE N85-15733 07-07) Sep. 1984 refs In FRENCH
Avail: NTIS HC A12/MF A01

Resistance to crack propagation was studied in different nuances of Inconel 718 at high temperatures (550 C to 650 C) in fatigue, creep, and fatigue creep. Tests were conducted in both vacuum and air. A notable sensitivity to the effect of holding time was observed. This sensitivity depends on the microstructure of the alloy (hydrocarbon distribution, grain size and shape, the presence or absence of Beta phase, cold hardening) as well as the effects of oxidation. Fundamental data relating to propagation velocity were applied to a test disk on which premature priming led to the production of a crack until rupture. A calculation of contraints using the finite element method, the use of curves obtained from tests on test pieces, in conditions representing influences on the test pieces, permitted accounting for experimental observations (number of propagation cycles determined by counting streaks). A.R.H.

N85-15741# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
CUMULATIVE DAMAGE MODELING OF FATIGUE CRACK GROWTH
J. M. LARSEN and T. NICHOLAS *In* AGARD Eng. Cyclic Durability by Analysis and Testing 15 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

Life predictions of turbine engine structural components utilize fracture mechanics principles to determine fatigue crack growth rates. Fatigue cracks grow under conditions of variable temperature, frequency, hold time, stress ratio, and stress level. At elevated temperatures, time dependent material behavior can play a significant role in the material behavior. Cumulative damage models must account for all these variables as well as interaction effects. The earliest modeling involved interaction schemes, and, primarily, time independent material behavior. More recent work focused on time dependence and creep fatigue interaction effects. A review of current modeling concepts and problems is presented. R.J.F.

N85-15742# National Aeronautical Establishment, Ottawa (Ontario). Structures and Materials Lab.
PROBLEMS AND POSSIBILITIES FOR LIFE EXTENSION IN GAS TURBINE COMPONENTS
A. K. KOUL, W. WALLACE, and R. THAMBURAJ (Carleton Univ., Ottawa) *In* AGARD Eng. Cyclic Durability by Analysis and Testing 32 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

Data showing the beneficial effects of hot isostatic processing on the stress rupture properties of new and service exposed Ni based superalloy turbine blades are presented. Creep design methods that are generally used to highlight the service induced degeneration effects are critically analyzed. A new life prediction method that systematically analyzes the creep degeneration effects with increasing service life is proposed. Results indicating the successful application of a damage tolerance based maintenance methodology in Canadian Forces J85 engine compressor and turbine discs are discussed. Possibilities of enhancing engine component durability through improved machining techniques and reheat treatments are also discussed. Author

N85-15743# Royal Aircraft Establishment, Farnborough (England). Materials and Engineering Research Div.
DISC FATIGUE LIFE PREDICTIONS FOR GAS TURBINE ENGINES
W. J. EVANS, M. E. F. SMITH, and C. H. H. WILLIAMS *In* AGARD Eng. Cyclic Durability by Analysis and Testing 13 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

Safe cyclic lives for discs in gas turbine engines were determined. The current procedures which are based on a life-to-first-crack philosophy and, in Britain, require full scale component testing to establish a service safe life are reviewed. The limitations of this approach are highlighted. It is then suggested that an alternative method based on fatigue crack propagation should overcome some of the limitations. Before this alternative can be adopted, however, it is important to develop quantitative models for the types of crack that occur in engine discs. These cracks tend to be embedded, situated at stress concentration features and subjected to multiaxial stress fields. Some of the published work on such cracks is reviewed and the more relevant models detailed. An experimental program on the titanium alloy Ti-6-4 is then described in which the behavior of small cracks is evaluated for stress concentration features in bend specimens and model discs. R.S.F.

N85-15744*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
ENGINE CYCLIC DURABILITY BY ANALYSIS AND MATERIAL TESTING
A. KAUFMAN and G. R. HALFORD *In* AGARD Eng. Cyclic Durability by Analysis and Testing 12 p (SEE N85-15733 07-07) Sep. 1984 refs Previously announced as N84-18683
Avail: NTIS HC A12/MF A01 CSCL 21E

The problem of calculating turbine engine component durability is addressed. Nonlinear, finite-element structural analyses, cyclic constitutive behavior models, and an advanced creep-fatigue life prediction method called strainrange partitioning were assessed for their applicability to the solution of durability problems in hot-section components of gas turbine engines. Three different component or subcomponent geometries are examined: a stress concentration in a turbine disk; a louver lip of a half-scale combustor linear; and a squealer tip of a first-stage high-pressure turbine blade. Cyclic structural analyses were performed for all three problems. The computed strain-temperature histories at the critical locations of the combustor linear and turbine blade components were imposed on smooth specimens in uniaxial, strain-controlled, thermomechanical fatigue tests of evaluate the structural and life analysis methods. Author

N85-15745# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
LIFE PREDICTION AT HIGH TEMPERATURE UNDER MULTIAXIAL LOADING
G. CAILLETAUD and J. L. CHABOCHE *In* AGARD Eng. Cyclic Durability by Analysis and Testing (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

The activities of ONERA concerning the life prediction of high temperature components are summarized. In the last few years, the viscoplastic finite element computer code EVPCYCL was developed which is suitable for any two-dimensional problem (plane stress or strain, axisymmetrical case). The code's main specificity is the choice of various possibilities concerning the consititutive equations: cyclic calculations can be made with kinematic and isotropic hardening, with the introduction of a memory effect, etc. Graphic post-processors are available as well as a life prediction program that takes into account creep and fatigue damage.
Author

N85-15746# Brown Boveri Research Center, Baden (Switzerland).
EXPERIENCES WITH THE MATERIAL BEVAVIOUR AND HIGH TEMPERATURE LOW CYCLE FATIGUE LIFE PREDICTION OF THE IN 738 BLADING ALLOY
M. Y. NAZMY, H. WETTSTEIN, and A. WICKI (Brown, Boveri and Co. Ltd, Baden, Switzerland) *In* AGARD Eng. Cyclic Durability by Analysis and Testing 12 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

The high temperature low cycle fatigue (HTLCF) behavior of the blading alloy IN 738 as studied in air at 850 C is studied. This aided in a basic understanding of the behavior of this alloy as well as the different methodologies used in life time prediction. Another part of the investigation was focused on the influence of different environmental effects on the (HTLCF) behavior. These environmental conditions were chosen to simulate as much as possible the actual conditions imposed on the gas turbine blades. Mainly sulfur containing environments were utilized for this purpose. Author

N85-15747# Rolls-Royce Ltd., Derby (England).
CYCLIC ENDURANCE TESTING OF THE RB211-22B CAST HP TURBINE BLADE
J. S. PONSFORD and G. K. WADDINGTON *In* AGARD Eng. Cyclic Durability by Analysis and Testing 11 p (SEE N85-15733 07-07) Sep. 1984
Avail: NTIS HC A12/MF A01

During the design and development of a cast directionally solidified high pressure turbine blade for the Rolls-Royce RB211-22B engine, it was recognized that a method of proving the design beyond the normal endurance testing was required in order to simulate the total service life of the turbine blade. This led to the creation of the intensive cyclic endurance program. The aim of the program was to prove that the new HP turbine blade was capable of achieving the design objective of a 10,000 hour service life. The objectives of the program the definition of the endurance cycles and the automation used in running the cyclic test are discussed. The modifications incorporated to ensure that testing was kept representative of the service environment are considered. The results of the program which demonstrated that the design objective would be achieved in airline service are included. B.W.

N85-15748# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Turbine Engine Div.
VERIFICATION OF LIFE PREDICTION THROUGH COMPONENT TESTING
R. J. HILL *In* AGARD Eng. Cyclic Durability by Analysis and Testing 9 p (SEE N85-15733 07-07) Sep. 1984
Avail: NTIS HC A12/MF A01

A status on report on the results of current rig and component testing being conducted under the life assessment testing (LAT) approach to turbine engine durability validation is given. Focus is the combination of using material of reduced life capability and creatin conditions of higher stress to produce short-time failure for cost effective validation of the tools and rules of life prediction. The three components discussed are combustors, compressor disks and turbine blades. B.W.

N85-15749# Brown, Boveri und Cie, A.G., Mannheim (West Germany).
MECHANICAL ASPECTS OF HIGH TEMPERATURE COATINGS
K. SCHNEIDER and H. W. GRUENLING *In* AGARD Eng. Cyclic Durability by Analysis and Testing 17 p (SEE N85-15733 07-07) Sep. 1984 refs
Avail: NTIS HC A12/MF A01

The strains that arise due to thermal expansion mismatch during the application of a coating are described. These strains cause cracks within a coating which reduce its ability to protect the base metal against a corrosion attack. The influence of the coating on the mechanical properties of the coated component is described. In general, a high temperature component is subjected to static loadings. The material undergoes creep, and in cyclic loadings, the component undergoes fatigue. In both cases a coating has some influence either through changes in the material properties due to a different heat treatment or through changes in the surface of a component due to the presence of the coating; hence a coating alters the conditions for crack initiation. From laboratory experience of high temperature coatings applied to gas turbine blades it can be shown that, depending on the type of coating and the method of application, the changes in materials might be positive, negative or negligible. B.W.

N85-15750# Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
CFM 56-2. OLIGOCYCLIC FATIGUE OF THE TURBOFAN DISK: DIMENSIONNING AND TESTS FOR VERIFICATION AND IMPROVEMENTS [CFM56-2 - FATIGUE OLIGOCYCLIQUE DU DISQUE DE SOUFFLANTE: DIMENSIONNEMENT ET ESSAIS POUR LA VERIFICATION ET LES AMELIORATIONS]
A. GUIBERT and G. HERMAN *In* AGARD Eng. Cyclic Durability by Analysis and Testing 13 p (SEE N85-15733 07-07) Sep. 1984 In FRENCH
Avail: NTIS HC A12/MF A01

Among other components, SNECMA developed the turbofan disk as part of the CFM56-2 program. Analysis of constraints and associated verifications were included from the start of the program by using finite element analysis techniques as well as sophisticated verification tests (photoelasticity). An important part of the analysis of life durability consisted of an understanding of the behavior of the material (studies of test pieces) and in the preparation of large scale oligocyclic tests. Results obtained in the latter tests allowed ultimate verification and improvement before engine certification. The combination of results thus obtained coherently demonstrated the life durability of the turbofan disk.
Transl. by A.R.H.

N85-15751# Pratt and Whitney Aircraft Group, West Palm Beach, Fla. Engineering Div.

VIEW OF FUTURE REQUIREMENTS FOR ENGINE CYCLIC DURABILITY BY ANALYSIS AND TESTING

T. E. FARMER *In* AGARD Eng. Cyclic Durability by Analysis and Testing 6 p (SEE N85-15733 07-07) Sep. 1984 refs

Avail: NTIS HC A12/MF A01

Future requirements of engine cyclic durability analysis and testing. These requirements must satisfy advancements in technology and configuration in a cost-effective manner. The importance are discussed of demonstrating engine durability is emphasized. It is essential that an integrated approach to durability verification be developed and involve component durability analysis, engine measured parameters, laboratory test and engine demonstrated capabilities. Automated analysis techniques must confidently relate test conditions to field operation; non-interference sensors and enhanced data acquisition systems are required for extended test periods; and engine testing must efficiently address sensitivities, operating limits and cyclic capabilities. Verified component durability prediction systems that are developed can reduce the number of required engine endurance tests. Through coordination of durability analysis, data acquisition and component demonstration testing, more complete knowledge of engine durability will be achieved in a cost-effective manner. B.W.

N86-24692# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).

PROPULSION AND ENERGETICS PANEL WORKING GROUP 14 ON SUITABLE AVERAGING TECHNIQUES IN NON-UNIFORM INTERNAL FLOWS [PANEL DE PROPULSION ET D'ENERGETIQUE GROUPE DE TRAVAIL 14 METHODES D'ESTABLISSEMENT DE CARACTERISTIQUES MOYENNES DANS LES ECOULEMENTS INTERNES HETEROGENES]

M. PIANKO, ed. and F. WAZELT, ed. (Technische Hochschule, Darmstadt, West Germany) Loughton, England Aug. 1983 183 p refs In FRENCH; ENGLISH summary

(AD-A133968; AGARD-AR-182(FR); ISBN-92-835-2110-2) Avail: NTIS HC A09/MF A01 CSCL 21E

The averaging techniques used for nonuniform internal flow of gas turbine systems, in which the actual flows are usually heterogeneous and three-dimensional was studied. The test analysis and performance prediction methods are based upon simple one-dimensional models. Current practices were reviewed and a theoretical analysis of the relations which may be correctly applied to steady flow was undertaken and known averaging methods were classified. Refinements to known methods and a new approach to averaging for use with engine components and propulsion system analysis are proposed. A variety of possible averaging techniques are identified and compared by preparing a number of sample calculations in ducted flows, turbojet components and a complete propulsion system. The merits and the limitations of the methods studied are outlined. One method is recommended for stagnation temperature averaging. E.A.K.

N86-25360# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

DAMAGE TOLERANCE CONCEPTS FOR CRITICAL ENGINE COMPONENTS

Loughton, England Oct. 1985 295 p refs Presented in San Antonio, Tex., 22-26 Apr. 1985

(AGARD-CP-393; ISBN-92-835-0380-5) Avail: NTIS HC A13/MF A01

The proceedings of a specialist meeting called by the AGARD Structures and Materials Panel on damage tolerance concepts for critical engine components is presented. The meeting discussed the overall philosophy of damage tolerance as applied to aircraft engine parts, considered and refined the parameters important in DTC, reviewed specialist techniques needed for the support of DTC, and surveyed the prospects for and experiences of the implementation of DTC. For individual titles see N86-25361 through N86-25383.

N86-25361# Rolls-Royce Ltd., Derby (England).

DAMAGE TOLERANCE CONCEPTS FOR CRITICAL ENGINE COMPONENTS

R. H. JEAL *In* AGARD Damage Tolerance Concepts for Critical Engine Components 12 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

The cost of failures in gas turbines has always been so high, both in human and financial terms, that it has been recognized since the earliest days that the behavior of components had to be fully characterized before the engines were used in service. The integrity of the gas turbine has therefore always been based upon two separate phases of development. The first has been the basic design itself where, as well as ensuring that the individual components meet their basic mechanical purpose, the designer attempts to match his understanding of the operating conditions to his perception of the capability of material chosen. The second has been the development phase where the actual behavior of the component has been assessed either as part of an operating engine - bench engine testing or as an individual component - rig testing - under conditions which are related to those the engine is expected to see in service. The results of this work are then used, together with prior experience, to identify the critical components of the engine, those that prejudice the safety of the aircraft if they fail. The development of damage tolerance concepts is traced from the earliest days, the current situation is examined in light of design needs and available technology, and possible directions are examined. E.R.

N86-25362# Naval Air Propulsion Test Center, Trenton, N.J. Systems Development and Evaluation Group.

ENGINE CYCLIC DURABILITY BY ANALYSIS AND TESTING: HIGHLIGHTS OF THE SPRING 1984 PEP MEETING

A. A. MARTINO *In* AGARD Damage Tolerance Concepts for Critical Engine Components 13 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

Research on gas turbine engine development during the past decade in NATO nations has concentrated heavily on gaining better understanding of the relationship between material characteristics, failure mechanisms, structural analysis and validation testing for increased service life. Recognizing this intense interest and activity level the Propulsion and Energetics Panel (PEP) sponsored a specialists' meeting that surveyed the state-of-art technical areas related to improving engine life and considered the technical and economical problems and possibilities of advanced cyclic testing in the development of engines. Discussions focused on relationships between engine use and failure modes, accelerated mission testing (AMT) development, critical material characteristics, component life assessment methods, recent results of component and engine cyclic testing, and future requirements. Author

N86-25363# Air Force Systems Command, Wright-Patterson AFB, Ohio.

DAMAGE TOLERANCE DESIGN CONCEPTS FOR MILITARY ENGINES

T. T. KING, W. D. COWIE, and W. H. REIMANN *In* AGARD Damage Tolerance Concepts for Critical Engine Components 13 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

The damage tolerance requirements that are applied to Air Force engine development programs are summarized. These requirements are an integral part of the Engine Structural Integrity Program (ENSIP). Application of damage tolerance requirements to existing inventory engines (F100 and TF34) has resulted in implementation of enhanced nondestructive evaluation methods at manufacturing and at field/depot. Experience has shown that these inspections have been successful in detecting early cracking and accelerating corrective actions. It has been highlighted that several development efforts in the last five years have identified FPI process improvements that must be implemented within industry and Air Force depots to improve flaw detection reliability. The need to quantify detection reliability for imbedded defects is also identified. The engine development process has been evolutionary in terms of application of upgraded requirements. The new process is contained in ENSIP. Recent experience clearly demonstrates that the damage tolerance requirement is cost effective when assessed on a life cycle basis. Author

N86-25364# Toronto Univ. (Ontario). Dept. of Mechanical Engineering.
PARAMETERS THAT INPUT TO APPLICATION OF DAMAGE TOLERANCE CONCEPTS TO CRITICAL ENGINE COMPONENTS
D. W. HOEPPNER *In* AGARD Damage Tolerance Concepts for Critical Engine Components 13 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

Numerous parameters affect the application of damage tolerance concepts to engine components. These parameters are reviewed in relation to overall integration of each parameter into the damage tolerance design methodology. Parameters such as initial crack size, defect level associated with the material and process, and model of the initial crack are discussed as related to nondestructive inspection and modelling the discontinuity within a framework such as generalized fracture mechanics. Subsequent to characterization of the initial discontinuity or heterogeneity (d,h), or the likelihood of forming one in the service cycle, it is necessary to evaluate the potential for growth of a (d,h). Factors that affect the growth of a discontinuity in engines are: material, manufacturing route, stress magnitude, stress state, (uniaxial, biaxial, triaxial), residual stress, temperature, loading waveform, frequency of loading, loading spectrum, chemical environment. Furthermore, material properties of importance are thresholds of growth, fatigue crack growth behavior, and toughness. Numerous synergisms such as creep fatigue, corrosion fatigue, and fretting fatigue occur and must be considered. Evaluation of these parameters is discussed, gaps are identified, and an overall plan to integrate these into a safety critical component design methodology is presented.
Author

N86-25365# Rolls-Royce Ltd., Derby (England). NDT Technology.
LIMITATIONS OF MANUAL NDT SYSTEMS AND THE NO EYES CONCEPT
R. G. TAYLOR *In* AGARD Damage Tolerance Concepts for Critical Engine Components 9 p (SEE N86-25360 16-07) Oct. 1985 refs Previously announced as N86-14215
Avail: NTIS HC A13/MF A01

Defect tolerant design, particularly of aircraft components, and its links with nondestructive testing (NDT) are discussed. Engineering of the NDT technique, defect detection requirements, and human factors in the inspection cycle are considered.
Author

N86-25366# Royal Aircraft Establishment, Farnborough (England). Propulsion Dept.
THE ROLE OF THERMAL AND STRESS ANALYSES IN THE APPLICATION OF DAMAGE TOLERANT DESIGN
G. F. HARRISON and T. H. EDMUNDS (Rolls-Royce Ltd., Bristol, England) *In* AGARD Damage Tolerance Concepts for Critical Engine Components 16 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

Some of the important factors affecting the accuracy of proven analysis techniques in support of a damage tolerant design methodology are illustrated. Temperature sensitivity analysis and the relevance of component geometry in controlling characterized material behavior into models suitable in stress analysis is demonstrated. Examples indentifying critical stresses and critical locations in typical engine discs are presented. The implementation of fracture mechanics analysis methods to these regions is discussed. Finally their relevance to damage tolerant design concepts is evaluated.
Author

N86-25367# Minho Univ., Braga (Portugal).
DAMAGE TOLERANCE ACCEPTANCE METHODS IN STRUCTURAL COMPONENTS OF A MEDIUM CARBON STEEL AND A MEDIUM STRENGTH AL-MG ALLOY
C. M. BRANCO *In* AGARD Damage Tolerance Concepts for Critical Engine Components 16 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

A review of damage tolerance methodology is presented referring to main factors, parameters and computational procedure for the assessment of flaws in the structure in order to avoid fatigue failures. Flaw acceptance and fatigue design methods are also reviewed and dicussed. Results of a defect tolerance study in cruciform welded joints of low and medium strength steels are presented. Theoretical defect tolerance curves relating initial flaw sizes, applied nominal stress, endurance and weld and plate geometry are obtained. The results are compared with some experimental data and also with the medium strength Al-Mg alloy 5083. COD and J integral data for this material is presented in the temperature range -120 C to 200 C.
Author

N86-25368# Systems Research Labs., Inc., Dayton, Ohio. NDE Systems Div.
MANUFACTURING TECHNOLOGY FOR NONDESTRUCTIVE EVALUATION (NDE) SYSTEM TO IMPLEMENT RETIREMENT FOR CAUSE (RFC) PROCEDURES FOR GAS TURBINE ENGINE COMPONENTS
D. L. BIRX and D. G. DOOLIN *In* AGARD Damage Tolerance Concepts for Critical Engine Components 8 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

An automated NDE inspection system to detect surface flaws and inclusions in jet engine rotary parts was developed. The system implements the Air Force Retirement for Cause philosophy in which good, used engine parts are returned to service, and flawed components are retired for cause. Emphasis has thus been placed on improving current flaw detection and characterization techniques by using computer algorithms (removing the human decision process) and achieving basic inspection and predictive capabilities via automated eddy current and ultrasonic inspection techniques.
Author

N86-25369# National Aerospace Lab., Amsterdam (Netherlands).
AGARD COOPERATIVE TEST PROGAMME ON TITANIUM ALLOY ENGINE DISC MATERIAL
A. J. A. MOM and M. D. RAIZENNE (National Research Council of Canada, Ottawa, Ontario) *In* AGARD Damage Tolerance Concepts for Critical Engine Components 15 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

In recent years a strong interest in the application of damage tolerance techniques for lifing of gas turbine engine discs has developed. Before the damage tolerance approach can be safely implemented it requires sensitive and reliable crack detection techniques, operational loading information and improved knowledge of fatigue crack growth and fracture under service conditions. This latter aspect is the main subject of an international test program, in which a number of laboratories from North America and Europe participate under AGARD coordination. The first phase of the program is directed to test and specimen standardization and calibration of the different laboratories. The second phase will specifically address parameters relevant for real service operation like mission loading, sequence and dwell effects, temperature, fatigue threshold, etc. The background and first phase of the program are discussed.
Author

N86-25370# Cambridge Univ. (England). Dept. of Metallurgy and Materials Science.
ASPECTS OF SMALL CRACK GROWTH
M. N. JAMES and J. F. KNOTT *In* AGARD Damage Tolerance Concepts for Critical Engine Components 16 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

The nature of small defects which occur in engineering components and structures, and their subsequent growth to a size detectable by nondestructive inspection techniques are discussed. Consideration is given to fundamental aspects such as the modifying influence of residual stresses and crack closure on the growth of small cracks. Possible differences between laboratory test data and in-service crack growth are highlighted. Practical aspects are illustrated with specific reference to the example of the safety-critical high pressure turbine disc of an aeroengine.
Author

N86-25371# Royal Aircraft Establishment, Farnborough (England). Propulsion Dept.

CRACK GROWTH IN NEAR-ALPHA TITANIUM ALLOYS

C. R. GOSTELOW *In* AGARD Damage Tolerance Concepts for Critical Engine Components 5 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

Ever since the first gas turbine aero engine entered into service there has been pressure to develop more powerful yet more efficient and lightweight units. To this end manufacturers have endeavored to increase overall pressure ratios and maximum cycle temperatures while trying to limit engine size by using materials having higher strength-to-weight ratios and higher temperature capability. Two main material approaches were followed in order to help meet these requirements. These are the development of high strength, high temperature capability nickel base superalloys for extensive use in the turbine and the replacement of heavy steels and nickel alloys in the compressor by advanced lightweight titanium alloys. The latter approach was the driving force behind the development in the UK of a unique range of creep-resistant near-alpha titanium alloys suitable for use up to 600 C. A variety of parameters are described which can influence the crack growth characteristics of near-alpha titanium alloys, with particular reference to the UK alloy IMI685. The relevance of these laboratory data to actual engine operation is assessed. Author

N86-25372# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

CRACK GROWTH, STRAIN AND DAMAGE MEASUREMENTS USING AN IMPROVED POTENTIAL DROP TECHNIQUE

H. POLICELLA, G. BAUDIN, and G. CAILLETAUD *In* AGARD Damage Tolerance Concepts for Critical Engine Components 9 p (SEE N86-25360 16-07) Oct. 1985 refs In FRENCH; ENGLISH summary

Avail: NTIS HC A13/MF A01

An improved version of the potential drop technique and its applications to crack length, strain and damage measurements is presented. The electronic device, developed at ONERA, which supplies the specimen with a pulsed current is described. Two types of applications are then presented. In the first type several tests were conducted on two dimensional cracked specimens, made of different materials at different temperatures. An extension of the method was also made to three dimensional crack fronts. The potential drop in an uncracked strained solid was the sum of three terms, respectively due to elastic strain, plastic strain and damage. Applications were performed on AISI 316 steel at room temperature, INCO 718 at 650 C and UN 100 at 900 C and 1000 C. The plastic strain and damage determined with the P.D. technique are then compared with the ones measured using others methods. Author

N86-25373# Fiat Research Center, Orbassano, Turin (Italy).

SMALL DEFECT CHARACTERIZATION IN POWDER METALLURGY MATERIALS

S. R. FIORENTIN and H. WALTHER (Fiat Aviazione S.p.A., Turin, Italy) *In* AGARD Damage Tolerance Concepts for Critical Engine Components 12 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

Powder metallurgy nickel base superalloys are becoming important structural materials for the manufacturing of critical complex-shaped aircraft components (e.g. turbine disks). Since fatigue life is largely affected by the presence of defects, in order to extend the limit of application of PM materials as far as possible, the need is felt for a nondestructive technique capable of detecting defects of size down to approximately 50 micrometers. An ultrasonic technique is presented which allows the detection and characterization of such small defects. It is based on the analysis of the signals backscattered by the material lying in the focal region of a short pulse transducer. During a first overall inspection of the component a real time data processing allows both the detection of critical defects and the evaluation of average grain size. In successive local inspections, confined in the regions where inclusions have been detected, further information on their characteristics may be collected. Some experimental results obtained on powder metallurgy samples containing seeded inclusions are presented. Author

N86-25374# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.

ADVANCED EXPERIMENTAL METHODS FOR MONITORING THE BEHAVIOR OF SMALL CRACKS

J. M. LARSEN *In* AGARD Damage Tolerance Concepts for Critical Engine Components 9 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

Two specialized techniques for monitoring the behavior of small fatigue cracks are discussed. The first of these is an automated photomicroscopic system that produces a permanent photographic record of the growth of small surface cracks. The system is automated by a microcomputer which controls fatigue testing and operates a 35 mm camera. Data are obtained for the growth of small cracks of approximate sizes ranging from 25 micrometers to fracture. The precision of the photographic measurements is approximately 1 micrometer for cracks of the order of 25 micrometers in length. In addition to the photographic technique, a unique Interferometric displacement gage (IDG) which monitors the crack mouth opening behavior of small surface cracks is discussed. The IDG measurements produce a complete record of applied load vs. crack opening displacement. The load-displacement data are analyzed to determine effective crack length from compliance calibrations and to determine crack closure behavior. The capabilities of both the photomicroscopic and the interferometric techniques are discussed, and typical small crack data are presented. Author

N86-25375# TRW, Inc., Cleveland, Ohio.

MULTIAXIAL AND THERMOMECHANICAL FATIGUE CONSIDERATIONS IN DAMAGE TOLERANT DESIGN

G. E. LEESE and R. C. BILL (Army Research and Technology Labs., Cleveland, Ohio) *In* AGARD Damage Tolerance Concepts for Critical Engine Components 17 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

In considering damage tolerant design concepts for gas turbine hot section components, several challenging concerns arise: Complex multiaxial loading situations are encountered; thermomechanical fatigue loading involving very wide temperature ranges is imposed on components; some hot section materials are extremely anisotropic; and coatings and environmental interactions play an important role in crack propagation. The effects of multiaxiality and thermomechanical fatigue are considered from the standpoint of their impact on damage tolerant design concepts. Recently obtained research results as well as results from the open literature are examined and their implications for damage tolerant design are discussed. Three important needs required to advance analytical capabilities in support of damage tolerant design become readily apparent: (1) a theoretical basis to account for the effect of nonproportional loading (mechanical and mechanical/thermal); (2) the development of practical crack growth parameters that are applicable to thermomechanical fatigue situations; (3) the development of crack growth models that address multiple crack failures. Author

N86-25376# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Materials Lab.

ADVANCED QUANTITATIVE METHODS FOR NONDESTRUCTIVE EVALUATION

D. E. CHIMENTI and T. J. MORAN *In* AGARD Damage Tolerance Concepts for Critical Engine Components 17 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

Over the past decade and a half progress in nondestructive evaluation (NDE) methods which yield quantitative flaw information has been considerable and has sparked a revolution in the way industry and government view the capabilities and benefits of quality assurance or component integrity. Almost no NDE technique, new or established, is selected for research and development without examining its potential for providing accurate, quantitative defect information. Concurrent with this trend has been the increasing use of fracture mechanics in the design and life management of aircraft systems, placing in turn stringent requirements on quantitative nondestructive evaluation (QNDE). Nowhere are these demands heavier than in the case of advanced aircraft engine alloys where critical flaw sizes are measured in hundredths of an inch. Research in NDE, therefore, has concentrated on improving

defect sensitivity and reliability and providing the quantitative information essential to the new system maintenance philosphies, such as Retirement-for-Cause. In addition to the well known quantitative capabilities of standard techniques like radiography, dye penetrant, and in some cases, eddy current, developments in quantitative ultrasonics, eddy current, thermal wave techniques and exploitation of new medicial X-ray imaging methods offer alternatives with enhanced capabilities and possibly reduced cost. The state of the art in QNDE is discussed, as well as advanced methods currently in development. Author

N86-25377# Naval Air Development Center, Warminster, Pa.
STATISTICAL ANALYSIS OF SPIN PIT FAILURE DATA TO PREDICT INSERVICE B.1 LIVES OF GAS TURBINE DISKS
R. MAHORTER, S. FOWLER, and J. SALVINO (Naval Air Propulsion Test Center, Trenton, N.J.) *In* AGARD Damage Tolerance Concepts for Critical Engine Components 15 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

Currently used analytical predictive methods for establishing gas turbine disk lives have basic limitations associated with stress, thermal, and mission analyses among other factors. The difference between predicted life and actual in-service life is usually not known since most parts are removed from service prior to crack formation. The Navy is developing a predictive method based on statistical analysis of data from parts run to crack initiation in spin pit testing. As part of this work, the minimum number of disks needed to establish a viable predictive method is determined. Although data from the small sample size (5) used has a great deal of statistical uncertainty, it appears that analytical predictions may be anti-conservative. Author

N86-25378# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).
FRACTURE MECHANICS AND LCF-PROPERTIES OF ENGINE DISCS OF TI 6AL-4V, INCONEL 718 AND UDIMET 700 P/M-HIP
W. SCHUETZ and R. HEIDENREICH *In* AGARD Damage Tolerance Concepts for Critical Engine Components 13 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

Over the last decade IABG has carried out a large number of tests on gas turbine materials to determine the materials data necessary for the conventional lifing approach, that is LCF data, including dwell time effects and some HCF data. The data necessary for a damage tolerance approach as well as crack propagation properties were also determined. These tests were done at room and typical service temperatures. The materials were Ti 6A1 4V, Inconel 718 and Udimet 700 P/M-HIP. The specimens were machined from a number of nominally identical compressor discs of Ti A16 V4, from compressor discs of Inconel 718 and from disc-shaped 'pancakes' of Udimet 700 P/M-HIP. Constant amplitude tests under strain control with unnotched specimens and under stress control with notched specimens were carried out, as well as a number or relatively simple variable amplitude tests. Author

N86-25379# Technische Univ., Munich (West Germany) Materials Lab.
EVALUATION OF CYCLIC SPIN PIT TESTS FOR THE DAMAGE TOLERANCE OF DISKS
H. HUFF and G. W. KOENIG *In* AGARD Damage Tolerance Concepts for Critical Engine Components 13 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

In order to determine the damage tolerance at critical areas of nickelbase engine disks (bore, eccentric hole, blade slot) the crack propagation behavior was investigated. The experiments include cyclic spin pit tests on disks and fracture mechanics tests on small crack specimens. The results of the spin pit tests are compared with the crack propagation behavior predicted by fracture mechanics. The tolerance of engine disks with respect to small crack-like defects is estimated and the potential of the crack propagation life for application in service is discussed. It was found that at low and intermediate temperatures the crack propagation life is sufficient to cover a substantial portion of the life required for disks. With increasing temperature the influence of time dependent processes results in a very strong reduction of the defect tolerance. Author

N86-25380# National Aerospace Lab., Amsterdam (Netherlands).
TURBISTAN: A STANDARD LOAD SEQUENCE FOR AIRCRAFT ENGINE DISCS
A. J. A. MOM, W. J. EVANS (Royal Aircraft Establishment, Farnborough, England), and A. A. TENHAVE *In* AGARD Damage Tolerance Concepts for Critical Engine Components 12 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

The development of TURBISTAN is a joint international effort to derive a loading standard representative for fighter aircraft engine disc usage. A representative loading standard offers considerable potential advantages over the present zero-max type of loading used for disc material evaluation. This is because the standard incorporates the effects of subcycles, their number, magnitude and sequence, which are known to seriously affect disc life and for which current life prediction techniques only partly account. Therefore usage of the standard in fatigue tests provides an improved evaluation of material properties, structural details, fabrication techniques, surface quality and life prediction. The compilation of operational flight data is described along with their analysis and the the generation of a preliminary TURBISTAN sequence for 'cold' compressor discs. The sequence contains about 8000 cycles which represent 100 flights. In addition, the background and philosophy of a material testing program meant to assess the effectiveness of the standard and to explore the validity of the assumptions made in its derivation is described. Author

N86-25381# Rolls-Royce Ltd., Derby (England).
AN ANALYSIS OF RIG TEST DISC FAILURES
G. ASQUITH *In* AGARD Damage Tolerance Concepts for Critical Engine Components 10 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

A major objective in gas turbine engineering is the design and manufacture of discs that are reliable in service. Much depends on the accurate prediction of safe total lives and inspection intervals. Accurate predictions come from a complete understanding of material behavior involving experimentation, interpretation and quantification, for which a balanced program of laboratory specimen and full sized disc evaluation is required. Cyclic testing of full size discs is essential, this allows each disc to do its own 'Monte Carlo' evaluation of the large number of variables that affect the final result. Where life can be predictd entirely by linear elastic fracture mechanics some simplification can be introduced; this encourages studies in the quantification of short crack propagation behavior. Author

N86-25382# National Aerospace Lab., Amsterdam (Netherlands).
CONTRIBUTION OF TURBINE BLADE SERVICE FAILURES TO A DAMAGE TOLERANCE APPROACH
R. J. H. WANHILL and A. J. A. MOM *In* AGARD Damage Tolerance Concepts for Critical Engine Components 13 p (SEE N86-25360 16-07) Oct. 1985 refs
Avail: NTIS HC A13/MF A01

Modified repair of uprated first stage turbine blades from large turbofans was followed by several fatigue failures in service. The failure mode was low and high cycle fatigue starting at leading edge cooling holes. Fractographic and metallographic analysis indicated that insufficient thickness of the leading edge walls was a primary cause of failure. A more comprehensive investigation by the engine manufacturer showed that other parameters besides leading edge wall thickness could be primary causes of failure, namely the leading edge and serpentine airflows and the backflow margin. Relative life reduction factors based on combinations of all four parameters were estimated for many failed, cracked and nominally undamaged blades. Then it became possible to reject blades with unacceptable life reduction factors both before and after repair. This is effectively a life-on-condition damage tolerance approach to blade use. Author

N86-25383# National Research Council of Canada, Ottawa (Ontario).

PRACTICAL EXPERIENCE WITH DAMAGE TOLERANCE BASED LIFE EXTENTION OF TURBINE ENGINE COMPONENTS

A. K. KOUL, R. THAMBURAJ (Carleton Univ., Ottawa, Ontario), M. D. RAIZENNE, W. WALLACE, and M. C. DEMALHERBE *In* AGARD Damage Tolerance Concepts for Critical Engine Components 9 p (SEE N86-25360 16-07) Oct. 1985 refs

Avail: NTIS HC A13/MF A01

A detailed experimental and statistical analysis carried out to determine the risks and benefit of implementing a damage tolerance based lifing procedure for the General Electric J85-CAN40 engine is described. This is a post-facto investigation, using components of this engine retired by the Canadian Forces and the data available regarding these used parts. The emphasis is on the 5th stage compressor disk, which is one of the most crack prone components of this engine. A number of procedures were demonstrated by which the safe life and the safe inspection interval for this component can be calculated reliably. The possibility of improving the existing lifing procedure through a damage tolerance approach, and the limitations of the damage tolerance approach are discussed on the basis of experimental observations and information available from field experience. Author

N86-29823# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

HEAT TRANSFER AND COOLING IN GAS TURBINES

Loughton, England Sep. 1985 528 p In ENGLISH and FRENCH Symposium held in Bergen, Norway, 6-10 May 1985 (AGARD-CP-390; ISBN-92-835-0378-3) Avail: NTIS HC A23/MF A01

Heat transfer and cooling in gas turbines is one of the crucial fields in the quest for higher performance as well as life and reliability. The purpose of this symposium was to bring together experts from industry, research establishments and universities to discuss fundamental and applied heat transfer problems relevant to gas turbines and to exchange practical experience gained in component and engine development and testing. The symposium focussed on turbine blade cooling including the interaction of cooling and aerodynamics. Furthermore, heat transfer in compressors and combustion systems as well as heat exchangers was covered. Emphasis was also placed on heat transfer modeling, experimental techniques, and test facilities. For individual titles see N86-29824 through N86-29862.

N86-29824# Arizona State Univ., Tempe. Dept. of Mechanical and Aerospace Engineering.

COOLING TECHNIQUES FOR GAS TURBINE AIRFOILS: A SURVEY

D. E. METZGER *In* AGARD Heat Transfer and Cooling in Gas Turbines 13 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

A brief general background discussion of turbine heat transfer and cooling with compressor discharge air is given. Specific reference is made to a selection of current research areas for gas turbine engine cooling, including blade tip heat transfer, heat transfer in serpentine passages, multiple jet array impingement, heat transfer in pin fin arrays, disk heat transfer, and film cooling. An overview of various experimental methods used to acquire heat transfer data is also given, with an emphasis on newer methods used to acquire detailed local convection heat transfer information. Author

N86-29825# Rolls-Royce Ltd., Bristol (England). Turbine Research and Methods.

ROTATING HEAT TRANSFER INVESTIGATIONS ON A MULTI-PASS COOLING GEOMETRY

R. J. CLIFFORD *In* AGARD Heat Transfer and Cooling in Gas Turbines 12 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

The effect of rotation on the heat transfer in a complex 3D multi-pass turbine blade cooling geometry is reviewed. The test rig, the experimental technique and the initial results are discussed in detail. Basic checks at zero rotational speed showed good agreement with data obtained earlier on this model using an alternative transient technique. Rotation was shown to have a significant effect on the heat transfer distribution (+ or - 30%) which when averaged over the gas washed surfaces showed a reduction to 90% of the static value. The effect of these changes on the blade predicted metal temperatures and lives are also reviewed. Investigations are continuing to fully evaluate the implications of both Coriolis and buoyancy effects on the heat transfer distributions in these complex 3D geometries. M.G.

N86-29826# Hull Univ. (England). Dept. of Engineering Design and Manufacture.

LOCAL AND MEAN HEAT TRANSFER ON THE LEADING AND TRAILING SURFACES OF A SQUARE-SECTIONED DUCT ROTATING IN THE ORTHOGONAL-MODE

W. D. MORRIS and S. P. HARASGAMA (Royal Aircraft Establishment, Farnborough (England).) *In* AGARD Heat Transfer and Cooling in Gas Turbines 12 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

The results of an experimental study of local and mean heat transfer over the leading and trailing surfaces of a square-sectioned duct which is constrained to rotate about an axis perpendicular to the main direction of through flow are described. Both radially outward and inward coolant flow conditions are considered. Physical arguments are discussed which explain the data trends found in terms of Coriolis-induced secondary flows and rotational buoyancy and these trends are compared with the corresponding problem in circular-sectioned tubes. Author

N86-29827# Pratt and Whitney Aircraft of Canada Ltd., Longueuil (Quebec).

PRESSURE DROP AND HEAT TRANSFER CHARACTERISTICS OF CIRCULAR AND OBLONG LOW ASPECT RATIO PIN FINS

S. C. ARORA and W. A. MESSEH *In* AGARD Heat Transfer and Cooling in Gas Turbines 15 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

The pressure drop and heat transfer characteristics of circular and oblong pin fins of height-to-diameter ratio of unity used to augment internal cooling of gas turbine airfoils are presented. Data were obtained for an array of 10 rows of staggered pin fins in a 25:1 aspect ratio channel, with both pins and channel endwalls forming the heat transfer surface. Results show that the array average friction factor increases with increasing blockage caused by different arrangement of pin fin geometries in the channel. The local heat transfer coefficient increases up to the 3rd row of pin fins and decreases thereafter. Oblong pin fins with gamma 90 deg (major axis parallel to the direction of flow) result in higher heat transfer rates and lower friction factor than the circular pin fins. For other orientations, oblong pin fins do not offer any advantage over circular pin fins for Re or 20,000 (typical of small gas turbine engines). M.G

N86-29828# Von Karman Inst for Fluid Dynamics, Rhode-Saint-Genese (Belgium)

EXTERNAL HEAT TRANSFER STUDY ON A HP TURBINE ROTOR BLADE

T. ARTS and C. G. GRAHAM (Rolls-Royce Ltd., Bristol (England).) *In* AGARD Heat Transfer and Cooling in Gas Turbines 12 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

An experimental investigation of the effects of Mach number, Reynolds numbers and free stream turbulence intensity on the heat transfer performance of a high pressure gas turbine rotor blade in a stationary linear cascade arrangement is described. This study was undertaken in the von Karman Institute short duration isentropic compression tube facility. The tests were performed for outlet Mach numbers ranging between 0.7 and 1, whereas the outlet Reynolds number was varied between 500,000 and 1,500,000; free stream turbulence levels between 1% and nearly 8% were considered. The experimental results were compared with boundary layer predictions provided by a finite difference program (STAN5), which solves the simplified, two dimensional, steady Navier-Stokes equations. M.G.

N86-29829# Karlsruhe Univ. (West Germany). Lehrstuhl und Inst. fuer Thermische Stroemungsmach

EFFECTS OF WAKES ON THE HEAT TRANSFER IN GAS TURBINE CASCADES

S. WITTIG, A. SCHULZ, H. J. BAUER, and K. H. SILL *In* AGARD Heat Transfer and Cooling in Gas Turbines 13 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

The interaction between consecutive blade rows can be expected to have important effects on the heat transfer in cooled gas turbine cascades. In the present study, the influence of the wake from a blade profile - traversed in front of a cooled gas turbine cascade in planes with varying distances from the leading edge - on the local heat transfer coefficient along the suction and pressure side has been analyzed. The investigation is part of a research program to develop experimentally verified numerical codes for heat transfer calculations. With the aid of a finite element program, the local heat transfer coefficients along the cooled blades are derived from surface and coolant temperature measurements. It is shown that in addition to the axial distances the orientation of the wake with respect to the leading edge is of dominant influence. In particular, the measurements demonstrate with increasing free stream turbulence levels a rapid rise of the heat transfer rate along the pressure surface as well as in the stagnation region. The laminar-turbulent transition is relocated towards the leading edge along the suction surface. The measurements are compared with those derived from flows with grid-produced turbulence. In general, slower transition behaviour is observed than foundwith numerical codes. Author

N86-29830# Oxford Univ. (England). Dept. of Engineering Science.

WAKE-PASSING IN A TURBINE ROTOR CASCADE

D. J. DOORLY, M. L. G. OLDFIELD, and C. T. J. SCRIVENER (Rolls-Royce Ltd., Derby, England) *In* AGARD Heat Transfer and Cooling in Gas Turbines 18 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

A technique for generating realistic wakes upstream of a stationary turbine blade cascade at full scale Mach numbers and Reynolds numbers is described. High speed Schlieren photographs showing the development of the wake flow through the cascade are presented, together with unique high speed measurements of the fluctuations of the surface heat transfer rate as the nozzle guide vane (NGV) wakes pass over the rotor blade surface. Combining the flow visualization results with the unsteady heat transfer measurements reveals the radically different nature of the boundary layer transition caused by wake passing; an understanding of which will be essential for the development of improved prediction techniques. M.G.

N86-29831# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Antriebstechnik.

EFFECTS OF HOLE GEOMETRY, WALL CURVATURE AND PRESSURE GRADIENT ON FILM COOLING DOWNSTREAM OF A SINGLE ROW

H. KRUSE *In* AGARD Heat Transfer and Cooling in Gas Turbines 13 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Film cooling with injection through a single row of discrete circular holes is a 3-dimensional process which becomes more and more 2-dimensional with downstream distance from the injection site. In order to develop and verify prediction methods experimental investigations within the mixing region downstream of the coolant injection were undertaken. The measurements discussed in this paper were carried out using simple film cooled models at a mainstream temperature of about 100 C and a coolant temperature of about 30 C. Coolant distributions on the adiabatic wall, adiabatic wall effectiveness and heat transfer coefficients affected by blowing are presented. The blowing parameter was varied from 0.5 to 2 and the pitch to diameter ratio was varied from 1.5 to 5 with a constant hole diameter of 2 mm. Injection angles of 10 deg., 45 deg. and 90 deg. are covered. A flexible wall was used to produce zero, favorable and adverse pressure gradients along the flat plate. Author

N86-29832# Sussex Univ., Brighton (England).

EFFECTS OF SURFACE ROUGHNESS ON HEAT TRANSFER TO GAS TURBINE BLADES

A. B. TURNER, F. H. A. TARADA, and F. J. BAYLEY *In* AGARD Heat Transfer and Cooling in Gas Turbines 10 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

A brief, preliminary sample of results of an investigation into the effect of surface roughness on heat transfer to gas turbine blades is presented. Only the kind of roughness due to the accretion of dirt or dust is considered and this has been simulated in cascade flow by attaching various grades of abrasive powders to the blade surface with a water soluble adhesive. A significant increase in heat is reported particularly with high free stream turbulent levels. Roughness on the pressure surface alone is shown to increase the overall heat transfer without any corresponding increase in profile loss. Author

N86-29833# Oxford Univ. (England). Dept. of Engineering Science.

THE EFFECT OF DENSITY RATIO ON THE FILM-COOLING OF A FLAT PLATE

C. J. P. FORTH, P. J. LOFTUS, and T. V. JONES *In* AGARD Heat Transfer and Cooling in Gas Turbines 12 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

The effect of varying the ratio of coolant-to-freestream density on the film-cooling process is illustrated. This effect is of great importance since most design data has been acquired at temperature ratios and hence density ratios far removed from those occurring in modern gas turbines. There is no consensus at present on how to scale this data to engine conditions. Experimental data is presented for heat transfer downstream from a single row of 30 degree-inclined film-cooling holes, obtained for air at a wide range of gas-to-coolant temperature ratios. These results exhibit a marked effect of density ratio. Scaling is discussed, and good collapse of data is achieved in the two regimes identified, characterised by weak and strong blowing. Conditions representative of the turbine environment are created using an isentropic light piston tunnel: the Mach number M = 0.55, and the unit Reynolds number Re/m = 2.7 x 10(5)/m. The experiments are unique in that they simulate the gas-to-coolant and gas-to-wall temperature ratios typical of those in gas turbines, producing density ratios hiterto only attained in experiments employing foreign gas injection. Author

N86-29834# Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Etudes Generales Aerothermiques.

STUDIES OF HEAT TRANSFER ON THE BASE OF TURBINE NOZZLES WITH AND WITHOUT FILM COOLING [ETUDES DES TRANSFERTS THERMIQUES SUR LES PLATES-FORMES DE DISTRIBUTEUR DE TURBINE AVEC ET SANS FILM DE REFROIDISSEMENT]

A. E. BOUIGUIGNON *In* AGARD Heat Transfer and Cooling in Gas Turbines 9 p (SEE N86-29823 21-07) Sep. 1985 In FRENCH

Avail: NTIS HC A23/MF A01

The severity of the aerothermal environment of high-pressure nozzles in modern engines requires base cooling using techniques similar to those used for guide vanes, i.e., convection, films etc. These experiments measure the exchange coefficients for several bases of different configurations, and which show variations in the film cooling structure; measurement of the characteristics of the flow in the vicinity of the wall is also done. This document presents the analysis of the results obtained, compared with the predicted results. The correlations deduced from this analysis show a general method of determining the thermal transfer coefficients for air injection cooling. M.G.

N86-29835# Rolls-Royce Ltd., Derby (England). Mechanical Technology.

SHROUD SEGMENTS FOR UNSHROUDED BLADE TURBINES

R. S. ATTWOOD *In* AGARD Heat Transfer and Cooling in Gas Turbines 14 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

For hot and high speed turbines it is desirable to use blades without tip shrouds, which are an embarrassment from the point

of view of centrifugal weight and cooling. The static shroud segments are then exposed to very severe thermal conditions. It is difficult to design shroud segments which will survive these conditions without demanding so much cooling air that the specific fuel consumption advantage of the shroudless blade is completely absorbed. The problem involves two parameters: cooling requirements and integrity. Therefore, for a variety of possible segment section design concepts, the fundamental relationships which control the cooling requirements are examined. The second part of the paper explains the decision to evaluate experimentally the integrity of section of designs, and a description and technical justification of the chosen test technique, which overcomes the heat-transfer compromises involved in testing at atmospheric pressure. Author

N86-29836# Brown, Boveri und Cie, A.G., Baden (Switzerland).
ENGINE TESTS ON A COOLED GAS TURBINE STAGE
H. J. GRAF *In* AGARD Heat Transfer and Cooling in Gas Turbines 16 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

A new cooling system was designed for the 45 MW gas turbine type 8. Extensive tests were carried out in a new power station to verify the reliability of the cooled components. Wall temperatures were measured using thermocouples, thermal paints and pyrometers. Cooling air temperature, pressure and mass flow measurements allowed a detailed analysis of the first stage under operating conditions. The results and comparisons with design calculations are presented. The applicability and accuracy of the three measuring techniques are discussed. Author

N86-29837# Westinghouse Canada, Inc., Hamilton (Ontario).
HEAT TRANSFER TEST EVALUATION OF THE SHELL-SPAR BLADE COOLING CONCEPT APPLIED TO INDUSTRIAL GAS TURBINES
G. P. BUTT and W. E. NORTH (Westinghouse Electric Corp., Concordville, Pa.) *In* AGARD Heat Transfer and Cooling in Gas Turbines 17 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

A series of heat transfer experiments to verify the theoretical prediction techniques adopted for the design of shell-spar cooled turbine vanes and blades is described. Tests were performed on flat plate specimens representing a wide range of channel geometries. Each specimen was installed in one wall of a test section downstream of a combustor which was run at various operating temperatures. A recommended design approach was formulated from analysing the results. The potential of shell-spar cooling applied to industrial gas turbines is discussed. Author

N86-29838# Calspan Advanced Technology Center, Buffalo, N.Y. Physical Sciences Dept.
HEAT-FLUX MEASUREMENTS AND ANALYSIS FOR A ROTATING TURBINE STAGE
M. G. DUNN *In* AGARD Heat Transfer and Cooling in Gas Turbines 13 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

A measurement and analysis program is described which utilizes: (1) a Garrett TFE 731-2 high-pressure turbine stage and (2) a Garrett low aspect ratio turbine (LART) stage. The major emphasis of this program has been placed on obtaining accurate measurements of heat-flux distributions in the full-scale rotating turbine stage. The experimental technique being used is the short-duration, shock-tunnel approach, in which fast-response, thin-film thermometers are used to measure the surface temperature histories at prescribed positions on the various component parts. Heat flux values are then inferred from these temperature histories using standard data reduction procedures. A summary and discussion of the TFE 731-2 high pressure turbine results with particular emphasis on nozzle guide vane (NGV) tip endwall data not previously reported are provided. A significantly more brief discussion of the LART stage instrumentation is also included. In addition, a summary discussion of the experimental technique and the associated instrumentation is included. Author

N86-29839# Karlsruhe Univ. (West Germany). Inst. fuer Hydromechanik.
CALCULATION OF LAMINAR-TURBULENT BOUNDARY LAYER TRANSITION ON TURBINE BLADES
W. RODI and G. SCHEUERER (Erlangen-Nuremberg Univ. (West Germany).) *In* AGARD Heat Tranfer and Cooling in Gas Turbines 13 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

Calculations are presented for the flow development and heat transfer in transitional two-dimensional boundary layers of relevance to turbine blades. They were obtained with the Patankar-Spalding finite difference program, using a low Reynolds number version of the k-epsilon turbulence model for simulating the turbulent transport. For the higher free-stream turbulence levels prevailing in gas turbines (say above 1%), the model is capable of simulating the physical transition mechanism which is governed by the transport of the turbulent fluctuations from the free stream into the laminar boundary layer. The calculation examples comprise a variety of flat-plate boundary layers with various favorable and adverse pressure gradients as well as various levels of free-stream turbulence, and a simulation of the boundary layer development of an experimentally investigated turbine blade. The calculations are compared with measurements in each case (mainly the distribution of heat transfer coefficients). The agreement is generally good, but the model has a tendency to predict a somewhat faster transition than was observed in the experiments. M.G.

N86-29840# Purdue Univ., West Lafayette, Ind. School of Mechanical Engineering.
A MODEL FOR CORRELATING FLAT PLATE FILM COOLING EFFECTIVENESS FOR ROWS OF ROUND HOLES
M. R. LECUYER and F. O. SOECHTING (Pratt and Whitney Aircraft, West Palm Beach, Fla.) *In* AGARD Heat Transfer and Cooling in Gas Turbines 12 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

An effective method of cooling, that has found widespread application in aircraft gas turbines, is the injection of a film of cooling air through holes into the hot mainstream gas to provide a buffer layer between the hot gas and the airfoil surface. Film cooling has been extensively investigated and the results have been reported in the literature. However, there is no generalized method reported in the literature to predict the film cooling performance as influenced by the major variables. A generalized film cooling correlation has been developed, utilizing data reported in the literature, for constant velocity and flat plate boundary layer development. This work provides a basic understanding of the complex interaction of the major variables effecting film cooling performance. Author

N86-29841# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
COMPUTATION OF THERMAL RADIATION FOR GAS TURBINE CONDITIONS
M. G. CARVALHO, D. F. G. DURAO, and F. C. LOCKWOOD (Imperial Coll. of Science and Technology, London (England).) *In* AGARD Heat Transfer and Cooling in Gas Turbines 7 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

The prediction of the fluid flow, combustion and heat release processes in a 'can' combustion chamber of a gas turbine is addressed. A three-dimensional numerical solution technique is used to solve the governing time-average partial differential equations and the physical modelling for the turbulence, combustion and thermal radiation. The thermal radiation modelling is emphasized in this paper. The implications of neglecting radiative heat transfer in gas turbine combustion chamber calculations are explored and discussed. Author

N86-29842# Sussex Univ., Brighton (England). Thermo-Fluid Mechanics Research Centre.
PREDICTION OF TRANSIENT TEMPERATURES FOR AN AIR-COOLED ROTATING DISC
C. A. LONG and J. M. OWEN *In* AGARD Heat Transfer and Cooling in Gas Turbines 14 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

The numerical solution of Fourier's conduction equation is used to compute the transient temperature distribution in a rotating disc.

The convective boundary conditions for the disc surfaces are based on simple formulae obtained from the solutions of the boundary-layer equations, and the computed surface temperatures are compared with measurements made on a rotating-disc rig. Free-disc tests, at rotational Reynolds numbers up to Re sub phi = 2.5 x 10(6), are used to provide a datum from which to judge the numerical method. Although the numerical solution tends to overestimate the cooling rate of the heated free disc at high Reynolds numbers, the agreement between computed and measured temperatures is considered reasonable. Rotating-cavity tests, in which a heated disc is cooled by a radial outflow of air, are used to examine the suitability of the simple convective boundary conditions. As the computed temperatures show reasonable agreement with the measured values, it is suggested that the proposed formulae for convection in a rotating cavity might be useful for design purposes. Author

N86-29843# Norges Tekniske Hoegskole, Trondheim. Dept. of Engineering Thermodynamics.

HEAT TRANSFER IN GAS TURBINE COMBUSTORS: A DISCUSSION OF MATHEMATICAL MODELING OF COMBUSTION, HEAT AND MASS TRANSFER WITH EMPHASIS ON HEAT TRANSFER IN GAS TURBINE COMBUSTORS

B. F. MAGNUSSEN *In* AGARD Heat Transfer and Cooling in Gas Turbines 17 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Heat transfer problems in gas turbine combustors are addressed with particular emphasis given to the treatment of heat generation in the combustor. The heat is generated through chemical reactions that take place when reactants are mixed at molecular scale at sufficient high temperature. It is known that the microscale processes which are decisive for the molecular mixing as well as the dissipation of turbulence energy into heat are severely intermittent, i.e. concentrated into isolated regions whose entire volume is only a small fraction of the volume of the fluid. The paper reviews the eddy dissipation concept (EDC) for chemical reactions in turbulent flow developed by Magnussen. The EDC is a reactor concept which is unique in that it takes into account the intermittent behavior of the small scale structures on the chemical reactions. Both fast and slow chemical reactions can be treated simultaneously. Flame stabilization, extinction and ignition characteristics, as well as blow-off, turbulent flame propagation velocities and reaction rates are discussed in relation to the EDC. Computations of heat transfer rates to the walls taking into a account the cooling effect of the secondary air are demonstrated. The physical implications of the various sub-models are discussed. M.G.

N86-29844# Trent Polytechnic, Nottingham (England). Dept. of Mechanical Engineering.

EFFECTIVENESS MEASUREMENTS FOR A COOLING FILM DISRUPTED BY A SINGLE JET WITH WALL PLUNGING

B. L. BUTTON *In* AGARD Heat Transfer and Cooling in Gas Turbines 10 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Experimental measurements of the effectiveness downstream of a slot airflow with the jet airflow normal to the wall were performed in a wind tunnel. The separate and combined effects of the slot and jet airflows with and without wall plunging on the effectiveness and flow characteristics are presented over a range of slot and jet airflow conditions relevant to gas turbine combustors. The slot consisted of three rows of holes inclined at 10 degrees to the main airflow. The jet center line was positioned one, two and three diameters downstream from the slot exit. The jet diameter corresponded to five slot heights. Three wall plunge heights were used and corresponded to : 02, 0.4 and 12 jet diameters. The main airflow was constant at a Mach number of 0.05 and various combinations of the slot mass velocity ratio (0.5, 1.0 and 1.5) with the jet mass velocity ratio (0.5, 1.0 and 2.0) were tested. The effectiveness measurements covered an area eight jet diameters downstream of the slot exit by four jet diameters laterally. The results show that the major interactions between the three airflows occur downstream of the jet center line in a small region about three diameters long and two diameters wide. In general, such interactions reduce the effectiveness by up to forty percent when compared to the values with no jet injection. The combined and the separate effectiveness of the slot airflow and of the jet airflow are presented. Author

N86-29845# Detroit Diesel Allison, Indianapolis, Ind.

ALTERNATE COOLING CONFIGURATIONS FOR GAS TURBINE COMBUSTION SYSTEMS

D. A. NEALY, S. B. REIDER, and H. C. MONGIA *In* AGARD Heat Transfer and Cooling in Gas Turbines 15 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Work aimed at the synthesis, characterization, and evaluation of several alternate types of advanced wall cooling schemes is reviewed -- specifically, film-convection cooling, laminated porous wall cooling, and angled, multihole (effusion) cooling. The concept definition, heat transfer performance characterization, and design problems associated with each basic concept are reviewed, and relevant rig and engine experience cited. A brief assessment of the structural limitations of the several cooling schemes is also made, together with a review of the key materials and fabrication considerations. M.G.

N86-29846# Leeds Univ. (England). Dept. of Fuel and Energy.

FULL COVERAGE IMPINGEMENT HEAT TRANSFER: THE VARIATION IN PITCH TO DIAMETER RATIO AT A CONSTANT GAPP

G. E. ANDREWS, A. A. ASERE, C. I. HUSSAIN, and M. C. MKPADI *In* AGARD Heat Transfer and Cooling in Gas Turbines 13 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Impingement heat transfer is widely used in turbine blade cooling and is becoming more common in combustion chamber wall cooling. For the latter application, geometries that give impingement cooling of large surface areas are required. The geometrical requirements of full coverage heat transfer for combustion chamber cooling are outlined. A series of hole sizes, D, are investigated at a constant pitch, X, and constant impingement gap Z. The usual practice of keeping Z/D constant as X/D has been varied and has been rejected as unrealistic. Design considerations limit practical values of Z to a fairly narrow range of 2-12 mm and it is shown that over this range, Z, has no influence on the impingement heat transfer. The application of the present type of heat transfer correlation to the prediction of impingement cooling chambers is considered. Measured wall temperature data is presented for an impingement/effusion wall cooling geometry. The heating of the impingement plate by the impingement jets being deflected backwards is identified an as area where no heat transfer correlations exist. At low coolant flow rates the temperature rise of the impingement air as it passes through the impingement plate is significant and unless it is taken into account the impingement cooling effectiveness will be overpredicted. Author

N86-29847# Societe Nationale d'Etudes et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Centre de Villaroche

COOLING TECHNIQUES FOR TURBOJET PRE-HEATER CHANNELS [TECHNIQUES DE FROIDISSEMENT DES CANAUX DE RECHAUFFE DES TURBOREACTEURS]

M. DESAULTY, P. TROULLOT, and S. COUTOR *In* AGARD Heat Transfer and Cooling in Gas Turbines 11 p (SEE N86-29823 21-07) Sep. 1985 In FRENCH

Avail: NTIS HC A23/MF A01

Increases in the performance of turbojets with pre-heating are dependent upon technological research in the area of protection of the wall in pre-heater channels. The procedures used to cool the thermal protection jackets have undergone important improvements which have optimized performance, reduced weight and improved cooling efficiency. This report presents a comparison of the thermal protection jackets for several SNECMA engines, as well as the principal stages of development for the jacket from the design stages through static engines tests. M.G.

N86-29848# Oxford Univ. (England). Dept. of Engineering Science.

THE MEASUREMENT OF LOCAL HEAT TRANSFER COEFFICIENTS IN BLADE COOLING GEOMETRIES

P. T. IRELAND and T. V. JONES *In* AGARD Heat Transfer and Cooling in Gas Turbines 8 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

An account is given of the experimental technique employed in measuring heat transfer coefficients in blade cooling passages.

A hot air flow is suddenly started through a perspex model of the blade cooling passage. The surface temperature of the model is monitored during this time and the internal heat transfer coefficient deduced from this temperature history. Thin and thick walled models are employed and the surface temperature measured using liquid crystal thermochromic indicators. The analysis for the interpretation of the experimental results is given together with the experimental precautions required for the measurement. The use of liquid crystals in this form of transient experiment is discussed. A study of the detailed heat transfer distribution around pedestals and other heat transfer enhancement devices is also described. These devices are tested at approximately x 100 scale in order to obtain the required detail and full scale Reynolds number is simulated. Author

N86-29849# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).

AN OPTICAL PYROMETER TO MEASURE TURBINE BLADE SURFACE TEMPERATURE

M. CHARPENEL and J. WILHEM *In* AGARD Heat Transfer and Cooling in Gas Turbines 10 p (SEE N86-29823 21-07) Sep. 1985 In FRENCH; ENGLISH summary

Avail: NTIS HC A23/MF A01

The development of a cooled infrared pyrometric probe, with a high spatial and temporal resolving power, made it possible to establish by pyrometric methods surface temperature charts of the mobile blades of a turbine. The use of a sensor with a 1 sec time constant yields a resulting power on the blade surface of the order of 2 sq mm. This sensor is cooled at -40 C, which ensures a good detectivity and temperature measurements above 450 C. A water cooled metallic tube, ending by a right angle deflecting prism, makes up the light guide of the pyrometer and can be inserted between the various turbine stages. The probe has been designed to withstand the pressure and temperature conditions prevailing in the turbine blade test section, and was subjected without damage to 20 bar and 2100 K. The use of this pyrometer with the expermental turbine specially designed for qualifying new blade cooling methods has shown that pyrometry involves difficulties connected to: the non-zero blade reflection coefficient (emissivity lower than 1); and the gas radiation due to the gases. The above difficulties were analyzed and solutions were proposed; in particular a correcting program for the temperatures was perfected which takes into account the blade to blade mutual reflections. Author

N86-29850# Massachusetts Inst. of Tech., Cambridge.

HIGH FREQUENCY RESPONSE HEAT FLUX GAUGE FOR METAL BLADING

A. H. EPSTEIN, G. R. GUENETTE, R. J. G. NORTON (Rolls-Royce, Inc., Atlanta, Ga.), and C. YUZHANG (Beijing Inst. of Aeronautics and Astronautics (China).) *In* AGARD Heat Transfer and Cooling in Gas Turbines 16 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Double-sided, high frequency response heat flux gauge technology developed specifically for use on metal turbine blading in short duration turbine test facilities is described in detail. The gauges consist of a metal film (1500A) resistance thermometer sputtered on both sides of a thin (25 micron) polyamide sheet. This sheet, containing 25 gauges, is then adhesively bonded (and completely covers) the airfoil surface. The temperature difference across the polyamide is a direct measure of the heat flux at low frequencies, while a quasi-1D analysis is used to infer the high frequency heat flux from the upper surface temperature history. The design criteria, construction and application techniques, and calibration procedures are discussed in detail. Sample measurements in a high pressure turbine are presented. Author

N86-29851# Royal Aircraft Establishment, Farnborough (England) Propulsion Dept.

THE ISENTROPIC LIGHT PISTON ANNULAR CASCADE FACILITY AT RAE PYESTOCK

A. J. BROOKS, D. E. COLBOURNE, E. T. WEDLAKE, T. V. JONES (Oxford Univ. (England).), M. L. G. OLDFIELD, D. L. SCHULTZ, and P. J. LOFTUS (Maryland Univ., College Park.) *In* AGARD Heat Transfer and Cooling in Gas Turbines 23 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

An accurate assessment of heat transfer rates to turbine vanes and blades is an important aspect of efficient cooling system design and component life prediction in gas turbines. Techniques have been developed at Oxford University which permit such measurements to be obtained in test rigs which provide short duration steady flow through a turbine cascade. The temperature ratio between the gas stream and the turbine correctly models that found in an engine environment. Reynolds number and Mach numaber can be varied over a wide range to match engine conditions. The design, construction and operation of a new facility at Royal Aircraft Establishment (RAE) Pyestock, incorporating these techniques, is described. Heat transfer and aerodynamic measurements have been made on airfoil surfaces and endwalls of a fully annular cascade of nozzle guide vanes. These results are discussed and compared with those obtained from the same profile in 2-D cascade tests, and with computed 3-D flow predictions. Author

N86-29852# Instituto Superior Tecnico, Lisbon (Portugal) Dept. of Mechanical Engineering.

MEASUREMENTS OF FLUCTUATING GAS TEMPERATURES USING COMPENSATED FINE WIRE THERMOCOUPLES

M. N. R. NINA and G. P. PITA *In* AGARD Heat transfer and Cooling in Gas Turbines 10 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Thermocouples with three different wire diameters (15, 40 and 50 microns) were used in association with an analog compensation circuit connected to a data acquisition system. Measurements of the time constant were performed using two different heating techniques; Joule effect and external heating by laser beam. The thermocouples were used to quantify the fluctuating temperature field in a hot air jet and in a premixed propane flame. In the reacting case the catalytic effect was evaluated by comparing coated and uncoated wires. Conclusions were also obtained regarding frequency spectra, temperature probability distribution function and time constant. Author

N86-29853# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Aero Propulsion Lab.

TWO SPOT LASER VELOCIMETER MEASUREMENTS OF VELOCITY AND TURBULENCE INTENSITY IN SHOCK TUBE DRIVEN TURBINE FLOWS

R. B. RIVIR, W. C. ELROD (Air Force Inst. of Tech., Wright-Patterson AFB, Ohio.), and M. G. DUNN (Calspan Advanced Technology Center, Buffalo, N.Y.) *In* AGARD Heat Transfer and Cooling in Gas Turbines 12 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

Full-scale rotating turbine heat transfer tests are discussed. The turbine is driven by a shock tube of short duration. Heat transfer distributions are measured during the test by thin film surface gages on the various component parts. Direct measurement of the velocity and turbulence intensity is needed to accurately compute the heat transfer for comparison with the measured values. An investigation to determine if measurements of velocity and turbulence intensity could be obtained with a two-spot laser velocimeter in the turbine for these short duration shock driven flows was undertaken. Two seed materials were investigated with satisfactory results: propylene glycol and Dow 200. The velocimeter was initially set up on a low-pressure-ratio shock tube which could be cycled quickly to determine the seeding requirements. The velocimeter was transferred to the high-pressure, full-scale turbine after successful measurements in the low-pressure shock tube. Author

N86-29854# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
INFLUENCE AND TIP CLEARANCE MEASUREMENT IN TURBOMACHINES
J. PAULON *In* AGARD Heat Transfer and Cooling in Gas Turbines 8 p (SEE N86-29823 21-07) Sep. 1985 In FRENCH; ENGLISH summary
Avail: NTIS HC A23/MF A01

The clearance between the tip of the blades and the casing of a turbomachine is an important parameter. The performances of an engine are strongly subject to tip clearance. These gap effects are illustrated and numbered through some examples. Then, it would be desirable to control it permanently and to adjust the temperature of the casing in order to operate in optimum conditions. To this effect, a capacitive transducer is in development at ONERA and good results have been obtained in comparison with other devices. Author

N86-29855# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
SIMULATION OF FLOW AND HEAT TRANSFER IN ANNULAR CAVITIES BETWEEN DISKS IN TURBOMACHINERY
D. DUTOYA *In* AGARD Heat Transfer and Cooling in Gas Turbines 14 p (SEE N86-29823 21-07) Sep. 1985 In FRENCH; ENGLISH summary
Avail: NTIS HC A23/MF A01

The first developments of a numerical code for the prediction of flow and heat transfer within the annular cavities extending between the rotating and stationary disks of turbomachines are discussed. A short description of the numerical method and of the turbulence model used is presented and a few examples of calculations performed in simple flow configurations are shown: acoustics within cavities, some turbulent flows with singular heat losses, and flow calculations in shrouded disk systems with or without radial outflow. Comparison with published experimental data allows one to measure the qualities and limits of the chosen turbulent model. Author

N86-29856# Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
TRANSIENT THERMAL BEHAVIOUR OF A COMPRESSOR ROTOR WITH VENTILATION: TEST RESULTS UNDER SIMULATED ENGINE CONDITIONS
E. REILE, U. RADONS, and D. K. HENNECKE *In* AGARD Heat Transfer and Cooling in Gas Turbines 9 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

The development of advanced compressors for modern aero-engines requires detailed knowledge of the transient thermal behavior of the rotor disks to enable accurate prediction of rotor life and, additionally, of the thermal growth of the rotor for the evaluation of tip clearances. In the quest for longer life and higher reliability of the parts as well as reduced clearances even at transient conditions, the designer has to be able to influence the thermal behavior of the rotor. A very effective way is to vent small amounts of air through the rotor cavities. The design of such a vented rotor is presented. The main emphasis is placed on a detailed description of a test rig specially built for this purpose. The testing was carried out under simulated engine conditions for a wide range of parameters. The results are compared with those obtained with a theoretical model derived from fundamental tests at the University of Sussex, where heat transfer in rotating cavities is investigated. Good agreement is observed. Some final tests were done in an engine. The results also exhibit good agreement with the rig results under simulated conditions, when the proper dimensionless parameters are considered, providing the validity of the simulation. Author

N86-29857# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
HEAT EXCHANGERS IN REGENERATIVE GAS TURBINE CYCLES
M. N. R. NINA and M. P. N. AGUAS *In* AGARD Heat Transfer and Cooling in Gas Turbines 8 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HC A23/MF A01

Advances in compact heat exchanger design and fabrication together with fuel cost rises continuously improve the attractability of regenerative gas turbine helicopter engines. In this study cycle parameters aiming at reduced specific fuel consumption and increased payload or mission range, have been optimized together with heat exchanger type and size. The discussion is based on a typical mission for an attack helicopter in the 900 kw power class. A range of heat exchangers is studied to define the most favorable geometry in terms of lower fuel consumption and minimum engine plus fuel weight. Heat exchanger volume, frontal area ratio and pressure drop effect on cycle efficiency are considered. Author

N86-29858# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
CERAMIC HEAT EXCHANGERS FOR GAS TURBINES OR TURBOJET ENGINES
S. BOUDIGUES and J. FABRI *In* AGARD Heat Transfer and Cooling in Gas Turbines 14 p (SEE N86-29823 21-07) Sep. 1985 In FRENCH; ENGLISH summary
Avail: NTIS HC A23/MF A01

Heat exchangers made of steel and placed downstream of the last turbine of a turbojet engine or any gas turbine are too heavy and too cumbersome. With a heat exchanger made of silicon carbide mass, performance, volume and cost balances which greatly benefit civilian or military use can be obtained. Silicon carbide has good thermal performance and makes it possible to situate the heat exchanger between turbine stages. Both the pressure of cold and hot gases are thus increased, the heat exchange processes are amplified, the length and the diameter of the exchanger are reduced. With the density of this material being only 3.2, the overall mass of the exchanger is considerably reduced. It is also possible to shortcut part of the cold air, and thus obtain a controlling parameter. A kind of after burner effect is obtained, although a single combustor is used, and the corresponding thermodynamic process has a higher efficiency than the after burning process. Author

N86-29859# Technische Univ., Aachen (West Germany). Inst. for Jet Propulsion and Turbomachinery.
EFFECT OF FILM COOLING ON THE AERODYNAMIC PERFORMANCE OF A TURBINE CASCADE
O. KOELLEN and W. KOSCHEL *In* AGARD Heat Transfer and Cooling in Gas Turbines 16 p (SEE N86-29823 21-07) Sep. 1985
Avail: NTIS HCA23/MF A01

The aerodynamic performance of a film cooled turbine cascade for a typical design with multiple rows of cooling holes was investigated in an annular cascade rig with air at room temperature. The work was concentrated on the individual effect of the injection row position on the aerodynamic cascade losses and on the downstream flow field. For six different single row configurations the tests were conducted in a wide range of varying coolant mass flow rates and main stream Mach numbers. Typical results of these measurements are presented and discussed. Three models for the aerodynamic loss prediction based on different theoretical approaches, which are known from literature, were examined and improved. The presented two mixing layer models take into account the penetration of the injected cooling air into the main stream, whereas the third model predicts flow losses by a boundary layer calculation with film cooling air injection. Some tests with flow visualization by Schlieren photography were carried out showing the mixing effects of the injected coolant flow. Finally results of the predicted performance are compared with the experimental data. M.G.

N86-29860# Ecole Centrale de Lyon (France). Lab. de Mecanique des Fluides.
THEORY AND EXPERIMENTAL STUDY OF A 3-D JET INTRODUCED INTO THE SECONDARY FLOW OF A TURBINE INLET GUIDE VANE [ETUDE EXPERIMENTALE ET THEORIQUE DUN JET TRIDIMENSIONNEL INTRODUIT DANS LECOULEMENT SEONDAIRE DUNE GREILLE DISTRIBUTRICE DE TURBINE]
A. ONVANI, C. OLLIVIER, F. BARIO, and F. LEBOEUF *In* AGARD Heat Transfer and Cooling in Gas Turbines 18 p (SEE N86-29823 21-07) Sep. 1985 In FRENCH; ENGLISH summary
Avail: NTIS HC A23/MF A01

The interaction effects between a jet introduced from the side wall and the 3-D secondary flow of a turbine inlet guide vane are defined. Only aerodynamical effects are studied. The trajectory,

velocity and characteristic lengths of the jet are determined. The experimental work gives the measurements of pressure and velocity. The measurement of an intermittence coefficient with a hot wire allows also the definition of the trajectory and the shape of the jet. Experimental results show that the jet trajectory is weakly influenced by yaw angle of the hole for the ratio of momentum quantities used. Theoretical prediction is done with the help of an integral calculation method based on the use of continuity and Navier-Stokes equations averaged on the transverse section of the jet. The streamwise vorticity generated in the jet and predicted with a transport equation, and the introduction of a sink effect allow the computation of the induced transverse velocities. Experimental results and calculated quantities are in a good agreement. Author

N86-29861# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Experimentelle Stroemungsmechanik.

AERODYNAMIC EFFECT OF COOLANT EJECTION IN THE REAR PART OF TRANSONIC ROTOR BLADES

F. H. KOST and A. T. HOLMES (Rolls-Royce Ltd., Bristol, England) *In* AGARD Heat transfer and Cooling in Gas Turbines 12 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

An investigation of transonic turbine blades designed by Rolls-Royce/Bristol concerning the aerodynamic penalties of coolant flow for two alternative cooling configurations is discussed. Rolls-Royce designed a blade with a thick trailing edge where the coolant is ejected through slots in the trailing edge and a second blade with a thin trailing edge where coolant is ejected through a row of holes on the pressure side and a row of holes on the suction side. Tests were performed in a plane cascade wind tunnel. The results indicate the sensitivity of the blade performance to cooling configuration and coolant flow rate. By combining measured data from blade surface and wake traverses it was possible to separate the various loss mechanisms. Therefore, the separate losses due to the momentum of the coolant, change of base pressure, and change of blade friction could be determined quantitatively as a function of coolant flow rate. M.G.

N86-29862# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. for Design Aerodynamics.

THE BOUNDARY LAYER BEHAVIOUR OF AN ADVANCED GAS TURBINE ROTOR BLADE UNDER THE INFLUENCE OF SIMULATED FILM COOLING

R. KIOCK, H. HOHEISEL, H. J. DIETRICHS (Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).), and A. T. HOLMES (Rolls-Royce Ltd., Bristol (England).) *In* AGARD Heat Transfer and Cooling in Gas Turbines 19 p (SEE N86-29823 21-07) Sep. 1985

Avail: NTIS HC A23/MF A01

The aerodynamic properties of highly loaded turbine blades are strongly influenced by local supersonic flow fields and cooling air ejection. The boundary layer interaction with shock waves and simulated cooling flows was examined in a cascade wind tunnel by means of boundary layer and wake traverses and pressure distribution measurements as well as by the application of Schlieren observation. Air was ejected through holes and slots at different locations of the blade contour. Special emphasis was put on magnitude and direction of the local jet velocity in case of multiple cooling operation. The characteristics of the blade without and with different cooling configurations were determined. The results show the effects of air ejection on boundary layer transition and shock configurations. Author

08

AIRCRAFT STABILITY AND CONTROL

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

N83-22215# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).

RECENT TRANSONIC FLUTTER INVESTIGATION FOR WINGS AND EXTERNAL STORES

Jan. 1983 66 p refs Meeting held in Toronto, Sep. 1982 (AD-A128162; ISBN-92-835-1443-2; AGARD-R-703) Avail: NTIS HC A04/MF A01

Recent activities in the areas of aeroelasticity, subsonic flutter and transonic flutter are described. Results achieved in developing an adaptive flutter-suppression are described. Wind tunnel test results on aeroelastic wing models with external stores are discussed. For individual titles, see N83-22216 through N83-22219.

N83-22216# National Aeronautical Establishment, Ottawa (Ontario). High Speed Aerodynamics Lab.

A CANADIAN APPROACH TO FLUTTER CLEARANCE FOR EXTERNAL STORES

B. H. K. LEE and J. H. GOODEY (Canadair Limited) *In* AGARD Recent Transonic Flutter Invest. for Wings and External Stores 20 p (SEE N83-22215 12-08) Jan. 1983 refs

Avail: NTIS HC A04/MF A01

The Canadian capability in flutter clearance of military aircraft carrying underwing stores is reviewed. The flight test facilities and procedures, on-line analogue and post-flight digital data analysis, and analytical flutter model are described. Some results for the LAU-5003/A rocket launchers carrying C14 rockets armed with Mk I warheads are presented. Frequencies and damping values obtained from strip derivatives and doublet lattice aerodynamics methods used in the flutter computational code are discussed. Experimental results from on-line and post-flight analyses are compared for one aircraft/store configuration. Author

N83-22217# Messerschmitt-Boelkow G.m.b.H., Munich (West Germany). Unternehemensbereich Flugzeuge.

FLUTTER INVESTIGATIONS IN THE TRANSONIC FLOW REGIME FOR A FIGHTER TYPE AIRCRAFT

W. LUBER and H. SCHMID *In* AGARD Recent Transonic Flutter Invest. for Wings and External Stores 14 p (SEE N83-22215 12-08) Jan. 1983 refs

Avail: NTIS HC A04/MF A01

A correction method for subsonic potential airforces especially for the transonic flow regime is proposed. The airforces are corrected by modifying the theoretical pressure coefficients locally with measured static pressure slopes. Trends of transonic airloads and moments with reduced frequency, Mach number and mean static incidence are given. The application of corrected airforces in flutter calculations is described, and its effect on flutter behavior is analyzed. It could be confirmed by analysis that the aerodynamic damping of the most important low-frequency vibration modes is reduced by aerodynamic transonic effects, which was indicated by flight flutter test results. Author

N83-22218*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

FLUTTER AND STEADY/UNSTEADY AERODYNAMIC CHARACTERISTICS OF SUPERCRITICAL AND CONVENTIONAL TRANSPORT WINGS

W. F. GROSSER (Lockheed-Georgia Co.), R. T. BRITT (Lockheed-Georgia Co.), C. B. CHILDS (Lockheed-Georgia Co.), O. J. CROOKS (Lockheed-Georgia Co.), and F. W. CAZIER, JR. *In* AGARD Recent Transonic Flutter Invest. for Wings and External Stores 14 p (SEE N83-22215 12-08) Jan. 1983 refs

Avail: NTIS HC A04/MF A01 CSCL 01C

This paper presents the technical details and results of a high-speed wind-tunnel test program of an aeroelastic cantilevered transport type wing with two pylon-mounted engines. The tests were conducted in the NASA-Langley 16-foot Transonic Dynamic tunnel (TDT) during December 1981. Flutter of identical planforms,

mass properties, and stiffness. The test parameters included different values of model stiffness and wing loading at various angles of attack. The models were instrumented at span-wise wing stations to determine bending and torsion deflections and vertical accelerations. At two model wing stations, pressure transducers were distributed along the chord to record static and unsteady oscillatory pressures during the approach to and onset of flutter. This paper presents the test program with results of the flutter characteristics and selected steady and unsteady aerodynamic data for both airfoils at different angles of attack for various Mach numbers and dynamic pressures. Author

N83-22219*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ADAPTIVE FLUTTER SUPPRESSION, ANALYSIS AND TEST
E. H. JOHNSON (Northrop Corp.), C. HWANG (Northrop Corp.), D. S. JOSHI (Northrop Corp.), C. A. HARVEY (Honeywell, Inc.), L. T. HUTTSELL (AFWAL), and M. G. FARMER *In* AGARD Recent Transonic Flutter Invest. for Wings and External Stores 12 p (SEE N83-22215 12-08) Jan. 1983 refs
Avail: NTIS HC A04/MF A01 CSCL 01C

Methods of adaptive control have been applied to suppress a potentially violent flutter condition of a half-span model of a lightweight figher aircraft. This marked the confluence of several technologies with active flutter suppression, digital control and adaptive control theory the primary contributors. The control algorithm was required to adapt both to slowly varying changes, corresponding to changes in the flight condition or fuel loading and to rapid changes, corresponding to a store release or the transition from a stable to an unstable flight condition. The development of the adaptive control methods was followed by a simulation and checkout of the complete system and a wind tunnel demonstration. As part of the test, a store was released from the model wing tip, transforming the model abruptly from a stable configuration to a violent flutter condition. The adaptive algorithm recognized the unstable nature of the resulting configuration and implemented a stabilizing control law in a fraction of a second. The algorithm was also shown to provide system stability over a range of wind tunnel Mach numbers and dynamic pressures. Author

N83-34956# Hydraulic Research Textron, Washington, D.C. Aircraft Technology.
TECHNICAL EVALUATION REPORT ON THE GUIDANCE AND CONTROL PANEL 35TH SYMPOSIUM ON ADVANCES IN GUIDANCE AND CONTROL SYSTEMS
H. A. REDIESS Jul. 1983 17 p
(AGARD-AR-195; ISBN-92-835-1456-4; AD-A132855) Avail: NTIS HC A02/MF A01

Highlights of papers and discussions on the use of emerging technologies in guidance and control systems are presented. Topics covered include: (1) applications of control theory; (2) design concepts; (3) system design; (4) systems synthesis - simulation and validation; and (5) recent systems experience. A.R.H.

N84-10082# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SPECIAL COURSE ON AERODYNAMIC CHARACTERISTICS OF CONTROLS
Jul. 1983 254 p refs Course held in Rhode-Saint-Genese, Belgium, 21-25 Mar. 1983
(AGARD-R-711; ISBN-92-835-1457-2; AD-A133950) Avail: NTIS HC A12/MF A01

The aerodynamic characteristics of aircraft control surfaces and methods for theoretical and experimental analysis of those characteristics are discussed. Direct force controls, device actuation, and unsteady and oscillatory controls are addressed. Some consideration is also given to missile controls. For individual titles, see N84-10083 through N84-10092.

N84-10083# London Univ. (England). Dept. of Aeronautical Engineering.
INTRODUCTORY REMARKS AND REVIEW OF 1979 SYMPOSIUM
A. D. YOUNG *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 7 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

A brief historical review of aircraft controls is given. The impact of recent technological development, novel controls, and the status of predictive theories and experimental techniques are also addressed. M.G.

N84-10084# Thomas (H. H. B. M.), Farnborough (England).
THE AERODYNAMICS OF AIRCRAFT CONTROL: A GENERAL SURVEY IN THE CONTEXT OF ACTIVE CONTROL TECHNOLOGY
H. H. B. M. THOMAS *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 40 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

The introduction of active control technology into the design of aircraft was accompanied by the use of additional control devices or motivators and an expansion in the uses to which existing motivators are put, either individually or in combination with each other or one of the novel forms of control. A general survey is made of the different properties such as maximum control powers, effectiveness generally, and to some extent the actuating moments as is an assessment of their relative importance in different contexts. The present data base available to the aircraft designer from different sources is examined in some detail with particular attention to identifying the direct and indirect effects. Particular emphasis is placed on the efficiency of the motivator at extreme flight conditions, characterized by high angle of attack and high subsonic speeds. Author

N84-10085# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. for Design-Aerodynamics.
MATHEMATICAL MODELLING AND THEORETICAL METHODS FOR THE AERODYNAMIC BEHAVIOUR OF CONTROL DEVICES
H. KORNER *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 23 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

A survey of the theoretical aerodynamic aspects of control devices is given. This is done for subsonic, transonic and supersonic attached flow; some comments on separated flow are also given. The basic flow equations are introduced and various calculation methods based on these equations are reviewed. This is followed by a comparison between theoretical and experimental results. Author

N84-10086# London Univ. (England). Dept. of Aeronautical Engineering.
DYNAMIC EFFECTS OF CONTROLS
G. J. HANCOCK *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 19 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

Some of the background concepts and methods underlying the interface of aerodynamics and dynamics are outlined. The topics discussed include: (1) qualitative descriptions of the unsteady aerodynamic characteristics associated with the movement of control surfaces (trailing edge controls, leading edge controls, spoilers) at various Mach numbers; (2) a summary of the methods of prediction of unsteady control surface aerodynamics; (3) a preliminary indication of comparisons between results from theory and experiment; (4) the concept of aerodynamic derivatives; and (5) the interface between aerodynamics and dynamics. M.G.

N84-10087# Royal Aircraft Establishment, Bedford (England). Aerodynamics Dept.
EXPERIMENTAL METHODS TO DETERMINE CONTROL EFFECTIVENESS IN WIND TUNNELS
D. G. MABEY *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 18 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

The methods used to determine control effectiveness in wind tunnels are reviewed using illustrative examples. Major experimental difficulties are enumerated. The controls discussed include tailplanes, ailerons, airbrakes and spoilers. Both steady and unsteady measurements are considered, although the emphasis is on unsteady measurements and transonic speeds. As an illustration of the current interest in active control technology, some results from an experiment are included in which a trailing edge flap is driven 'closed loop' to reduce the response of a model wing to flow unsteadiness. M.G.

N84-10088*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
CONTROL OF THE FOREBODY VORTEX ORIENTATION BY ASYMMETRIC AIR INJECTION. PART A: APPLICATION TO ENHANCE DEPARTURE/SPIN RECOVERY OF FIGHTER AIRCRAFT AND PART B: DETAILS OF THE FLOW STRUCTURE
A. M. SKOW (Northrop Corp., Hawthorne, Calif.) and D. J. PEAKE *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 22 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

A concept developed to provide powerful directional control effectiveness for a fighter aircraft at high angles of attack is described. The concept utilizes the energy concentrated in the strong forebody vortices (which form on slender bodies of high relative incidence) by controlling the lateral orientation of the vortices with respect to the body. The objective was to utilize the side force associated with asymmetric vortices, in a controlled manner, to enhance the ability of the fighter to recover from a departure from controlled flight. The results from water tunnel and wind tunnel experiments show that a small amount of tangential blowing along the forebody near the apex can effectively alter the forebody vortex system and generate large restoring yawing moments. Six degree of freedom digital simulation results show that this concept can substantially enhance recovery characteristics of fighter aircraft with long, slender forebodies. Also, the results of experiments which were conducted on a cone model are discussed where the principal test objective was to develop an understanding of the fluid mechanics involved in the process of vortex control. Knowledge gained in these more generic tests should allow the concept to be applied to a wider range of configurations. M.G.

N84-10089# Northrop Corp., Hawthorne, Calif. Aircraft Div.
CONTROL OF ADVANCED FIGHTER AIRCRAFT
A. M. SKOW *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 31 p (SEE N84-10082 01-08) Jul. 1983
Avail: NTIS HC A12/MF A01

An overview of traditional and projected control technologies for fighter aircraft is presented. Basic aerodynamic effectiveness and control criteria are examined and controversies regarding tail location and angle of attack limiting are discussed. Future research directions are described including thrust vectoring, control implications of new air combat maneuvering tactics, ultra-fast actuators, and novel controls. M.G.

N84-10090# Hochschule der Bundeswehr, Munich (West Germany).
DIRECT FORCE CONTROL
G. SACHS *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 17 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

Direct force control provides novel and unique motion capabilities of the aircraft due to independent control of flight path and attitude. In addition, flight path response characteristics can be speeded up. For direct lift control, it is shown how these novel capabilities may be utilized, with a discussion of possible deficiencies of conventional elevator control added for comparison. The aerodynamic characteristics of direct lift devices are described. This concerns not only lift but also drag characteristics which may be of significance for the long term response of the aircraft (flight path stability). For direct side force control, the novel motion capabilities possible are shown. This is followed by a description of the aerodynamic force characteristics of control surfaces applicable for direct side force control. In addition, coupling effects are discussed as well as effects on stability. In regard to direct drag control, some basic aspects concerning control surfaces and deceleration levels achievable are described. Author

N84-10091# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.
EXPERIMENTAL METHODS IN FLIGHT FOR THE MEASUREMENT OF CONTROL CHARACTERISTICS
M. E. ESHELBY *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 17 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

Although the measurement of control characteristics is relatively simple in the wind tunnel their flight measurement is not so straightforward. In general the control characteristics are implicit in the measurement of the handling qualities of the aircraft and do not appear as separately measured quantities. It is, however, possible to extract some data on control characteristics from the handling qualities trials; some methods of their assessment are considered. Principally the longitudinal control characteristics can be determined from static stability trials whereas the lateral directional control characteristics are derived from dynamic tests. Special trials in respect of aircraft flying beyond their normal limitations are discussed. Methods of handling qualities assessment are also considered since these encompass the control characteristics of the aircraft. Author

N84-10092# Nielsen Engineering and Research, Inc., Mountain View, Calif.
AERODYNAMIC CHARACTERISTICS OF MISSILE CONTROLS
J. N. NIELSEN *In* AGARD Spec. Course on Aerodyn. Characteristics of Controls 53 p (SEE N84-10082 01-08) Jul. 1983 refs
Avail: NTIS HC A12/MF A01

Missile types and terminology are reviewed. The subjects of jet spoilers and combining controls and the airframe are considered. As the basic approach to integrating the presentation of all movable controls, the equivalent angle of attack concept is next taken up followed by detailed considerations of all movable planar and cruciform controls. These are treated from the phenomenological point of view as well as from the quantitative point of view. Methods of determining the effects of vortices on control characteristics are presented in sufficient detail to carry out calculations. Final control hinge moments and a preliminary method for their calculation at supersonic speed are discussed. Author

N84-10093# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
COMPUTER-AIDED DESIGN AND ANALYSIS OF DIGITAL GUIDANCE AND CONTROL SYSTEMS
Jul. 1983 137 p refs Lecture held in Stuttgart, 8-9 Sep. 1983 and in Paris, 12-13 Sep. 1983
(AGARD-LS-128; ISBN-92-835-1455-6; AD-A133798) Avail: NTIS HC A07/MF A01

Basic concepts, theories, and computer methods involved in the design of advanced guidance and control systems are presented. Direct digital analysis and synthesis procedures are reviewed. Computer aided and graphical techniques that can be employed in preliminary design, synthesis and real time simulation are presented. A supporting bibliography is included. For individual titles, see N84-10094 through N84-10101.

N84-10094# Stanford Univ., Calif. Dept. of Electrical Engineering.
FUNDAMENTALS OF ANALYSIS FOR DIGITAL CONTROL SYSTEMS
G. F. FRANKLIN *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 15 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

The theoretical background and practical tools for the design of a control system which is to be implemented using a computer

or microprocessor are provided. The methods studied are primarily for closed loop (feedback) systems in which the dynamic response of the process being controlled is a major consideration in the design. The design methods are applicable to any type of computer (from microprocessors to large scale computers); however, the effects of small word size and slow sample rates take on a more important role when using microprocessors. Both the continuous design and digitization method and the direct digital method are covered. The advantages and disadvantages are discussed.
A.R.H.

N84-10095# Kingston Polytechnic, Kingston-Upon-Thames (England).
DESIGN ENVIRONMENTS AND THE USER INTERFACE FOR CAD OF CONTROL SYSTEMS
M. J. DENHAM *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 9 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

The design of a total CAD environment in which control systems design software can be embedded is considered. This environment includes a rich set of software tools for the creation, modification, simulation and analysis of dynamic system models and a powerful user interface to these tools which incorporates an interactive algorithmic design language. An analogy can be made between such a CAD environment and those which exist currently for software development, e.g., Interlisp. The features which such an environment should possess and how these might be developed are described. Particular attention is devoted to the user interface since it is now generally recognized that the quality of the man computer interface is crucial to the successful use of a CAD system. The human factors aspects of the interface are reviewed and examples of how a CAD system can be designed to take account of these aspects. The DELIGHT system from the University of California, Berkeley, is referred to as an example of a user orientated design environment.
Author

N84-10096# Lund Inst. of Tech. (Sweden). Dept. of Automatic Control.
MODELING AND SIMULATION TECHNIQUES
K. J. ASTROEM *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 18 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

Systematic methods for design of control systems require mathematical models of the dynamics of processes and disturbances. An overview of techniques for obtaining such models is presented. Modeling from first principles and modeling from data are discussed. Particular emphasis is given to computer aided tools for obtaining and verifying the models. Two interactive software packages: Simnon, for nonlinear simulation, and Idpac, for data analysis and identification are described. Speculation on future trends is included.
Author

N84-10097# University of Southern California, Los Angeles. Dept. of Electrical Engineering Systems.
NUMERICAL ASPECTS OF CONTROL DESIGN COMPUTATIONS
A. J. LAUB *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 16 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

The interplay between recent results and methodologies in numerical linear algebra and mathematical software and their application to problems arising in systems, control, and estimation theory is discussed. The impact of finite precision, finite range arithmetic (including the implications of the proposed IEEE Floating Point Standard(s) on control design computations is illustrated with numerous examples as are pertinent remarks concerning numerical stability and conditioning. Basic tools from numerical linear algebra such as linear equations, linear least squares, eigenproblems, generalized eigenproblems, and singular value decomposition are then outlined. A selected list of applications of the basic tools follows including algorithms for solution of problems such as matrix exponentials, frequency response, system balancing, and matrix Riccati equations. The implementation of such algorithms as robust mathematical software is discussed. Characteristics of reliable mathematical software, availability and evaluation, language implications (FORTRAN, ADA, etc.), and the overall role of mathematical software as a component of computer aided control system design are among the issues addressed.
A.R.H.

N84-10098# Honeywell, Inc., Minneapolis, Minn. Systems and Research Center.
PERFORMANCE AND ROBUSTNESS ASPECTS OF DIGITAL CONTROL SYSTEMS
J. E. WALL, J. C. DOYLE, G. L. HARTMANN, N. A. LEHTOMAKI, and G. STEIN *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 33 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

A formulation of the feedback control problem captures both the performance and robustness aspects of feedback. The structured singular value provides the solution to this problem. The problem formulation and solution are reviewed and its applicability is extended and its applicability to digital feedback control systems. A digital compensator is treated as though it were an analog compensator through the use of sectors. An integrated flight propulsion control system is used as an illustrative example.
Author

N84-10099# Stanford Univ., Calif. Dept. of Electrical Engineering.
DIRECT DIGITAL DESIGN VIA POLE PLACEMENT TECHNIQUES
G. F. FRANKLIN *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 13 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

The design of the dynamics of a digital control for satisfactory transient response can be done in a number of ways. One of the more effective ways is to do the design so that the poles of the closed loop system are in desired or at least acceptable locations. Such design schemes are known as pole placement methods. The method of pole placement is described and formulas suitable for computer implementation are given. Also, the method is compared to both transform methods and to methods based on optimal control, including stochastic control and the Kalman filter. Several examples illustrate the methods.
Author

N84-10100# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Dynamik der Flugsysteme
SYSTEMATIC COMPUTER AIDED CONTROL DESIGN
G. GRUEBEL and G. KREISSELMEIER *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 7 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

Computerized synthesis techniques of modern control theory are in widespread use, but a number of fundamental design problems still remain: the design specifications problem, the free design parameter problem, the plant complexity versus controller simplicity problem, and the dirty design environment problem. A design procedure which comes close to solving these design problems is recommended. It is an iterative design technique using a performance index vector which provides a systematic guidance for the designer to take care of multiple design objectives simultaneously and individually. As a design tool, unconstrained parameter optimization is used. A practical application is reported: the design of a robust control loop for a fighter aircraft where 42 performance criteria of 9 different sorts are considered simultaneously.
Author

N84-10101# Lund Inst. of Tech. (Sweden). Dept. of Automatic Control.
PRACTICAL ASPECTS OF DIGITAL IMPLEMENTATION OF CONTROL LAWS
K. J. ASTROEM *In* AGARD Computer-Aided Design and Anal. of Digital Guidance and Control Systems 9 p (SEE N84-10093 01-08) Jul. 1983 refs
Avail: NTIS HC A07/MF A01

Practical problems associated with digital computer implementation control laws are discussed. The key problem is to convert a digital control law in state space or polynomial form into a computer program which gives the desired results. The

paper covers: sensor and actuator interfaces, analog prefiltering, actuator saturation, anti-windup, numerics and coding. Author

N84-25718# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany).
PROBLEMS OF SYSTEM IDENTIFICATION IN FLIGHT VIBRATION TESTING
K. KOENIG 1983 27 p refs Presented at the 5th Meeting of the Struct. and Mater. Panel held in Vimeiro, Portugal, 9-14 Oct. 1983
(AGARD-R-720; AD-A142556) Avail: NTIS HC A03/MF A01

The state of the art of system identification in flight vibration tests is investigated. The accuracy of modal data analysis is studied for two tests with eight different methods of analysis. M.A.C.

N85-26730# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TECHNICAL EVALUATION REPORT ON THE FLIGHT MECHANICS SYMPOSIUM ON ACTIVE CONTROL SYSTEMS: REVIEW, EVALUATION AND PROJECTIONS Abstracts Only
L. D. REID (Toronto Univ.) Loughton, England Mar. 1985 17 p Symp. held in Toronto, 15-18 Oct. 1984
(AGARD-AR-220; ISBN-92-835-1493-9; AD-A154472) Avail: NTIS HC A02/MF A01

Research and development in active control systems (ACS) was evaluated. Areas discussed include; handling qualities specifications, use of flight control system backups, development of high integrity systems at reasonable cost, demonstration of system reliability, survivability, and certification. For individual titles see N85-26731 through N85-26758.

N85-26731# Centre d'Etudes et de Recherches, Toulouse (France).
ACTIVE CONTROL TECHNOLOGY: PAST, PRESENT, FUTURE Abstract Only
M. J. PELEGRIN *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 2 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A wide range of topics related to active control technology are reviewed (ACT). It provides the first contact with most of the topics contained in the papers to follow. Areas of discussion include: hardware, software, applications of ACT and reliability considerations. E.A.K.

N85-26732# General Electric Co., Binghamton, N.Y.
THE STATE-OF-THE-ART AND FUTURE OF FLIGHT CONTROL SYSTEMS Abstract Only
R. QUINLIVAN *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 2 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The evolution of active control technology (ACT) from early stability augmentation systems to current full authority flight control systems was covered. The philosophy behind the design of current and future ACS is presented. Both the benefits and the problems involved are highlighted. The potential hazards inherent in reverting to a backup FCS following a total failure of the primary system are discussed. E.A.K.

N85-26733# Systems Technology, Inc., Hawthorne, Calif.
A PERSPECTIVE ON SUPERAUGMENTED FLIGHT CONTROL ADVANTAGES AND PROBLEMS Abstract Only
D. T. MCRUER, D. E. JOHNSTON, and T. T. MYERS *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 2 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A superaugmented FCS both stabilizes an unstble aircraft and provides novel effective vehicle dynamics. The longitudinal dynamics of such an aircraft and FCS are discussed. The total available gain range (TAGR) factor was presented as a basic measure that relates degree of instability, control system limitations, and key control system adjustments. The flying qualities of superaugmented aircraft are discussed and highlighted. E.A.K.

N85-26734# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany).
ASPECTS OF APPLICATION OF ACT SYSTEMS FOR PILOT WORKLOAD ALLEVIATION Abstract Only
K. WILHELM and B. GMELIN *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 2 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

Aspects of the application of active control technology (ACT) systems for pilot workload alleviation were described for both fixed-wing aircraft and helicopters. The work involved wind tunnel tests of a rotor vibration control system and flight tests of a helicopter control decoupling system. Flight tests in the HFB 320 in-flight simulator were conducted on DLC incorporated within two flight path control techniques. It is found that DLC can only improve flight path control capability without HQ degradation if the pilot is supported by an inner loop augmentation system such as a Rate Command/Attitude Hold (RC/AH) system. Tests carried out in the same aircrft showed the influence of FCS time delays of up to 1.3s in degrading HQ ratings. E.A.K.

N85-26735# General Dynamics Corp., Fort Worth, Tex.
APPLICATION OF AFTI/F-16 TASK-TAILORED CONTROL MODES IN ADVANCED MULTIROLE FIGHTERS Abstract Only
R. D. TOLES, D. R. MCMONAGLE (Air Force Flight Test Center, Edwards AFB, Calif.), and D. C. ANDERSON *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 2-3 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

Flight tests carried out with a highly modified F-16 aircraft to demonsrate the effectiveness of a digital FCS and task-tailored modes are described. The tests specifically dealt with how task-tailoring the longitudinal control laws provide improved HQ for the air-to-air and bombing missions, how a flat turn mode gives the pilot an addedadvantages for the bombing and strafing tasks, and how Level 1 HQ for the landing system are obtained. The key to the flat turn mode is zero sideslip during the maneuver to reduce the aerodynamic load on the stores carried. E.A.K.

N85-26736# Grumman Aerospace Corp., Bethpage, N.Y.
X-29A DIGITAL FLIGHT CONTROL SYSTEM DESIGN Abstract Only
A. B. WHITAKER and J. CHIN *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 3 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The structural and control elements going into the design and construction of this unique test aircraft incorporating a forward swept wing are outlined. A number of active control technology (ACT) related concepts were included such as relaxed longitudinal stability, triplex digital FBW system and high gain FCS, a DLC type of response, task-tailoring, drag minimization and an analog backup FCS. E.A.K.

N85-26737# Royal Aircraft Establishment, Farnborough (England).
THE EVALUATION OF ACS FOR HELICOPTERS: CONCEPTUAL SIMULATION STUDIES TO PRELIMINARY DESIGN Abstract Only
J. S. WINTER, G. D. PADFIELD, and S. L. BUCKINGHAM *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 3 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The means by which design aims are defined and how they may be implemented through to the preliminary design stage were investigated. The use of a simplified helicopter model in a ground-based simulator was demonstrated to provide a quick means of studying control problems. A possible control law design for a helicopter is described. A technique for assessing the robustness of a control system design is outlined in the face of unknown or varying elements in the aircrft state matrix. This method, based on the use of maximum singular values, appears to be a useful design tool. E.A.K.

N85-26738# Smiths Industries Ltd., London (England).
ACT APPLIED TO HELICOPTER FLIGHT CONTROL Abstract Only
W. R. RICHARDS *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 3 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The ACS configurations suitable for installation in the 1988 and 1992 time scales were identified. Reliability aspects, control law philosophy and the impact of advanced technology are discussed. It appears that fibre optics and the replacement of electrical devices by optical ones where possible will be required to meet the challenge of EMP/EMC and lightning strikes. E.A.K.

N85-26739# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
SOME FLIGHT TEST RESULTS WITH REDUNDANT DIGITAL FLIGHT CONTROL SYSTEMS Abstract Only
U. KORTE *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 3 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The successful flight test program carried out in a modified F-104G was outlined. A digital quadruplex FBW and FCS was used to stabilize the airframe which was destabilized longitudinally by the addition of aft located ballast and a canard surface. Flights were completed in which the successful operation of the FCS was demonstrated along with reversion to a simplified digital backup system. It is indicated that FCS software verification is not as great a problem as many think and that reversion to a properly implemented backup FCS can be handled by pilots in an operational environment. E.A.K.

N85-26740# British Aerospace Aircraft Group, Preston (England).
AN UPDATE ON EXPERIENCE ON THE FLY BY WIRE JAGUAR EQUIPPED WITH A FULL-TIME DIGITAL FLIGHT CONTROL SYSTEM Abstract Only
E. DALEY *In* AGARD Tech Evaluation Rept on the Flight Mech. Symp. on Active Control Systems p 3 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A technology demonstration program was presented which emphasized relaxed stability, carefree maneuvering and protection against EM interference in the form of lightning and high frequency radio signals. The quadruplex fly by wire (FBW) system had no mechanical backup. The FCS was demonstrated during close to 100 flights and the EM immunity of the complete system was proven during extensive ground tests. It is concluded that, both customer and aircraft manufacturer are confident that active control systems can be implemented safely and cheaply with similar integrity to present day mechanical systems, and that the aircrft can be acceptably hardened against natural and man-made EM interference. E.A.K.

N85-26741# British Aerospace Public Ltd. Co., Brough (England).
ACT FLIGHT RESEARCH EXPERIENCE Abstract Only
D. J. WALKER and R. M. HORNER (RAE) *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 3 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The Hunter ACT aircraft development and flight test program was reviewed. A number of practical hardware aspects of the project were discussed. The FCS in-flight tests included a nonlinear pitch filter (with an effect much like the pitch axis task tailoring) and a depressed roll axis (about the sight axis). Mixed success in using ground based simulators during system development was reported. E.A.K.

N85-26742# McDonnell Aircraft Co., St. Louis, Mo.
OPERATIONAL AND DEVELOPMENTAL EXPERIENCE WITH THE F/A-18A DIGITAL FLIGHT CONTROL SYSTEM Abstract Only
W. A. MORAN *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 3-4 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

An operational aircraft making full use of ACT is described. Of particular interest was the use of the digital FCS to help solve several developmental problems encountered during the flight testing of the F/A-18A. Four problems were highlighted: poor nosewheel liftoff characteristics; insufficient roll performance; excessive structural loads; unwanted roll coupling. All these difficulties were overcome in a unique and cost effective manner with the help of the digital FCS. The system designers managed to reduce an unacceptably large FCS time delay to a reasonable value of 70 ms. E.A.K.

N85-26743# Naval Air Test Center, Patuxent River, Md.
FLIGHT TESTING AND DEVELOPMENT OF THE F/A-18A DIGITAL FLIGHT CONTROL SYSTEM Abstract Only
R. A. BURTON, B. T. KNEELAND, U. H. RABIN (Systems Control Technology, Inc.), and R. S. HANSEN (Systems Control Technology, Inc.) *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 4 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A new technique was presented for extracting equivalent system models, which uses several algorithms including a maximum likelihood estimator method. This and the use of closed loop pilot mission related task testing was successfully employed to evaluate the FCS during its development. The use of the equivalent model is recommended for ground based simulation during the design phase. E.A.K.

N85-26744# Dornier-Werke G.m.b.H., Munich (West Germany)
OLGA: AN OPEN LOOP GUST ALLEVIATION Abstract Only
H. BOHRET, B. KRAG (DFVLR, Brunswick, West Germany), and J. SKUDRIDAKIS (DFVLR, Brunswick, West Germany) *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 4 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

Following sophisticated wind tunnel trials, a flight test program was carried out using a Do 28 TNT aircraft to evaluate the effectiveness of an open loop gust alleviation system. By using an open loop approach the basic airframe dynamics were left unaltered. Ecitation of the wing's first bending mode by the system was removed by employing a suitably tuned notch filter. It is found that the suppression of low frequency accelerations by the OLGA system made the passengers more conscious of other sources of discomfort. E.A.K.

N85-26745# Lockheed-California Co., Burbank
DEMONSTRATION OF RELAXED STABILITY ON A COMMERCIAL TRANSPORT Abstract Only
J. J. RISING, W. J. DAVIS, and C. S. WILLEY *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 4 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The application of relaxed stability to current transport aircraft can lead to a 2% drag reduction. This can rise to 4% for next generation aircraft. A flight test program and a ground based flight simulator program employing an L-1011 aircraft have demonstrated the successful implementation of this concept. Stability augmentation was provided by a digital FCS and HQ ratings were obtained for a range of conditions. It was concluded that, careful tailoring of the augmentation system authority will result in acceptable failure characteristics, thereby eliminating the need for multisystem redundancy. Author

N85-26746# Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany).
REALISATION OF RELAXED STATIC STABILITY ON A COMMERCIAL TRANSPORT Abstract Only
U. P. GRAEBER *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 4 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

This paper deals with the use of fuel transfer to an aft located tank in order to reduce the trim drag on a commercial transport. Both ground based simulator trials and flight tests in an Airbus A300 were employed to demonstrate the aircraft could be flown both manually and by the autopilot with significantly aft c.g. locations. it is suggested that the use of such fuel transfer techniques is the only practical way to achieve reduced stability in an operational commercial transport. Author

N85-26747*# National Aeronautics and Space Administration. Dryden (Hugh L.) Flight Research Center, Edwards, Calif.
ACTIVE CONTROL TECHNOLOGY EXPERIENCE WITH THE SPACE SHUTTLE IN THE LANDING REGIME Abstract Only
B. G. POWERS *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 4 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01 CSCL 01C

An interesting description was provided of the development of the shuttle flight control systems. Of particular concern was a tendency to excite PIO during the landing phase. Both ground based and in-flight simulation were used to study the problem. It was found that in-flight simulation was the only reliable method to use in the study of PIO. Two of the major contributions to the PIO problem were found to be system time delay and the lack of a clear motion cue at the pilot's location following a pitch up command. The PIO problem was solved by reducing the demands of the piloting task and introducing an adaptive stick gain limiter. Author

N85-26748# London Univ. (England).
THE AERODYNAMICS OF CONTROLS Abstract Only
A. D. YOUNG *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 4 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A comprehensive review is given of the various conventional and unconventional control surfaces (or motivators) available for use as part of an active control system. A better understanding of the aerodynamics of such motivators is needed in order to make effective use of them. In particular, dynamic effects and the influence of flight at high angles of attack and at transonic speeds on these devices needs further study. A better data base must be generated to aid the designer. B.W

N85-26749*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ACTIVE CONTROL LANDING GEAR FOR GROUND LOADS ALLEVIATION Abstract Only
J. R. MCGEHEE *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 4-5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01 CSCL 01C

An active landing gear has been created by connecting the hydraulic piston in an oleo strut to a hydraulic supply. A controller modulates the pressure in the oleo to achieve the desired dynamic characteristics. Tests on ground rigs (documented by a film) have demonstrated the successful alleviation of induced structural ground loads and the next step will be a flight test using a fighter aircraft. Author

N85-26750# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
WING BUFFETING ACTIVE CONTROL TESTING ON A TRANSPORT AIRCRAFT CONFIGURATION IN A LARGE SONIC TUNNEL Abstract Only
R. DESTUYNDER *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A sophisticated large aerelastic half model has been developed to duplicate the structural characteristics of a typical civil transport aircraft. An active flaperon system has been developed to dampen out structural response to buffeting experienced at high angles of attack and/or Mach numbers of the range 0.50-0.82. This was achieved without increasing the structural modal frequencies. The resulting reduced structural strain and airframe motion effectively increase the usable flight envelope. Author

N85-26751# British Aerospace Aircraft Group, Brough (England).
A MODULAR DISSIMILAR REDUNDANT COMPUTER DESIGNED FOR HIGH INTEGRITY CONTROL Abstract Only
S. M. WRIGHT and R. G. BURRAGE (Lucas Aerospace Ltd., Birmingham, England) *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

In order to apply modern digital hardware in a full authority high integrity control system, suitable precautions must be taken to avoid the consequences of a common mode data dependent error in a multi-lane system. A pseudo code based dissimilar modular multiprocessor design was described as a possible routine way of applying dissimilar techniques and hardwre at minimum cost. A safety map approach was developed to aid the designer in selection the system architecture. Author

N85-26752# National Aero- and Astronautical Research Inst., Amsterdam (Netherlands).
HOW TO HANDLE FAILURES IN ADVANCED FLIGHT CONTROL SYSTEMS OF FUTURE TRANSPORT AIRCRAFT Abstract Only
M. VANGOOL *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A ground-based simulator program in which reversion to an unstable flight control system backup occurred following the failure of the primary system. Of interest was the large scatter in the HQ ratings given to the backup system. It was found that existing longitudinal HQ criteria have difficulty in explaining the trend in pilot aircraft will be a very complicated task. B.W.

N85-26753# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
INTERACTIVE DESIGN OF SPECIFICATIONS FOR AIRBORNE SOFTWARE SET (GISELE) Abstract Only
J. CHOPLIN and D. BEURRIER *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

An flight control system software development process/system is described that possesses the features needed to generate production level certifiable software. It was designed to assist the user at all stages of development and testing and to generate the required level of documentation. Giesele has been in use since 1983.

N85-26754# Societe Nationale Industrielle Aerospatiale, Paris (France).
THE CERTIFICATION OF AIRBORNE COMPLEX DIGITAL SYSTEMS Abstract Only
P. TOULOUSE *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

An overview is presented of how the certification process might be applied to future active control based aircraft. Present regulations (FAR/JAR 25) are not very specific as to how compliance with safety consideration might be carried out. Presently

more specific regulations (e.g., AC/ACJ 1309 and RTCA DO 178/EUROCAE ED. 12) are being developed in which step by step procedures are proposed. Demonstration of compliance will require a combination of risk analysis, software analysis and ground test reports. It is suggested that all software maintenance should be under the control of the original designer. B.W.

N85-26755# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
THE FLIGHT CONTROL SYSTEM FOR THE EXPERIMENTAL AIRCRAFT PROGRAMME (EAP) DEMONSTRATOR AIRCRAFT Abstract Only
J. KAUL, F. SELLA (Aeritalia S.p.A), and M. J. WALKER (British Aerospace Aircraft Group) *In* AGARD Tech. Evaluation Rept. on the Flight Mech Symp. on Active Control Systems p 5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The historial background of the Experimental Aircraft Program is (EAP) presented. Because the first flight is planned for May 1986 the FCS design is based on previously proven technology. The aircraft is intended to demonstrate: (1) advanced structures and materials; (2) advanced aerodynamics ; (3) active control; (4) digital data bus; (5) modern cockpit; (6) stealthiness; and (7) digital control of the engine. B.W.

N85-26756# Boeing Aerospace Co., Seattle, Wash.
AUTOMATIC FLIGHT CONTROL MODES FOR THE AFTI/F-111 MISSION ADAPTIVE WING AIRCRAFT Abstract Only
M. R. EVANS, R. J. HYNES, D. C. NORMAN, and R. E. THOMASSON *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 5 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

This program involves the fitting of an experimental F-111 with a variable-camber wing and a digital FCS that makes use of this feature. The following automatic modes have been implemented: (1) Maneuver camber control to maximize lift/drg; (2) Cruise camber control - to maximize horizontal velocity; (3) Maneuver load control - to reduce wing root bending; and (4) Maneuver enhancement and gust alleviation - uses variable camber and the horizontal tail to increase maneuver response and to reduce gust response. B.W.

N85-26757# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
THE STOL AND MANEUVER TECHNOLOGY PROGRAM INTEGRATED CONTROL SYSTEM Abstract Only
D. J. MOORHOUSE and D. R. SELEGAN *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 6 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

The application of STOL capability to a supersonic fighter is discussed. This will be accomplished by employing a level of control integration beyond any attempted so far. In particular to a highly modified propulsion system will be incorporated as a primary control element. The control system design will require an integrated team of aerodynamics, stability and control, flying qualities, guidance, display, propulsion and controls specialists. The test aircraft will be an F-15 and the project will extend over the next 4-5 years. B.W.

N85-26758# Westland Helicopters Ltd., Yeovil (England).
THE EVOLUTION OF ACTIVE CONTROL TECHNOLOGY SYSTEMS FOR THE 1990'S HELICOPTER Abstract Only
G. C. F. WYATT *In* AGARD Tech. Evaluation Rept. on the Flight Mech. Symp. on Active Control Systems p 6 (SEE N85-26730 16-08) Mar. 1985
Avail: NTIS HC A02/MF A01

A reviewed is presented of the application of active control systems in helicopters. System failures and how best to deal with them are discussed. The author emphasized the need for: (1) Considering civil active control technology applications when undertaking military R and D; (2) More study of the common mode failure problem; and (3) Increased flight testing of ACT aircraft. B.W.

N85-27883# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ACTIVE CONTROL SYSTEMS: REVIEW, EVALUATION AND PROJECTIONS
Loughton, England Mar. 1985 392 p refs In ENGLISH and FRENCH Symp. held in Toronto, 15-18 Oct. 1984
(AGARD-CP-384; ISBN-92-835-0375-9; AD-A155853) Avail: NTIS HC A17/MF A01

Numerous topics relative to digital flight control systems are discussed. Active control technology applications, optimization of systems architecture for both reliability and costs control cam design, handling qualities, and the operational demonstration of systems reliability are among the topics covered. For individual titles see N85-27884 through N85-27911.

N85-27884# Centre d'Etudes et de Recherches, Toulouse (France).
ACTIVE CONTROL TECHNOLOGY (ACT): PAST, PRESENT AND FUTURE
M. J. PELEGRIN *In* AGARD Active Control Systems: Rev., Evaluation and Projections 30 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01

The past, present and future developments in the field of active control technology are surveyed. The improvement of aircraft performance, the reduction of operating costs, and the reduction of workloads are seen as benefits derived from active control technology. R.J.F.

N85-27885# General Electric Co., Binghamton, N.Y.
THE STATE-OF-THE-ART AND FUTURE OF FLIGHT CONTROL SYSTEMS
In AGARD Active Control Systems: Rev., Evaluation and Projections 4 p (SEE N85-27883 17-08) Mar. 1985
Avail: NTIS HC A17/MF A01

The evolution of flight control systems from non-electronic primary controls with electronic secondary augmentation systems to modern electronic Primary Fly-By-Wire systems is traced. Current system configurations are related to their origins in both aircraft and electronics technology. The future of flight control technology is discussed in view of the payoff which is expected from the increased integration of the various aircraft control functions. The integration of the aerodynamic and propulsive control systems provides a new level of control which will make the aircraft dramatically more maneuverable. The coupling of the integrated flight control system with the avionics system will permit advanced guidance and attack modes which will combine to increase the lethality of the combat system. The system will reconfigure its control laws to allow continuation of the mission or at least controlled flight in the face of battle damage if sufficient control power, lift, and propulsion remain. System architecture will be such as to support advanced maintainability features which will provide vastly improved system availability and persistance. R.J.F.

N85-27886*# Systems Technology, Inc., Hawthorne, Calif.
A PERSPECTIVE ON SUPERAUGMENTED FLIGHT CONTROL ADVANTAGES AND PROBLEMS
D. T. MCRUER, D. JOHNSTON, and T. MYERS *In* AGARD *Active Control Systems: Rev., Evaluation and Projections* 20 p (SEE N85-27883 17-08) Mar. 1985 refs
(Contract NAS2-11388)
Avail: NTIS HC A17/MF A01 CSCL 01C

Superaugmented aircraft are an important subclass of actively controlled, higly-augmented aircraft. The aircraft without augmentation is unstable, and the control system not only redresses the stability and control imbalance but also provides effective vehicle dynamics which may differ in kind from those associated with conventional aircraft. The properties of highly unstable aircraft and typical superaugmented control systems used to remedy their dynamic deficiencies are explored generically. The following topics are considered: basic flight control system architectures suitable to reduce or completely alleviate the unstable aircraft characteristics; the primary dynamic characteristics and regulatory properties of typical superaugmented aircraft control systems, including governing factors in the linear system, dominant mode characteristics, and fundamental stability margin properties; and flying qualities features for superaugmented aircraft with rate

command/attitude hold, extended bandwidth, and attitude command configurations. R.J.F.

N85-27887# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugmechanik.

ASPECTS OF APPLICATION OF ACT SYSTEMS FOR PILOT WORKLOAD ALLEVIATION

K. WILHELM and B. GMELIN *In* AGARD Active Control Systems: Rev., Evaluation and Projections 20 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

An essential element in the construction of future civil and military aircraft will be the inclusion of Active Control Technology (ACT) in the design process. This will be true for fixed-wing aircraft as well as for rotary-wing aircraft. The implementation of ACT makes possible improvements in flight performance and handling qualities. In particular, ACT can lead to alleviation of pilot workload in performing a specific task. This can be achieved by reducing undesirable motions and effects and adjusting the aircraft dynamics to a certain flight task and to the pilot. The above-mentioned problem areas concerning the implementation of ACT are discussed. Piloting problems with conventional systems and the influence of ACT systems on flying qualities and pilot workload are covered. Results from wind tunnel testing and flight testing using a BO 105 type helicopter and the HFB 320 in-flight simulator are given. R.J.F.

N85-27888# General Dynamics Corp., Fort Worth, Tex.

APPLICATION OF AFTI/F-16 TASK-TAILORED CONTROL MODES IN ADVANCED MULTIROLE FIGHTERS

R. D. TOLES, D. R. MCMONAGLE (Air Force, Edwards AFB, Calif.), D. C. ANDERSON, and J. H. WATSON *In* AGARD Active Control Systems: Rev., Evaluation and Projections 11 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

The next generation of multirole fighter aircraft will benefit from recent advances in flight control technology. The advent of digital fly-by-wire flight control capability for vehicles with relaxed static stability, as recently demonstrated by the AFTI/F-16, means a much higher level of performance is now attainable in handling qualities and weapon delivery effectiveness. Specifically, digital implementation of control laws permits the designer to attain a higher level of man/machine capability and performance, even at the flight envelope extremities. Multiple, separate task-tailored modes can be designed and employed to perform tasks with distinctly different flight dynamics requirements, achieving better performance than any single, multipurpose mode. Recently developed design concepts which support the above assertions are discussed. These concepts were employed on the AFTI/F-16 aircraft which dramatically demonstrated the benefits of digital flight control and task-tailored modes. R.J.F

N85-27889# Grumman Aircraft Engineering Corp., Bethpage, N. Y.

X-29 DIGITAL FLIGHT CONTROL SYSTEM DESIGN

A. B. WHITAKER and J. CHIN *In* AGARD Active Control Systems: Rev., Evaluation and Projections 13 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

The X-29 Technology Demonstrator is a Forward Swept Wing Aircraft with primary longitudinal control provided by a large canard. The wing body is balanced to be neutrally stable for minimum drag. The canard is sized for high maneuverability resulting in a configuration which is 35% unstable. This configuration with its high aerodynamic efficiency became practical through the application of Active Control System Technology in the design of the Digital Flight Control System. The design concept for the X-29 flight control system was to utilize the available state-of-the-art and existing hardware to fly a very unusual aircraft. The purpose was to achieve an Advanced Application of Control Configured Vehicle with minimum cost and risk in the hardware development. As a result, the system architecture is very conservative using demonstrated techniques. The Normal Longitudinal Control Law, on the other hand, is based on Modern Control Theory. The unique features of the aircraft configuration, the control system architecture, and control surface arrangement are discussed. The hardware selected for implementation is described. The control law development is outlined to include the constraints which result from the 35% static instability. R.J.F.

N85-27890# Royal Aircraft Establishment, Bedford (England). Flight Systems Dept.

THE EVOLUTION OF ACS FOR HELICOPTERS: CONCEPTUAL SIMULATION STUDIES TO PRELIMINARY DESIGN

J. S. WINTER, G. D. PADFIELD, and S. L. BUCKINGHAM *In* AGARD Active Control Systems: Rev., Evaluation and Projections 14 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

In the development of suitable control algorithms for future active control technology battlefield helicopters, handling qualities appropriate to a wide range of tasks will need to be identified and incorporated into the design process before detailed control laws may be defined. Work in identifying appropriate characteristics through piloted simulation studies of a conceptual model of the controlled helicopter, subsequent control law studies and the use of computer aided design and analysis of the sensitivity of the controlled vehicle are discussed. R.J.F.

N85-27891# Smiths Industries Ltd., Bishops Cleeve (England).

ACT APPLIED TO HELICOPTER FLIGHT CONTROL

W. R. RICHARDS *In* AGARD Active Control Systems: Rev., Evaluation and Projections 12 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

Benefits of ACT applied to helicopters are potentially significant resulting in a considerable challenge to avionic equipment suppliers. The impact of mechanical link removal and replacement by electrical/optical signalling is discussed. ACT control systems configurations suitable for installation in helicopters in the 1988 and 1992 time scales with anticipation of continued component technological development are identified. New control laws are discussed based on requirements for higher bandwidth controllers, and non-interaction of control axes. Author

N85-27892# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Aircraft Div.

SOME FLIGHT TEST RESULTS WITH REDUNDANT DIGITAL FLIGHT CONTROL SYSTEMS

U. KORTE *In* AGARD Active Control Systems: Rev., Evaluation and Projections 14 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

Under contract of the German MOD a quadruredundant, full authority digital Flight Control System has been developed by MBB for use in naturally unstable aircraft and flight tested in a single seater F-104 G which has been modified as a CCV demonstrator aircraft. From Dec. 1977 to Nov. 1981 the new FCS was tested in 118 flights in five different configurations of the aircraft. 22 of the flights were made in unstable configurations with instabilities up to 22 % MAC. In a follow-on program from Aug. 1982 to April 1984 a simple digital Backup-Controller (Software) and an integrated digital Autopilot were developed and successfully flight tested. Total number of flights with the digital FBW-system was 176. Some of the experiences and results are presented which were made with the operational FBW-system and the backup-software. Author

N85-27893# British Aerospace Public Ltd. Co., Lancashire (England). Aircraft Group.

AN UPDATE OF EXPERIENCE ON THE FLY BY WIRE JAGUAR EQUIPPED WITH A FULL-TIME DIGITAL FLIGHT CONTROL SYSTEM

E. DALEY *In* AGARD Active Control Systems: Rev., Evaluation and Projections 15 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

An overview of the Fly By Wire Jaguar Demonstrator Program which was recently successfully completed with the flight trials of a highly unstable configuration of 10% negative maneuver margin. The aircraft is unique, being equipped from the outset with a quadruplex digital flight control system, with no form of electrical or mechanical backup system. The U.K. demonstrator program was sponsored by MoD, with the aim of the design, development and demonstration of a safe, practical, full time fly by wire flight control system for a combat aircraft. The primary aim was achieved in 1981 with the first flight of the aircraft, and further objectives of the flight demonstration of the aircraft in a highly unstable

configuration in pitch, and with a Stall Departure/Spin Prevention system, was successfully completed. The flight control system, its flight certification and all phases of its flight trials is briefly described. Author

N85-27894# British Aerospace Aircraft Group, Brough (England). Aircraft Group.
ACT FLIGHT RESEARCH EXPERIENCE
D. J. WALKER and R. M. HORNER (RAE, Farnborough) *In* AGARD Active Control Systems: Rev., Evaluation and Projections 7 p (SEE N85-27883 17-08) Mar. 1985
Avail: NTIS HC A17/MF A01

Hunter XE 531 was the subject of a 15 year ACT program. The initial years involved the design, implementation and flight testing of a full authority quadruplex FCS flight control system. Using the aircraft as an experimental facility, a joint program emerged with British Aerospace, concentrating on handling aspects, ending with the loss of the aircraft through engine failure on take-off in 1982. The whole program is reviewed and the large variety of multidisciplinary topics covered are briefly described. Author

N85-27895# McDonnell Aircraft Co., St. Louis, Mo.
OPERATIONAL AND DEVELOPMENTAL EXPERIENCE WITH THE F/A-18A DIGITAL FLIGHT CONTROL SYSTEM
W. A. MORAN *In* AGARD Active Control Systems: Rev., Evaluation and Projections 13 p (SEE N85-27883 17-08) Mar. 1985
Avail: NTIS HC A17/MF A01

The control system of the F/A-184 Hornet is a four channel fly by wire system using digital processors. During the development of the F/A-18, more than 75 control law variations were flown. Many of these variations were made necessary by flexible aerodynamic characteristics which sometimes defied prediction and by evolving structural loads requirements, as well as by the usual refinements in control laws resulting from flight experience. The digital flight control computer provided the ability to make these changes with relative ease. It also provided the flexibility to solve problems which on past generation aircraft might have been treated either with placards or with expensive structural modifications. The control system and the testing of the system is described in detail. Author

N85-27896# Naval Air Test Center, Patuxent River, Md. Strike Aircraft Test Directorate.
FLIGHT TESTING AND DEVELOPMENT OF THE F/A-18A DIGITAL FLIGHT CONTROL SYSTEM
R. A. BURTON, B. T. KNEELAND, U. H. RABIN (Systems Control Technology, Inc., Palo Alto, Calif.), and R. S. HANSEN (Systems Control Technology, Inc., Palo Alto, Calif.) *In* AGARD Active Control Systems: Rev., Evaluation and Projections 18 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01

The improvement in the F/A-18 handling qualities from level 3 to level 1 for several mission tasks is documented. A new approach to the problem of extracting equivalent system models are handling qualities characteristics for fully augmented aircraft is introduced. This approach identified equivalent aerodynamic parameters and time delays of the flight control system and instrumentation system. This approach makes use of a mature and efficient integrated system identification procedure which uses several algorithms including a maximum likelihood method. This advanced equivalent system analysis method and the use of closed loop pilot mission related task testing are used to evaluate the F/A-18 digital FCS during its development. This is in contrast to classical open loop test techiques such as droplet inputs which gave little insight into the FCS and airframe interface. The correlation between equivalent time delays and the pilot handling qualities rating's obtained from closed loop mission task demonstrate that the equivalent system methodology can successfully be used to document the handling qualities of a highly augmented aircraft. In addition, the flexibility of the F/A-18 digital FCS allow for the correction of handling qualities and structural problems in a manner that has not previously been possible. Author

N85-27897# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
OLGA: AN OPEN LOOP GUST ALLEVIATION SYSTEM
H. BOEHRET, B. KRAG (DFVLR, Brunswick), and J. SKUDRIDAKIS (DFVLR, Wesseling, West Germany) *In* AGARD Active Control Systems: Rev., Evaluation and Projections 16 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01

Aircraft with a modern wing of high aerodynamic efficiency and low wing loading are sensitive to gusts and, therefore, only offer limited passenger comfort in turbulent weather. The OLGA (Open Loop Alleviation) system was developed in cooperation with the DFVLR to improve the passenger ride comfort for such types of aircraft. The open loop principle was chosen because investigations showed this to be superior to a feed back type system. The gust angle of attack, calculated from sensor signals determines the performance of the system. Symmetric aileron deflection and the elevator are used for the compensation of the gust induced lift and pitching moment. Both control surfaces are operated by electromechanical actuators. After theoretical design work, the open loop principle was the subject of intensive wind tunnel investigation using a remotely controlled wind tunnel model of the Do 28 TNT experimental aircraft. After realizing the hardware, the system was implemented and flight tested in the real Do 28 TNT airplane. The flight test results and its comparison with those obtained from the hardware simulation and the wind tunnel investigations are discussed. Author

N85-27898*# Lockheed-California Co., Burbank.
DEMONSTRATION OF RELAXED STATIC STABILITY ON A COMMERCIAL TRANSPORT
J. J. RISING, W. J. DAVIS, and C. S. WILLEY *In* AGARD Active Control Systems: Rev., Evaluation and Projections 18 p (SEE N85-27883 17-08) Mar. 1985 refs
(Contract NAS1-15326)
Avail: NTIS HC A17/MF A01 CSCL 01C

The application of relaxed static stability was studied under a program to determine ways of improving the energy efficiency in current and future transport aircraft. Pitch active control systems (PACs) were developed for application in the near term to current aircraft and in the next generation to advanced aircrft of the future. Analyses identified potential drag benefits of: (1) 2% for current transport aircraft with neutral stability; and (2) as much as 17% for next generation aircraft with high aspect ratio supercritical wings which must operate 10 to 15% statistically unstable to achieve optimum performance. Flight test evaluations of the near-term PACs were conducted to a 3% mean aerodynamic chord (MAC) negative static margin on a Lockheed L-1011 aircraft. The advanced PACs was demonstrated to a 20% MAC negative static margin on a piloted visual motion simulator at the NASA Langley Research Center. Test results for both systems showed flying qualities characteristics as good as current conventional aircraft. M.G.

N85-27899# Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany). Transport Aircraft Div.
REALISATION OF RELAXED STATIC STABILITY ON A COMMERCIAL TRANSPORT
U. P. GRAEBER *In* AGARD Active Control Systems: Rev., Evaluation and Projection 11 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01

The requirements of some airlines to increase the fuel capacity of a given transport aircraft led to a combined solution of an additional tank and the application of relaxed static stability. Some steps that led to the final solution are reviewed and some of its problems and benefits are shown. Author

N85-27900*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
ACTIVE CONTROL TECHNOLOGY EXPERIENCE WITH THE SPACE SHUTTLE IN THE LANDING REGIME
B. G. POWERS *In* AGARD Active Control Systems: Rev., Evaluation and Projections 9 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01 CSCL 01C

The shuttle program took on the challenge of providing a manual landing capability for an operational vehicle returning from orbit. Some complex challenges were encountered in developing the

longitudinal flying qualities required to land the orbiter manually in an operational environment. Approach and landing test flights indicated a tendency for pilot-induced oscillation near landing. Changes in the operational procedures reduced the difficulty of the landing task, and an adaptive stick filter was incorporated to reduce the severity of any pilot-induced oscillatory motions. Fixed-base, moving-base, and in-flight simulations were used for the evaluations, and in general, flight simulation has been the only reliable means of assessing the low-speed longitudinal flying qualities problems. Overall, the orbiter control system and operational procedures have produced a good capability for routinely performing precise landings in a large, unpowered vehicle with a low lift-to-drag ratio. Author

N85-27901# London Univ. (England).
THE AERODYNAMICS OF CONTROL
A. D. YOUNG *In* AGARD Active Control Systems: Rev., Evaluation and Projections 17 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01

Traditional forms of control, novel forms developed to deal with flight conditions where the traditional forms lose effectiveness, and direct force controls are reviewed. Dynamic effects, missile controls and computational methods for predicting the aerodynamic characteristics of controls (or motivators) are briefly discussed. Finally, comments are offered on major areas calling for future research. Author

N85-27902*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ACTIVE CONTROL LANDING GEAR FOR GROUND LOAD ALLEVIATION
J. R. MCGEHEE and D. L. MORRIS (AFWAL) *In* AGARD Active Control Systems: Rev., Evaluation and Projections 12 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01 CSCL 01C

Results of analytical and experimental investigations of a series-hydraulic active control landing gear show that such a gear is feasible when using existing hardware and is very effective in reducing loads, relative to those generated by a conventional (passive year) gear, transmitted to the airframe during ground operations. Analytical results obtained from an active gear, flexible aircraft, take-off and landing analysis are in good agreement with experimental data and indicate that the analysis is a valid tool for study and initial design of series-hydraulic active control landing gears. An analytical study of a series-hydraulic active control main landing gear on an operational supersonic airplane shows that the active gear has the potential for improving the dynamic response of the aircraft and significantly reducing structural fatigue damage during ground operations. M.G

N85-27903# Office National d'Etudes et de Recherches Aerospatiales, Paris (France)
WING BUFFETING ACTIVE CONTROL TESTING ON A TRANSPORT AIRCRAFT CONFIGURATION IN A LARGE SONIC WINDTUNNEL
R. DESTUYNDER *In* AGARD Active Control Systems: Rev., Evaluation and Projections 10 p (SEE N85-27883 17-08) Mar. 1985 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

A large half-model, duplicating the structural characteristics of a typical civil transport aircraft, was developed to study the unsteady response of active flaperons in the ONERA/S1 Modane Sonic Tunnel. The buffeting envelope results at large angles of attack or large Mach numbers were analyzed and the structural response to the buffeting phenomena was damped by introducing unsteady aerodynamic forces generated by the active flaperons. Thus a multicontrol system, operating on the various eigen modes of the wing structure was applied. Significant reduction of the consequences of this buffeting, both structural strain (fatigue) and airframe motion (comfort), were obtained, which could be translated into an effective widening of the usable flight envelope. Author

N85-27904# British Aerospace Public Ltd. Co., Brough (England). Aircraft Group.
A MODULAR DISSIMILAR REDUNDANT COMPUTER DESIGNED FOR HIGH INTEGRITY CONTROL
S. M. WRIGHT and R. G. BURRAGE (Lucas Aerospace Limited) *In* AGARD Active Control Systems: Rev., Evaluation and Projections 8 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01

Digital circuits present considerable testing problems since to prove the correct operation of the logic, each possible logical state has to be shown to function as expected. As digital VLSI designs become more complex, this absolute proof of design and manufacturing correctness has become impossible. In order to apply these devices in full authority high integrity control systems *suitable precautions must be taken to avoid* the consequences should such a common mode data dependant error be encountered. A pseudo code based dissimilar modular multiprocessor design is described as a possible routine way of applying dissimilar techniques at minimum cost. The pseudo code approach is shown to have advantages for the production of an integrated software support environment and the modularity is shown to allow a number of possible control system architecture developments. These are analyzed using a safety map approach and conclusions drawn. Author

N85-27905# National Aerospace Lab., Amsterdam (Netherlands).
HOW TO HANDLE FAILURES IN ADVANCED FLIGHT CONTROL SYSTEMS OF FUTURE TRANSPORT AIRCRAFT
M. VANGOOL *In* AGARD Active Control Systems: Rev., Evaluation and Projections 11 p (SEE N85-27883 17-08) Mar. 1985 refs
Avail: NTIS HC A17/MF A01

Indications exist that future transport aircraft will be designed according to active control technology concepts, using fly-by-wire flight control systems. Some philosophical considerations on the treatment of failures in these advanced flight control systems are given both from the industry and from the certification authorities point of view. It is concluded that early cooperation of parties involved is of utmost importance. Some results of an exploratory simulator investigation directed at the pilot appreciation of degradation in the aircraft handling qualities after failures in the primary flight control system are included. One of the problems encountered was large variability of the pilot ratings. The existing handling qualities criteria can be shown to have difficulty in explaining the pilot rating trend. Author

N85-27906# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France). Div. des Etudes Avancees.
THE INTERACTIVE GENERATION OF SPECIFICATIONS FOR AN ONBOARD SOFTWARE SERIES (GISELE) [GENERATION INTERACTIVE DE SPECIFICATIONS D'ENSEMBLE LOGICIEL EMBARQUE (GISELE)]
J. CHOPLIN and D. BEURRIER *In* AGARD Active Control Systems: Rev., Evaluation and Projections 11 p (SEE N85-27883 17-08) Mar. 1985 refs In FRENCH
Avail: NTIS HC A17/MF A01

GISELE is a software tool designed to be used for establishing software specifications for onboard systems which require a very high level of security. This interactive tool permits the design and editing of specifications in an appropriate language as well as the design of a very complete group of tests under the specifications. In addition, GISELE provides an aid to management and modification of specifications, and contributes a method for the means for the design and preparation of tests of the software constructed from these specifications. Transl. by A.R.H.

N85-27907# Societe Nationale Industrielle Aerospatiale, Toulouse (France).
CERTIFYING COMPLEX DIGITAL SYSTEMS ON CIVIL AVIATION AIRCRAFT [CERTIFICATION DES SYSTEMES DIGITAUX COMPLEXES A BORD D'AVIONS CIVILS]
P. TOULOUSE *In* AGARD Active Control Systems: Rev., Evaluation and Projections 12 p (SEE N85-27883 17-08) Mar. 1985 In FRENCH
Avail: NTIS HC A17/MF A01

The certification of equipment using digital techniques creates a delay with regards to demonstrating the security level because

the software which controls these systems is subject to a new category of definition errors which are not present in analog systems. The demonstration of an acceptable level of security is applied in a qualitative manner considering together a total analysis equipment faults, a process of verifying the software in relation to the criticality of the function provided by the equipment using the software, and, if necessary, by architectural precautions which provide freedom from the consequences of eventual latent software errors or of not easily predicted failure modes of equipment. This effort should be reflected in documentation acknowledged as acceptable by all parties to the certification. Transl. by A.R.H.

N85-27908# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).

THE FLIGHT CONTROL SYSTEM FOR THE EXPERIMENTAL AIRCRAFT PROGRAMME (EAP) DEMONSTRATION AIRCRAFT

H. J. KAUL, F. SELLA (Aeritalia, Turin), and M. J. WALKER (British Aerospace P.L.C., Preston, England) *In* AGARD Active Control Systems: Rev., Evaluation and Projections 16 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

The EAP is designed to be a highly maneuverable combat aircraft with a primary role of air superiority and a secondary role of ground attack. The performance capability is optimized by making the aircraft both longitudinally and directionally aerodynamically unstable in parts of the flight envelope. This requires artificial stabilization which is provided by the flight control system (FCS). *The control laws also include control of angle of attack to prevent* departure and spin, and features to safeguard the structure, to give a carefree maneuvering capability. The FCS is a full time fly by wire system based upon quadruplex digital computing and duo-duplex primary actuation, requiring no facility for reversion to back up or mechanical control. The system includes an extensive preflight test capability which checks that the system is fully operational prior to flight. It is designed to have a very high level of integrity; the design aim is to achieve a safety critical failure rate of less than 1.0 x 10 to the -6 power per flight hour. Author

N85-27909# Boeing Military Airplane Development, Seattle, Wash.

AUTOMATIC FLIGHT CONTROL MODES FOR THE AFTI/F-111 MISSION ADAPTIVE WING AIRCRAFT

M. R. EVANS, R. J. HYNES, D. C. NORMAN, and R. E. THOMASSON *In* AGARD Active Control Systems: Rev., Evaluation and Projections 13 p (SEE N85-27883 17-08) Mar. 1985

Avail: NTIS HC A17/MF A01

The advanced fighter technology integration F-111 mission adaptive wing (AFTI/F-111 MAW) is a joint Air Force and NASA Program that involves equipping an experimental F-111 aircraft with a variable camber wing and control modes that utilize the capabilities of this advanced technology wing. These new control *modes are both manual and automatic modes that use variable* camber to increase the performance of the aircraft. The automatic modes that have been added are: (1) maneuver camber control (MCC) - varies the camber to maximize lift/drag (L/D); (2) cruise camber control (CCC) - varies the camber to maximize horizontal velocity using an online optimization technique; (3) maneuver load *control (MLC) - directly controls wing root bending moment once* a threshold has been exceeded; and (4) maneuver enhancement and gust alleviation (ME/GA) - generates variable camber and horizontal tail commands to increase the maneuver response of the aircraft to pilot inputs and reduce the gust induced normal acceleration. These modes were integrated with the existing F-111 command augmentation system in a dual digital fail safe control system configuration for flight testing. Author

N85-27910# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.

THE STOL AND MANEUVER TECHNOLOGY PROGRAM INTEGRATED CONTROL SYSTEM DEVELOPMENT

D. J. MOORHOUSE and D. R. SELEGAN *In* AGARD Active Control Systems: Rev., Evaluation and Projections 10 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

A technology demonstration program was initiated to flight validate and mature near-term technologies applicable to adding STOL capability to a supersonic fighter, with a goal of also enhancing combat mission performance using the same technologies. A key technology is the development of a control system to integrate flight, propulsion, braking and steering controls. The STOL and Maneuver Technology Demonstration Program is defined with emphasis on the control system development. Many design options are available for such a system and criteria are not well defined. The expected benefits and problems of the control system development, the design options, the status of control system and flying qualities design criteria and the specific approach taken in defining program requirements are discussed. Finally, the expected contribution to future aircraft designs is examined.

Author

N85-27911# Westland Aircraft Ltd., Yeovil (England). Systems Technology.

THE EVOLUTION OF ACTIVE CONTROL TECHNOLOGY SYSTEMS FOR THE 1990'S HELICOPTER

G. C. F. WYATT *In* AGARD Active Control Systems: Rev., Evaluation and Projections 11 p (SEE N85-27883 17-08) Mar. 1985 refs

Avail: NTIS HC A17/MF A01

The primary flight control system requirements for both military and civil helicopters operating in the 1990's are reviewed and a rationale for system architectures which maximize the common features of military and civil active control systems is proposed. While the need for caution is recognized if system performance is not to be compromised through an unbalanced application of the methodology, substantial cost and weight savings are predicted. The particularly demanding problems of the avoidance of common mode system faults in a civil application are addressed and a solution to these problems is proposed. Author

N86-20399# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

FAULT TOLERANT HARDWARE/SOFTWARE ARCHITECTURE FOR FLIGHT CRITICAL FUNCTION

Loughton, England Sep. 1985 146 p refs Lecture series held at Edwards AFB, Calif., 1-2 Oct. 1985, in Copenhagen, Denmark, 17-18 Oct. 1985, and in Athens, Greece, 21-22 Oct. 1985

(AGARD-LS-143; ISBN-92-835-1510-2; AD-A161950) Avail: NTIS HC A07/MF A01

This Lecture Series is intended to provide basic concepts and theories in the design of fault-tolerant architectures for flight critical systems. It is intended to cover experience with flight tested fly-by-wire systems as well as issues in redundancy management of synchronous and asynchronous approaches. It will specifically address the individual aspects of software fault tolerance, actuation fault tolerance, reliable data communication, and multi-computer operation using the Ada language. For individual titles see N86-20400 through N86-20409.

N86-20400# Honeywell Systems and Research Center, Minneapolis, Minn.

INTRODUCTION TO LECTURE SERIES NO. 143: FAULT TOLERANT HARDWARE/SOFTWARE ARCHITECTURES FOR FLIGHT CRITICAL FUNCTIONS

G. L. HARTMANN *In* AGARD Fault Tolerant Hardware/Software Architecture 3 p (SEE N86-20399 11-08) Sep. 1985 refs

Avail: NTIS HC A07/MF A01

Modern weapon systems, driven by escalating performance demands, are becoming complex and sophisticated. Demands for higher accuracy, improved reliability/survivability, all-weather operation, and more automation are placing increased emphasis on the control function. Nowhere is this increased emphasis more evident than in the control functions required in advanced aircraft systems. Due to the expanded role of automation many functions are becoming flight-critical (i.e., loss of this function is catastrophic). Flight critical architectures are more complex than fault-tolerant computers. In addition to airborne computers, overall reliability depends on proper design and management of: (1) Sensors and their interfaces; (2) Actuation elements; and (3) Data communication along the distributed elements. Previous NATO-AGARD publications have dealt with related aspects of this subject. This lecture series covers experience with flight tested fly-by-wire systems as well as issues in redundancy management of synchronous and asynchronous systems. It specifically

addresses software fault tolerance, actuation fault tolerance, reliable data communications, and multi-computer operation using the Ada language. Author

N86-20401# Marconi Avionics Ltd., Rochester (England). Flight Controls Div.
DIGITAL FLY-BY-WIRE EXPERIENCE
A. D. HILLS *In* AGARD Fault Tolerant Hardware/Software Architecture 8 p (SEE N86-20399 11-08) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

A description of two recent GEC Avionics (GAv) systems is included: (1) A310 Slats and Flaps Control System; and (2) Jaguar FBW Demonstrator Flight Control System. Particular reference is made to the architecture of the computers and embedded software. Data is included on the two different system design requirements, especially those relating to integrity and availability. Emphasis is placed on the reasons for selecting dissimilarity, as an implementation philosophy, for the A310 system, as against the multiple similar Jaguar demonstrator architecture. The paper then provides a brief description of the design and development program for the two computer units with emphasis on lessons learned, specially in the software areas. The aspects of the system and computer design involved with maintainability and reliability are detailed and current in-service experience discussed where applicable. Conclusions are drawn particularly on dissimilarity, highlighting lessons learned from these successful FBW programs. A potential method of providing software fault tolerance within a dissimilar implementation is discussed and preliminary results of a GEC research program in this area provided. Author

N86-20402# Massachusetts Inst. of Tech., Cambridge. Lab. for Computer Science.
REDUNDANCY MANAGEMENT OF SYCHRONOUS AND ASYNCHRONOUS SYSTEMS
G. M. PAPADOPOULOS *In* AGARD Fault Tolerant Hardware/Software Architecture 15 p (SEE N86-20399 11-08) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

While asynchronous systems may initially appear attractive due to the uncoupling the channels, the cross-channel interactions are much greater than what might be expected. Both synchronous and asynchronous systems share the burden of cross-channel consistency maintenance, the requirement that inputs and internal states are not allowed to diverge too far from each other. In fact, consistency maintenance often dominates the engineering process in a correctly designed system. In asynchronous systems, consistency maintenance takes the form of cross-channel equalization along with techniques for handling discrete changes in operating mode. In synchronous systems, consistency maintenance is implemented with source congruence algorithms. Synchronous and asynchronous systems must both support reliable resolution of redundant channel outputs, the process of isolating correct effectuator commands from faulty ones. A correctly designed synchronous system may rely on exact bit-for-bit voting to isolate faulty channels, while an asynchronous system must employ more heuristic means such as threshold and reasonableness tests. This research concludes that data synchronous principle is the approach of choice. the systems provide general purpose vehicles on which increasingly complex and diverse flight critical applications may execute. Author

N86-20403# Newcastle-upon-Tyne Univ. (England). Computing Lab.
SOFTWARE FAULT TOLERANCE EXPERIMENTS
T. ANDERSON and P. A. BARRETT *In* AGARD Fault Tolerant Hardware/Software Architecture 5 p (SEE N86-20399 11-08) Sep. 1985 refs Sponsored in part by UK Science and Engineering Research Council and by the Ministry of Defence
Avail: NTIS HC A07/MF A01

A major experimental program has been undertaken in order to evaluate the effectiveness of software fault tolerance techniques in practical systems. This paper presents the results of phases two and three of these experiments, which indicate that the techniques can significantly enhance software reliability. The particular application used for these experiments was a naval command and control system, thus confirming that software fault tolerance can be successfully utilized in critical real-time systems. Author

N86-20404# Newcastle-upon-Tyne Univ. (England). Computing Lab.
CAN DESIGN FAULTS BE TOLERATED?
T. ANDERSON *In* AGARD Fault Tolerant Hardware/Software Architecture 5 p (SEE N86-20399 11-08) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

The fault tolerant approach to building a reliable system acknowledges that perfection is impossible (or at best, very expensive) and therefore tries to cope with the consequences of residual defects within the system. Fault tolerance has an established role in detecting and masking component faults in hardware systems, but has also been advocated as a defense against deficiencies of design. This paper argues, in question and answer format, the case for adopting design fault tolerance techniques in practical systems. Author

N86-20405# Laboratoire d'Automatique et d'Analyse des Systemes, Toulouse (France).
DEPENDABLE AVIONIC DATA TRANSMISSION
D. R. POWELL and J. C. VALADIER *In* AGARD Fault Tolerant Hardware/Software Architecture 19 p (SEE N86-20399 11-08) Sep. 1985 refs Sponsored in part by Direction des Recherches, Etudes et Techniques. Prepared in cooperation with Crouzet Aerospace and Systems, Valence, France, and Electronique Serge Dassault, St. Cloud, France
Avail: NTIS HC A07/MF A01

This paper outlines the major constraints imposed on the design of dependable local area networks for avionic systems and underlines the essential differences in requirements that exist with respect to those of ground-based (civil) LANs. The different choices available to the system designer are then discussed: technology (electrical or optical), architecture (bus or loop), general philosophy (centralized or decentralized), medium access control (competition or consultation). The paper then goes on to summarize two different and independent avionic LAN research projects; one which focusses on fault and damage-tolerance and the other on high-speed. Author

N86-20406# Honeywell Systems and Research Center, Minneapolis, Minn.
MULTI-COMPUTER FAULT TOLERANT SYSTEMS USING ADA
W. L. HEIMERDINGER *In* AGARD Fault Tolerant Hardware/Software Architecture 8 p (SEE N86-20399 11-08) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

Ada will be the language of choice for a number of flight critical applications in the future. Ada incorporates a number of constructs to aid in constructing reliable software, including packages and private data types to manage the visibility of data and strong typing to control the values and operations that can be applied to a data object. Ada also provides constructs to assist in the construction of fault tolerant software. These include tasks and the Ada mechanisms for synchronizing and communicating between tasks, for exception handling and for timing. These mechanisms rely to a large degree on an Ada run time kernel, a set of routines to provide Ada features that can only be implemented while the application program is running. Since multiple computer architectures are often used for fault tolerant systems, the implementation of Ada software for multiple computers is an important consideration. Two ongoing projects illustrate the range of options for distributing Ada software on multiple computers. The first approach, which creates a separate Ada program for each computer, makes the least demands on the Ada compiler and run time software. The second approach, which treats all software for a multiple computer system as a single Ada program, requires a specialized Ada compiler and special distributed run time support routines, but separates software partitioning from the application programming. Author

N86-20407# Massachusetts Inst. of Tech., Cambridge. Lab. for Computer Science.
DESIGN ISSUES IN DATA SYNCHRONOUS SYSTEMS
G. M. PAPADOPOULOS *In* AGARD Fault Tolerant Hardware/Software Architecture 12 p (SEE N86-20399 11-08) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

Fault tolerant data synchronous systems are ones where the outputs of all correctly operating redundant channels are

guaranteed to bit-for-bit agree, independent of whether the channels are clock, instruction or frame synchronous. Data synchronous systems offer a form of fault tolerant processing capable of correctly supporting a very general class of programs. In fact, the redundancy becomes relatively transparent to the programmer of applications for data synchronous systems, making them ideally suited for complex, algorithmically intensive programs that would be otherwise impossible to support. The various aspects of the design of correct data synchronous systems are examined in detail. These include: Source consistency, the requirement that all correctly operating channels receive precisely the same inputs, Event synchronization, the problem of keeping the time skew between channels within predetermined bounds, as well system initialization. The unsolved problem of latent faults is also presented along with the need for self-test heuristics. Sequential fault tolerant and parallel fault tolerant approaches are contrasted for systems requiring protection from multiple faults. Both hardware and software solutions to these problems are given, emphasizing system performance and economy. The paper concludes with the application of these techniques to the design of triplex fail-operational and quadruplex and dual-dual fail-operational-fail-operational systems. Author

N86-20408# Northrop Corp., Hawthorne, Calif. Aircraft Div.
DIGITAL FAULT-TOLERANT FLIGHT ACTUATION SYSTEMS
H. H. BELMONT *In* AGARD Fault Tolerant Hardware/Software Architecture 19 p (SEE N86-20399 11-08) Sep. 1985
(Contract F33615-80-C-3623)
(AFWAL-83-3041) Avail: NTIS HC A07/MF A01

A study was made of the equipments making up a typical flight control actuation system (servo electronics, servo valves, actuators and transducers) to determine where digital technology could replace analog technology for the purpose of providing a more fault-tolerant flight control actuation system. The investigation involved an analysis of where digital-to-analog conversion should take place between the light control computer and the analog control surface, and led to an evaluation of several architectural design issues. Among these were how to functionally partition the system, where to locate the servo electronics, the adequacy of military standard serial bus systems for control (versus data) applications, and the feasibility of providing electronics which could survive severe environments. Several actuation system configurations were evaluated. This led to recommending, as the best development prospect, a locally integrated actuation system consisting of servo electronics, servo valves, actuators, and transducers, interfacing with a digital flight control computer over a serial bus. Author

N86-20409# Honeywell Systems and Research Center, Minneapolis, Minn.
DESIGN VALIDATION OF FLY-BY-WIRE FLIGHT CONTROL SYSTEMS
G. L. HARTMANN, J. E. WALL, JR., and E. R. RANG *In* AGARD Fault Tolerant Hardware/Software Architecture 17 p (SEE N86-20399 11-08) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

This paper addresses the problem of design validation of fault tolerant architectures. Finite-state machines are used to formally specify flight control functions. Their application is not new to engineering practice in flight control. However, it is believed that their systematic and formal use to form the structure of the system specification will be an aid in the design phase and in the validation phase. Examples are used to illustrate their application to flight control specifications. The second portion of this paper is concerned with the problem of testing highly reliable systems. Models based on fault-trees in the early definition phase of estimating reliability are used to design tests to be performed at the iron bird state (hardware in-the-loop). Confidence in the overall system reliability is derived from a combination of component life-tests and a careful evaluation of the faults that the system is designed to accommodate without loss of control. Author

09

RESEARCH AND SUPPORT FACILITIES (AIR)

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

N83-29276# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SURVEY OF MISSILE SIMULATION AND FLIGHT MECHANICS FACILITIES IN NATO
W. M. HOLMES (Army Missile Command, Redstone Arsenal, Ala.) 1982 103 p
(AD-A128440; ISBN-92-835-1448-3; AGARD-AG-279) Avail: NTIS HC A06/MF A01

A survey of missile system simulation facilities was conducted. Information from this task addresses missile system and subsystem simulation capabilities, methodology of simulation development, simulation model verification and validation. In addition, approaches and procedures were recommended that would enhance cooperative development of missile system simulation, test and evaluation as related to missile system flight mechanics. S.L.

N83-29277# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PROCEEDINGS OF THE AGARD FLUID DYNAMICS PANEL SPECIALISTS MEETING ON WALL INTERFERENCE IN WIND TUNNELS Technical Evaluation Report
T. W. BINION, JR. (Calspan Field Services, Inc., Arnold AFS, Tenn.) 1982 12 p refs Proc. held in London, 19-20 May 1982 Submitted for publication
(AGARD-AR-190; AGARD-CP-335; ISBN-92-835-1447-5; AD-A130883) Avail: NTIS HC A02/MF A01

The effects of wind tunnel wall interference are studied. Endeavors were undertaken to learn how to correct wind tunnel data or to reduce the wall induced interference. Successful efforts are largely limited to solid wall, low speed situations. The invention of ventilated wall tunnels did much to reduce the tunnel boundary induced interferences, and the adaptive wall concept promises to finally provide a test environment with neglibible wall interference. Author

N83-30438*# National Aeronautics and Space Administration, Washington, D.C.
WEATHER HAZARD SIMULATION IN THE MODANE WIND-TUNNELS
G. FASSO, G. LECLERE, and F. CHARPIN Apr. 1983 20 p refs Transl. into ENGLISH of "Simulation des Intemperies dans les Soufflerie de Modane" rept. AGARD-CP-174 Paris, Mar. 1976 8 p Fluid Dyn. Panel Symp. held in London, 6-8 Oct. 1975 Document was also announced as N76-25244 Transl. by Kanner (Leo) Associates, Redwood City, Calif.
(Contract NASW-3541)
(NASA-TM-77069; NAS 1.15:77069; AGARD-CP-174) Avail: NTIS HC A02/MF A01 CSCL 14B

Specially designed wind tunnel setups make it possible to simulate various weather hazards, in an imperfect but systematic manner. Systems installed in the Modane wind tunnels for rain and icing tests are described. A gust simulator being developed is also discussed. Author

N84-25723# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
OPERATIONAL AND PERFORMANCE MEASUREMENT ON ENGINES IN SEA LEVEL TEST FACILITIES
Loughton, England Mar. 1984 176 p refs Lecture held in Rome, 26-27 Apr. 1984, in Ankara, Turkey, 30 Apr. - 1 May 1984, and in Athens, 3-4 May 1984
(AGARD-LS-132; ISBN-92-835-0350-3; AD-A144211) Avail: NTIS HC A09/MF A01

This Lecture Series considers all the basic features of turbojets and turbofan testing. In the introduction, test cell design is set in historical perspective with brief descriptions of the test arrangement and instrumentation used to test the early jet engines. The way in which these have evolved to modern designs is outlined. Three

typical uses for sea level test beds, routine proof testing following overhaul, performance evaluation for type certification and general development testing are described and covered in detail by specialist lectures. One lecture is devoted specifically to turboprop testing. Instrumentation and data handling are dealt with in two lectures, one covering measurement techniques and the other covering data acquisitions and handling. One lecture is devoted to the derivation of the performance of the engine from the test bed measurements. For individual titles, see N84-25724 through N84-25731.

N84-25724# Ashwood (P. F.), Farnham (England).
OPERATION AND PERFORMANCE MEASUREMENT ON ENGINES IN SEA-LEVEL TEST FACILITIES: INTRODUCTION AND GENERAL SURVEY
P. F. ASHWOOD *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 15p (SEE N84-25723 16-09) Mar. 1984
Avail: NTIS HC A09/MF A01

Several aspects of sea level testing are reviewed to provide an introduction and background to the specialist papers which make up this Lecture Series. The review commences by setting cell design in historical perspective and considering the facilities that were used in the UK to test the early jet engines. A more modern cell, the Glen Test House at Pyestock, is described in detail because its design contains all the basic features required for testing turbojets and turbofans. Attention is drawn to two areas where the original Glen systems have been enhanced to meet modern requirements: the instrumentation and the method of measuring thrust. Three typical uses for sea level test beds, routine proof testing, performance evaluation and general development testing, are each briefly described and their influence on test bed design and instrumentation requirements discussed. Instrumentation is considered only in outline because of its highly specialist nature, but attention is drawn to the need for the data output to be presented in easily assimilated form, particularly when processing is carried out on line. Finally an account is given of an investigation made at Pyestock under the author's direction to examine the aerodynamic factors which influence thrust measurement. As published information on this topic is still extremely limited, and in view of its relevance to the present Lecture Series, the opportunity has been taken to make the results of these tests more widely available. Author

N84-25725# Ecole Royale Militaire, Brussels (Belgium).
AERO/THERMODYNAMIC AND ACOUSTIC CONSIDERATIONS IN THE DESIGN OF TEST-BEDS FOR TURBOJETS AND TURBOFANS
R. JACQUES *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 23p (SEE N84-25723 16-09) Mar. 1984 refs
Avail: NTIS HC A09/MF A01

The testing of noninstalled engines or trimming of engines installed on aircraft has to be performed in closed test beds on most of the airfields. The lecture starts with a general presentation of the closed test bed and the layout of the buildings. The thermodynamic equations for the calculation of the air and waterflows needed for the cooling of the hot gases ejected by the turbojet are established. These flows are a function of the thermodynamic performance parameters of the engine, and the maximum value of the temperature allowed by the materials used in the exhaust. Correct measurement of the thrust imposes restrictions on the aerodynamics of the flow such as speeds and depression in the test room. The required air flow enables us to determine the cross section of the test room. The choice of a test bed with one or two air intakes depends on the airflows. The aerodynamic equations must be established in order to calculate approximately the airflows through the test bed. The airflows are functions of the cross sectional areas of intake and exhaust stacks, ejector, flow loss coefficients and such engine parameters as thrust, temperatures and airflow. Noise reduction in the surrounding environment is the first aim of the test bed designer. The allowable noise level imposed by the user depends on the location and the orientation of the test cell, and the distances from residential buildings, offices or workshops. B.W.

N84-25726# Rolls-Royce Ltd., Bristol (England). Dept. of Developmental Engineering.
DEVELOPMENT TESTING: USE OF SEA LEVEL TEST BEDS AND RIGS
M. H. BEANLAND *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 6p (SEE N84-25723 16-09) Mar. 1984
Avail: NTIS HC A09/MF A01

An in-depth description is given of the types of development programs used in the testing of jet engines in sea level test facilities. Types of development tests include: piece parts level testing; module level testing; spool level testing; full engine level testing; and integrity testing. B.W.

N84-25727# Pratt and Whitney Aircraft, West Palm Beach, Fla. Dept. of Test Instrumentation.
INSTRUMENTATION TECHNIQUES IN SEA LEVEL TEST FACILITIES
C. E. CRONIN *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 10p (SEE N84-25723 16-09) Mar. 1984 refs
Avail: NTIS HC A09/MF A01

This paper describes the application of instrumentation used during testing of turbojet and turbofan engines in sea level test facilities. The operating principal of various transducer types are discussed along with errors encountered and techniques used for calibration. A brief description of systems used for data acquisition, monitoring of engine health, and ensuring safety of the engine under test is also presented. It is the intention of this paper to present general information in the application of instrumentation devices and systems for the benefit of individuals with limited experience in the field of instrumentation. It discusses some, but by no means all, of the measurement techniques practiced in the engine development process. A selection of references is provided for those interested in reading further. Author

N84-25728# National Research Council of Canada, Ottawa (Ontario). Div. of Mechanical Engineering.
PERFORMANCE DERIVATION OF TURBOJETS AND TURBOFANS FROM TESTS IN SEA-LEVEL TEST CELLS
D. M. RUDNITSKI *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 22p (SEE N84-25723 16-09) Mar. 1984 refs
Avail: NTIS HC A09/MF A01

To most users of aircraft jet engines, the definition of engine performance means the thrust level, and the fuel consumption required to generate it. Just as important, however, is mechanical performance, as an engine may meet the thrust requirement, yet lack sufficient mechanical integrity. The operator must therefore have some means of quantifying engine performance before he can pronounce it as healthy. This type of routine testing is generally conducted in an enclosed ground level test bed. During an engine test, data are recorded at several power settings, corrected for cell effects, and compared against manufacturer's supplied curves to determine actual performance. If an engine was tested on an outdoor stand, under zero wind conditions, the measured thrust, corrected for instrument error, would be the true engine thrust. The act of bringing the engine into an enclosed facility has an effect on measured engine performance. The procedure for quantifying this effect, sometimes called establishing a cell factor, is usually done by correlating the customer's facility to the manufacturer's standard test cell using a gold plated engine. This paper describes the types of measurements, performance parameters, and methods of data presentation for a correlation program. Author

N84-25729# Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
TESTING OF TURBOSHAFT ENGINES
M. D. WUNDER *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 11p (SEE N84-25723 16-09) Mar. 1984
Avail: NTIS HC A09/MF A01

Safety in flying is of paramount importance. The high standard of the theoretical principles behind research and design and quality measures during production on their own are not sufficient for guaranteeing adequate safety. Therefore testing of components and engines before installation in aircraft is still required. It may

prove possible to reduce the extent of testing, based on more sophisticated evaluation methods and testing techniques. Modular designed engines may be tested even less in the future, if the effect of specific replaced modules is well understood. This lecture is concerned with engine development, manufacturing and maintenance. B.W.

N84-25730# Royal Aircraft Establishment, Farnborough (England). Test Operations Div.

DATA ACQUISITION AND PROCESSING IN SEA-LEVEL TEST BEDS

M. HOLMES, P. G. BOOKER, and B. M. WATTS *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 17p (SEE N84-25723 16-09) Mar. 1984
Avail: NTIS HC A09/MF A01

This lecture presents an overview of modern day data acquisition display in sea level test beds, and to aid an understanding of the subject it has been conveniently divided into several sections, each of which covers a particular aspect of the overall process. Starting at the engine, or perhaps within it, a physical quantity such as pressure or temperature has to be converted into an analogue of its value and then transmitted to the control room where its value can be displayed to the test engineer as well as being recorded for later analysis. Thus the lecture first of all discusses the range of parameters that may need to be measured on a test engine and the nature of the signals which are output by the measuring devices. Next, the question of signal transmission is dealt with, and here the importance of preventing noise from degrading the transmitted signal is described. This is followed by a section on the important aspect of measurement calibration. Finally, the methods whereby signals are collected, stored and displayed are given some attention. In each section mention is made of the increasingly important role of microprocessors, particularly for data reduction, data analysis and monitoring of test data. B.W.

N84-25731# Royal Air Force, Barry (England).

UNINSTALLED AERO ENGINE TESTING IN OPERATION IN THE ROYAL AIR FORCE

J. A. ROWLAND, B. SCOFIELD, C. HAYNES, and C. BROAD *In* AGARD Operational and Performance Meas. on Eng. in Sea Level Test Facilities 19p (SEE N84-25723 16-09) Mar. 1984
Avail: NTIS HC A09/MF A01

The RAF started with Avon and Spey Uninstalled Testing Run Up Stands (UTRUS) with limited scope, but soon established firm requirements for the comprehensive UETF facilities which we now have to support Adour and RB199. These have full thrust measurement and comprehensive instrumentation; various developments are described. Data analysis methods are emphasized including the use of desk top calculators and the advantages gained from ADP and Automated Power Plant Testing (APT). CSDE's work on continuous calibration is described with examples and a brief introduction to their V mask technique. The paper concludes with a description of the RAF Training schemes for UETF Operators. Author

N84-29894 Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).

A SURVEY OF BIODYNAMIC TEST DEVICES AND METHODS

N. S. NUSSBAUM (Aerospace Medical Research Lab.) Apr. 1984 58 p refs
(AD-A142467; AGARD-AG-276) Avail: NTIS HC A04/MF A01 CSCL 06S

The author has up-dated AGARD Report No. 658 "A Catalogue of Current Impact Devices" to include new/revised facilities, has presented research procedures in use at each facility and described the personnel capabilities available. The information about each facility has been obtained largely from inputs completed by the establishments concerned, technical reports, previous listings and personal visits. Author

N84-32401# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

FUTURE REQUIREMENTS FOR AIRBORNE SIMULATION

J. BUHRMAN (National Aerospace Lab.) Apr. 1984 17 p refs
(AGARD-AR-188; ISBN-92-835-1471-8; AD-A145386) Avail: NTIS HC A02/MF A01

Airborne and ground-based flight simulation are complementary techniques widely used in aeronautical research and development. The rapid advances in recent years both in the level of sophistication and in the degree of attainable fidelity for modern ground-based flight simulation systems has, however, called into question the future role of in-flight simulators in the research and development processes. The premise that this role may soon disappear has been addressed by a Subcommittee of the AGARD Flight Mechanics Panel. General purpose airborne simulators and special purpose research aircraft will continue to serve a useful complementary role to the ground-based simulator through the next generation of aircraft development programs. Author

N84-32402# National Aerospace Lab., Amsterdam (Netherlands). Compressible Aerodynamics Dept.

TECHNICAL EVALUATION REPORT ON THE FLUID DYNAMICS PANEL SYMPOSIUM ON WIND TUNNELS AND TESTING TECHNIQUES

A. ELSENAAR May 1984 13 p refs Symp. held in Cesme, Turkey, 26-29 Sep. 1983
(AGARD-AR-193; ISBN-92-835-1473-4; AD-A146208) Avail: NTIS HC A02/MF A01 CSCL 14B

Testing techniques and wind tunnels were discussed. New facilities and their performance, design, wind tunnel tests like scale effects and disturbance effect were reported. New developments in cryogenic testing techniques, and refinement of conventional techniques, instrumentation, model design and construction are reported. The increasing impact of computer development on wind tunnel testing is addressed. E.A.K.

N86-20415# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.

SPECIAL COURSE ON CRYOGENIC TECHNOLOGY FOR WIND TUNNEL TESTING

Loughton, England Jul. 1985 408 p refs Course held in Rhode-Saint-Genese, Belgium, 22-26 Apr. 1985; sponsored by the Von Karmen Inst. and AGARD
(AGARD-R-722; ISBN-92-835-1506-4; AD-A161833) Avail: NTIS HC A18/MF A01

Following a brief review of the development and early application of cryogenic wind tunnels, the 16 lectures examine the following aspects of cryogenic wind tunnel technology related to the design and operation of cryogenic tunnels: cryogenic engineering and safety, properties of materials at cryogenic temperatures, model design requirements and fabrication techniques, instrumentation for control and data acquisition, data accuracy, productivity, and costs of models and operation. A review of the status of cryogenic wind tunnel projects is also presented. For individual titles see N86-20416 through N86-20431.

N86-20416# Southampton Univ. (England). Dept. of Aeronautics and Astronautics

INTRODUCTION TO CRYOGENIC WIND TUNNELS

M. J. GOODYER *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 11 p (SEE N86-20415 11-09) Jul. 1985 refs Previously announced in IAA as N86-12238
Avail: NTIS HC A18/MF A01

The backgrcund to the evolution of the cryogenic wind tunnel is outlined, with particular reference to the late 60's/early 70's when efforts were begun to re-equip with larger wind tunnels. The problems of providing full scale Reynolds numbers in transonic testing were proving particularly intractible, when the motion of satisfying the needs with the cryogenic tunnel was proposed, and then adopted. The principles and advantages of the cryogenic tunnel are outlined, along with guidance on the coolant needs when this is liquid nitrogen, and with a note on energy recovery. Operational features of the tunnels are introduced with reference to a small low speed tunnel. Finally the outstanding contributions are highlighted on the 0.3-Meter Transonic Cryogenic Tunnel (TCT)

at NASA Langley Research Center, and its personnel, to the furtherance of knowlege and confidence in the concept. Author

N86-20417*# Applied Cryogenics and Materials Consultants, New Castle, Del.
BASIC CRYOGENICS AND MATERIALS
D. A. WIGLEY *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 18 p (SEE N86-20415 11-09) Jul. 1985 refs Previously announced in IAA as N85-32215 Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 13B

The effects of cryogenic temperatures on the mechanical and physical properties of materials are summarized. Heat capacity and thermal conductivity are considered in the context of conservation of liquid nitrogen, thermal stability of the gas stream, and the response time for changes in operating temperature. Particular attention is given to the effects of differential expansion and failure due to thermal fatigue. Factors affecting safety are discussed, including hazards created due to the inadvertent production of liquid oxygen and the physiological effects of exposure to liquid and gaseous nitrogen, such as cold burns and asphyxiation. The preference for using f.c.c. metals at low temperatures is explained in terms of their superior toughness. The limitations on the use of ferritic steels is also considered. Nonmetallic materials are discussed, mainly in the context of their LOX compatibility and their use in the form of foams and fibers as insulatants, seals, and fiber reinforced composites. Author

N86-20418*# Applied Cryogenics and Materials Consultants, New Castle, Del.
MATERIALS AND TECHNIQUES FOR MODEL CONSTRUCTION
D. A. WIGLEY *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 19 p (SEE N86-20415 11-09) Jul. 1985 refs Previously announced in IAA as N85-31066 Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 14B

The problems confronting the designer of models for cryogenic wind tunnel models are discussed with particular reference to the difficulties in obtaining appropriate data on the mechanical and physical properties of candidate materials and their fabrication technologies. The relationship between strength and toughness of alloys is discussed in the context of maximizing both and avoiding the problem of dimensional and microstructural instability. All major classes of materials used in model construction are considered in some detail and in the Appendix selected numerical data is given for the most relevant materials. The stepped-specimen program to investigate stress-induced dimensional changes in alloys is discussed in detail together with interpretation of the initial results. The methods used to bond model components are considered with particular reference to the selection of filler alloys and temperature cycles to avoid microstructural degradation and loss of mechanical properties. Author

N86-20419*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DESIGN AND CONSTRUCTION OF MODELS FOR THE NATIONAL TRANSONIC FACILITY, PART 1
C. P. YOUNG, JR. *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 17 p (SEE N86-20415 11-09) Jul. 1985 refs Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 11F

The design and construction of models for the National Transonic Facility (NTF) has resulted in significant technology developments in many areas. This lecture covers the development of design criteria and major research and development work that has contributed to the successful design and fabrication models for testing at full scale Reynolds number the NTF. Emphasis is placed on the materials aspect of the design and fabrication proces, including metallic materials, mechanical properties characterization, new steel alloy development, fracture toughness enhancement, and identification of fillers and solders suitable for use in cryogenic models. Quantitative data are provided which will be of value to the potential user of NTF or for application to the design and fabrication of model systems for other cryogenic wind tunnels. Author

N86-20420*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DESIGN AND CONSTRUCTION OF MODELS FOR THE NATIONAL TRANSONIC FACILITY, PART 2
C. P. YOUNG, JR. *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 16 p (SEE N86-20415 11-09) Jul. 1985 refs Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 17G

This lecture presents the results of fastener load and retention systems tests which were carried out as a part of the cryogenic models technology development program a the NASA Langley Research Center (LaRC). Various design concepts for the National Transonic Facility (NTF) developmental and production models are discussed. A number of NTF models are described with emphasis on materials used, uniqueness of design and design drivers. Design and fabrication experience is presented in terms of the primary thermal and mechanical considerations required for design as well as fabrication. Cost considerations are addressed in terms of factors influencing costs for NTF models and cost data comparisons which are taken from both NASA Langley and industry experience. Author

N86-20421# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
CRYOGENIC WIND TUNNEL INSTRUMENTATION
M. BAZIN *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 28 p (SEE N86-20415 11-09) Jul. 1985 refs Previously announced in IAA as A85-47284
Avail: NTIS HC A18/MF A01

Research conducted under the European Wind Tunnel project with the objective of adapting wind tunnel instrumentation to cryogenic conditions is reviewed. In particular, attention is given to the development of cryogenic balances, pressure transducers, accelerometers, temperature transducers, skin friction gages, and instruments for attitude and deformation measurements. Model instrumentation and model motorization are also discussed. V.L. (IAA)

N86-20422# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France).
FUNDAMENTAL REFLECTIONS ON CRYOGENIC TESTING
A. MIGNOSI *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 25 p (SEE N86-20415 11-09) Jul. 1985 refs
Avail: NTIS HC A18/MF A01

This paper concerns a number of aerodynamic problems related to cryogenic testing but which can also be encountered during testing at room temperature. The first part describes the various factors involved to achieve the best similarity possible between an aircraft in flight and the model in the wind tunnel. The second part covers the analysis of these factors: effects of a non adiabatic wall, boundary layer transition, two-dimensional testing, effects of the Reynolds number. In the paper, an attempt is made to alternate theoretical considerations with practical examples in order to illustrate the importance of experimental/theoretical correlations. Finally, the paper endeavors to highlight a few areas to which effort must be devoted in the future so that the new technique of cryogenic wind tunnels now available to scientists and manufacturers provides reliable and accurate results leading to a better analysis of aerodynamic phenomena and improved prediction and optimization of aircraft performance. Author

N86-20423# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PRODUCTIVITY: THE ECONOMIC ASPECTS OF CRYOGENIC WIND TUNNEL DESIGN AND USE
J. CHRISTOPHE *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 21 p (SEE N86-20415 11-09) Jul. 1985 refs
Avail: NTIS HC A18/MF A01

The idea of productivity, as it is applied to large non-cryogenic wind tunnels is investigated. These considerations can be extended to the new cryogenic wind tunnels; but these have some special features we attempt to define precisely. Important focal points in designing a cryogenic wind tunnel or good productivity in operation are examined. Author

N86-20424# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France) Dept dAerothermodynamique
THE T2 CRYOGENIC INDUCTION TUNNEL IN TOULOUSE
J. B. DOR *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 22 p (SEE N86-20415 11-09) Jul 1985 refs
Avail: NTIS HC A18/MF A01

This paper summarizes the main results obtained by the experimental activity at the ONERA/CERT T2 induction tunnel in Toulouse since it was converted for cryogenic operation in 1981. It describes the main characteristics of this facility, operating by short pressurized transonic runs driven by induction, with a test section equipped with two self-adapting walls and its adaptation to cold flows: internal thermal insulation, cooling by injection of liquid nitrogen, system for precooling profile models and introducing them in the test section. The following subjects concerning cryogenic operation are then discussed: pressure and temperature fluctuations, thermal behavior of the walls, transverse temperature distributions in the flow, thermal equilibrium of a profile with the fluid, condensation phenomena in the cold flow and problems of particles. Finally, the test results at high Reynolds number conducted on a CAST 7 profile with a 150 mm chord are given. Author

N86-20425# Aerodynamische Versuchsanstalt, Goettingen (West Germany) Inst fuer Experimentelle Stroemungamechanik
THE CRYOGENIC LUDWIEG TUBE TUNNEL AT GOETTINGER
G. HEFER *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 6 p (SEE N86-20415 11-09) Jul. 1985 refs
Avail: NTIS HC A18/MF A01

At the Research Center Gottingen of the DFVLR a cryogenic Ludwieg tube wind tunnel for transonic operation is under construction. The tunnel, having an effective run time of 1 second, a test section of 0.4 x 0.35 sq m, and a stagnation pressure of 10 bars, is to be operated with nitrogen at temperatures between ambient and 120 K, achieving a Reynolds number of 70 x 10 to the 6th power based on a model chord of 0.15 m. In addition to reviewing the Ludwieg tube concept, this paper presents the main features of design and operation of the tunnel. Author

N86-20426# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).
THE KRYO-KANAL-KOELN (KKK) PROJECT: DESCRIPTION OF TUNNEL CONVERSION, INSULATION, CONTROLS, INSTRUMENTATION, OPERATIONAL EXPERIENCE AND FIRST PRELIMINARY TEST RESULTS
G. VIEHWEGER *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 20 p (SEE N86-20415 11-09) Jul. 1985 refs Previously announced in IAA as A85-40314
Avail: NTIS HC A18/MF A01

The fundamental principles, costs, and operational phases (cooldown, preparation, starting, measurement, rundown, and warming) of cryogenic wind tunnels are discussed, and the problems encountered in modifying the conventional low-speed wind tunnel at Cologne for cryogenic operation are discussed. Particular attention is given to the test section, the blowers and power plant, the liquid-N2 system, the exhaust and safety system, and the interior insulation; and photographs, drawings, and diagrams are provided. The first trial operation of the KKK took place in September 1984, with calibration under cryogenic conditions scheduled for the second half of 1985. T.K. (IAA)

N86-20427# National Aerospace Lab., Amsterdam (Netherlands) Technical Group ETW.
THE EUROPEAN TRANSONIC WINDTUNNEL (ETW) PROJECT
J. A. TIZARD and J. P. HARTZUIKER *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 23 p (SEE N86-20415 11-09) Jul. 1985 refs Previously announced in IAA as N84-23566
Avail: NTIS HC A18/MF A01

The status of the preliminary design phase of the European Transonic Wind Tunnel project is described. The latest version of the proposed tunnel is given together with some details of its estimated performance. Some features of the tunnel which were revised following the first preliminary design proposals are discussed and the results of an investigation into the expected future use of the tunnel are summarized. An aerodynamic circuit test-rig is described along with some of the results obtained. Information on the pilot tunnel is included as well as reference to the supporting program on cryogenic technology. Author

N86-20428*# National Aeronautics and Space Administration Langley Research Center, Hampton, Va
THE NASA LANGLEY 0.3-M TRANSONIC CRYOGENIC TUNNEL
R. A. KILGORE *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 15 p (SEE N86-20415 11-09) Jul 1985 refs Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 14B

The Langley 0.3-m Transonic Cryogenic Tunnel (0.3-m TCT) can operate from ambient to cryogenic temperatures at absolute pressures from 1 to 6 bars. Since the 0.3-m TCT began operation in 1973, it has been used to develop instrumentation and operating techniques for cryogenic tunnels as well as for aerodynamic tests where advantage can be taken of the extremely wide range of Reynolds number available. This paper describes the present capabilities of the 0.3-m TCT and gives an overview of recent research activities which include both steady and unsteady testing. Emphasis is given to safety and the development of testing techniques for cryogenic tunnels. Results of studies aimed at establishing the lower limits of operating temperature are presented and the impact of these studies on tunnel operation is discussed. Finally, the design features and operating characteristics of a new self-streamlining wall test section recently installed in the tunnel circuit are described. Author

N86-20429*# National Aeronautics and Space Administration Langley Research Center, Hampton, Va
THE US NATIONAL TRANSONIC FACILITY, PART 1
W. E. BRUCE, JR. *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 10 p (SEE N86-20415 11-09) Jul. 1985 refs Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 14B

The construction of the National Transonic Facility was completed in September 1982, and checkout operations started the following month, with the maximum Reynolds number being obtained in May 1983. Following, most of the effort was devoted to installing the model access housings, and adjusting or altering various tunnel hardware systems. In May 1984, preliminary aerodynamic calibration of the tunnel was initiated in parallel with checkout of the tunnel operating systems, and in August 1984, the tunnel was declared operational and turned over to the user organization for a complete aerodynamic calibration and research and development testing. The facility has been operated in both the air and nitrogen modes covering a Mach number range of 0.2 to 1.22 at pressures up to 8.5 atm and at temperatures down to 100K. This paper presents a status of the tunnel operating systems and an overview of the major milestones during checkout. Author

N86-20430*# National Aeronautics and Space Administration Langley Research Center, Hampton, Va.
THE US NATIONAL TRANSONIC FACILITY, PART 2
W. E. BRUCE, JR. *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 10 p (SEE N86-20415 11-09) Jul 1985 refs Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 14B

The construction of the National Transonic Facility was completed in September 1982, and checkout operations started the following month with the maximum Reynolds number being obtained in May 1983. Afterwards, effort was primarily devoted to installing the model access housings and adjusting or altering various tunnel hardware systems. In May 1984, the aerodynamic calibration started and was performed in parallel with checkout of the tunnel systems. In August 1984, the final operation readiness review was conducted and the facility declared operational for research testing. The facility has been operated in both air and nitrogen modes covering a Mach number range of 0.2 to 1.22 at pressures up to 8.5 atm and at temperatures down to 100K. A limited amount of tunnel circuit performance information has been obtained and is presented in this paper. An aerodynamic calibration plan has been outlined, and the first part of the steady-state calibration has been completed, of which some results are presented in this paper. The first aerodynamic vehicle, Pathfinder

I, was installed in December 1984 for checkout of instrumentation systems, and a status report and some results are presented
Author

N86-20431*# National Aeronautics and Space Administration Langley Research Center, Hampton, Va.
OTHER CRYOGENIC WIND-TUNNEL PROJECTS
R. A. KILGORE *In* AGARD Special Course on Cryogenic Technology for Wind Tunnel Testing 15 p (SEE N86-20415 11-09) Jul. 1985 refs Sponsored in part by NASA
Avail: NTIS HC A18/MF A01 CSCL 14B

Following the development of the cryogenic wind tunnel at the NASA Langley Research Center in 1972, a large number of cryogenic wind-tunnel projects have been undertaken at various research establishments around the world. Described in this lecture are cryogenic wind-tunnel projects in China (Chinese Aeronautical Research and Development Center), England (College of Aeronautics at Cranfield, Royal Aircraft Establishment - Bedford, and University of Southampton), Japan (National Aerospace Laboratory, University of Tsukuba, and National Defense Academy), Sweden (Rollab), and the United States (Douglas Aircraft Co., University of Illinois at Urbana-Champaign, and NASA Langley)
Author

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ASTRONAUTICS (GENERAL)

N83-30479# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France)
ENVIRONMENTAL EFFECTS ON MATERIALS FOR SPACE APPLICATIONS
Loughton, England Specialised Printing Services Ltd Mar 1983 221 p refs Conf. held in Toronto, 19-24 Sep 1982 (AD-A129847, ISBN-92-835-0330-9; AGARD-CP-327) Avail NTIS HC A10/MF A01

The mechanical, surface, electrical, and thermal properties of spacecraft construction materials are examined as well as the effects of temperature, vacuum, radiation, charged particles, micrometeoroids, contaminants, and the pre-launch environment on these materials Tests methods are assessed For individual titles, see N83-30480 through N83-30496.

N83-30480# Aeritalia S.p.A., Torino (Italy). Space Sector.
FRACTURE MECHANICS AND FATIGUE CRITERIA IN MATERIAL SELECTION FOR SPACE APPLICATIONS
E. VALLERANI, P. MARCHESE, and G. BANINO *In* AGARD Environ. Effects on Mater. for Space Appl. 19 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01

The basic concepts employed in selecting fatigue and fracture resistance materials for the Spacelab design are reviewed, and specific examples of the application of these concepts are presented. The importance of the consideration of the strength and stress corrosion resistence is addition to toughness and fatigue strength is emphasized, especially for the selection of the aluminum alloys that cover most of the pressurized shell and internal structure. Weld material behavior and welding processes were carefully evaluated prior to material selection, and after the selection largely tested to confirm the choice. The possibility of automatic or manual repair without changes fracture-resistance and strength properties is considered. Fracture mechanics and fatigue analysis is summarized as well as nondistructive inspection methodologies and their practical application. Full scale fatigue and fracture mechanics tests and component level tests on some Spacelab structural parts are considered.
Author

N83-30481# Spar Aerospace Ltd., Weston (Ontario) Space and Electronics Group
STRUCTURAL DESIGN AND TEST OF THE SHUTTLE RMS
D. M. GOSSAIN and P. J. SMITH *In* AGARD Environ Effects on Mater. for Space Appl. 10 p (SEE N83-30479 19-12) Mar 1983 refs Sponsored in part by the National Research Council of Canada
Avail: NTIS HC A10/MF A01

The 15.24 m (50 ft) long mechanical arm of the remote manipulator system (RMS) of the space shuttle orbiter was designed to meet stringent weight, stiffness and spatial envelope requirements. The design constraints on the arm structure and joints are described. Structural loads are evaluated and materials selection is considered. The design details of the structural elements and the joints are given An extensive test program undertaken to qualify and verify the design at component, joint, subsystem and system level is discussed with emphasis on dynamic and static structural tests of structural elements and joints
Author

N83-30482# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
SPACECRAFT THERMAL CONTROL SELECTION FOR SEVEN YEARS LIFETIME IN SYNCHRONOUS ORBIT
L. PREUSS *In* AGARD Environ Effects on Mater. for Space Appl. 9 p (SEE N83-30479 19-12) Mar 1983
Avail: NTIS HC A10/MF A01

Nonconductive and conductive flexible secondary surface mirrors (SSMs) with interference filters on top are examined The SSM composition is analyzed and defined and the optimization procedure is outlined The qualification of the SSMs in laboratory scale for the synchronous orbit is demonstrated The most essential characteristics of the improved SSMs are summarized. Specifications for handling, application, and performance are established for SSMs
Author

N83-30483# Societe Nationale Industrielle Aerospatiale, Cannes (France).
DESIGN AND TESTING OF A CARBON-EPOXY TRELLIS STRUCTURE FOR SATELLITES [REALISATION ET ESSAIS D'UNE STRUCTURE TREILLIS CARBONE-EPOXY POUR SATELLITES]
J. F. PATIN and J. L. CECCONI *In* AGARD Environ Effects on Mater for Space Appl. 8 p (SEE N83-30479 19-12) Mar 1983 In FRENCH
Avail: NTIS HC A10/MF A01

A trellis structure with high dimensional stability was studied and constructed The bars of the trellis are based on high modulus (GY 70) high resistant (T 300) fibers and have a specific elevated rigidity and an expansion coefficient near zero. The joining elements between the bars are based on high modulus (M 40) fibers. The expansion coefficients of each element were adjusted so as to have an equivalent coefficient of expansion (near zero) between the points where the bars converge. The dimensional stability of the different connections as a function of temperature was verified. Space-type thermal cycling does not affect the mechanical behavior of the structure. Static tests of the trellis show that the high rigidity of the structures conform to the hypothesis of dimensioning. The mechanical strength was confirmed by tests, a first stage needed joint reinforcement.
Transl. by A.R.H

N83-30484# Toronto Univ. (Ontario). Inst. for Aerospace Studies.
THE EFFECT OF SPACE ENVIRONMENT ON THE THERMAL DISTORTION OF POLYMER MATRIX COMPOSITES
R. C. TENNYSON, G. E. MABSON, and S. AHMED (Communication Research Centre) *In* AGARD Environ. Effects on Mater. for Space Appl. 14 p (SEE N83-30479 19-12) Mar. 1983 refs Sponsored in part by Communication Research Centre of Canada (Contract AF-AFOSR-3694-78)
Avail: NTIS HC A10/MF A01

The combined effects of vacuum, thermal cycling, and UV radiation on the thermal distortion of selected polymer matrix composites were investigated. Data was obtained for exposure periods exceeding 400 days in hard vacuum and over 180 equivalent sun days of UV radiation. During this time, in situ measurements of the thermal distortion and coefficients of thermal expansion (CTE) were made using strain gauges and laser

interferometry. Results were compared to an analytical model to demonstrate the usefulness of the data in predicting the thermal response of arbitrary laminates. Author

N83-30485*# National Aeronautics and Space Administration Langley Research Center, Hampton, Va.
SPACE ENVIRONMENTAL EFFECTS ON MATERIALS
D. R. TENNY, G. F. SYKES, and D. E. BOWLES. *In* AGARD Environ. Effects on Mater. for Space Appl. 24 p (SEE N83-30479 19-12) Mar. 1983 refs. Previously announced as A83-14125
Avail: NTIS HC A10/MF A01. CSCL 07B

Research efforts at NASA-Langley to characterize the durability of composite materials which are candidates or use as components on various space hardware systems are reviewed. The material applications include large space structures, antennas, cables, thermal control coatings, solar reflectors, and satellite power systems. Simulation facilities have been built to study radiation effects on polymer matrix composites, and the dimensional stability of the matrix composites and tension stabilized. M.S.K. (IAA)

N83-30486# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
SIMULATION OF THE ACOUSTIC ENVIRONMENT OF A LAUNCHER AND OF THE NOISE-INDUCED VIBRATIONS ON ITS STRUCTURES [SIMULATION DE L'ENVIRONEMENT ACOUSTIQUE D'UNE LANCEUR AU DECOLLAGE ET DE SES EFFETS VIBRATOIRES SUR LES STRUCTURES]
A. BOURGINE. *In* AGARD Environ. Effects on Mater. for Space Appl. 11 p (SEE N83-30479 19-12) Mar. 1983 refs. In FRENCH, ENGLISH summary
Avail: NTIS HC A10/MF A01

During the launching and transonic flight of a launcher, high level and wide-band frequency vibrations are transmitted to the payload and equipments. Preliminary simulation tests are planned to reproduce these dangerous phenomena; however, classical test facilities (reverberant acoustic chambers) generally do not provide simultaneously the true space and time distribution of the flight pressure fluctuations. A method is described for forcing the vibratory response of the launcher wall, for instance at the shroud which shelters the satellite. (Statistical characteristics of this response are known by a previous analytical prediction). Forced vibrations are produced by using a few number of electrodynamic shakers acting on the wall; the N random forces are simultaneously synthesized on a digital computer. The proper simulation is realized when measured responses at N points exhibit spectral distributions and overall RMS levels very close to the predicted flight values. Then, the noise level inside the shroud and the vibrations transmitted to the payload are also very close to the flight conditions. Some examples of applications to realistic structures, as the shroud of the Ariane vehicle, are presented. Author

N83-30487# Royal Aircraft Establishment, Farnborough (England).
ELECTROSTATIC DISCHARGING BEHAVIOUR OF KAPTON AND OTHER DIELECTRIC MATERIALS IN A SIMULATED SPACE ENVIRONMENT
A. A. DOLLERY and D. VERDIN (Atomic Energy Research Estab.). *In* AGARD Environ. Effects on Mater. for Space Appl. 16 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01

The electrostatic charging and discharging of different thicknesses of Kapton when irradiated in vacuum with mono-energetic electrons of 5 to 30 keV energy was studied at different temperatures. The leakage currents and rates of discharging always increased with the incident electron energy and flux, whereas the surface voltage showed a more complex behavior, exhibiting a maximum and then falling at higher energies for the thinner films. The surface voltage, the rate of discharging, the peak current, and the total charge flow during a discharge were enhanced as the temperature was decreased from +70 C to -180 C. The results are discussed in terms of the resistivity of the polymer and the secondary emission of electrons, and they demonstrate that very thin Kapton films are markedly less susceptible to electrostatic charging and discharging. The electrostatic behavior of Kapton when it is incorporated into a laminated material, or when used as an insulator for an electric heater pad, or in the form of a substrate for a flexible solar array is also described. In addition, data are presented which demonstrate the performance of thermal control paints (Chemglaze A276 and L300), aluminized PTFE, and solar cell cover glasses under similar conditions. M.G.

N83-30488# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
CANDIDATE MATERIALS FOR PRETENSIONED MEMBRANES OF FIBRE COMPOSITE MATERIALS FOR SPACE APPLICATION
W. BUCHS. *In* AGARD Environ. Effects on Mater. for Space Appl. 6 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01

The properties of pretensioned membranes of fiber composite materials under consideration for use as solar cell substrates, thermal shields, etc., were examined. Various particular areas of investigation arose from loads (launch vibrations) and environmental conditions (vacuum, temperature, irradiation). Glass-, carbon- and aramidfabric composite materials were analyzed with respect to the requirements and the interfaces determined by the tensioning frame. Sections and full-scale samples of some membranes were manufactured and tested with methods, which in several cases had to be specifically developed for these purposes. Special attention was given to the decrease of characteristics of aramid-fiber composites under UV-irradiation. Analysis results are presented as well as test data and manufacturing experience. Author

N83-30489*# National Aeronautics and Space Administration Marshall Space Flight Center, Huntsville, Ala.
EFFECTS OF LONG DURATION EXPOSURE TO SIMULATED SPACE ENVIRONMENT ON NONMETALLIC MATERIALS PROPERTIES
C. L. PEACOCK, JR. and A. F. WHITAKER. *In* AGARD Environ. Effects on Mater. for Space Appl. 14 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01. CSCL 11G

Nonmetallic materials specimens from the Viking program were tested in situ invacuo after continuous thermal vacuum exposure from 1971/1972 to the present. Eleven tests were done on appropriate specimens of 30 materials; however, no single material received all the tests. Some specimens also were exposed to 1 or 2.5 MeV electrons at differing fluences before testing. Baseline exposure data is reported for graphite/epoxy specimens that were exposed to vacuum since 1974. These materials were transferred to the thermal vacuum storage facility for future in situ testing and irradiation. Thin G/E specimens were tensile tested after thermal-vacuum cycling exposure. Photomicrographic examinations and SEM analyses were done on the failed specimens. Author

N83-30490# Istituto di Tecnologia Aerospaziale, Rome (Italy).
STRUCTURAL DAMPING OF COMPOSITE MATERIALS FOR SPACE APPLICATIONS
L. BALIS-CREMA, R. BARBONI, and A. CASTELLANI. *In* AGARD Environ. Effects on Mater. for Space Appl. 8 p (SEE N83-30479 19-12) Mar. 1983 refs. Sponsored in part by Ministero Pubblica Istruzione
Avail: NTIS HC A10/MF A01

A series of experimental tests carried out on specimens of composite materials is presented. The measured damping ratios were obtained, in a vacuum chamber (10 to the -6 power torr), from the three first bending modes resonance (frequency range between 15 and 1400 Hz). The influence of the following parameters is considered: vibration amplitudes, frequency, air pressure, laminae number and mode shape. The tests were performed with an electromagnetic exciter and a vibration detector; the measurements of the damping coefficient were worked by the frequency sweep and the decay transient method. Author

N83-30491*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
SILICON SOLAR CELL CHARACTERIZATION AT LOW TEMPERATURES AND LOW ILLUMINATION AS A FUNCTION OF PARTICULATE IRRADIATION
A. F. WHITAKER, S. A. LITTLE, and C. L. PEACOCK, JR. *In* AGARD Environ. Effects on Mater. for Space Appl. 9 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01 CSCL 10A

Various configurations of back surface reflector silicon solar cells including small (2 x 2) cm and large (approx. 6 x 6) cm cells with conventional and wraparound contacts were subjected to 1 MeV electron irradiation and characterized under both Earth orbital and deep space conditions of temperatures and illuminations. Current-Voltage (I-V) data were generated from +65 C to -150 C and at incident illuminations from 135.3 mW/sq cm to 5.4 mW/sq cm for these cells. Degradation in cell performance which is manifested only under deep space conditions is emphasized. In addition, the effect of particle irradiation on the high temperature and high intensity and low temperature and low intensity performance of the cells is described. The cells with wraparound contacts were found to have lower efficiencies at Earth orbital conditions than the cells with conventional contacts. Author

N83-30492# Toronto Univ. (Ontario). Inst. for Aerospace Studies.
THE EFFECT OF SPACE ENVIRONMENT ON THE DAMPING OF POLYMER MATRIX COMPOSITE
R. C. TENNYSON, W. D. MORISON, and G. E. MABSON *In* AGARD Environ. Effects on Mater. for Space Appl. 15 p (SEE N83-30479 19-12) Mar. 1983 refs Sponsored in part by Natural Sciences and Engineering Research Council of Canada (Contract AF-AFOSR-3694-78)
Avail: NTIS HC A10/MF A01

A combined experimental and analytical investigation was undertaken to evaluate material damping of laminated composites. Particular emphasis was given to the effect of thermal-vacuum exposure and U.V. radiation on the change in damping response. A laminate analysis was developed for predicting material damping utilizing experimentaly determined principal damping coefficients. Results are presented based on flexural vibration and creep compliance tests performed on graphite/epoxy laminates at ambient conditions and in a space simulator. Author

N83-30493# Spar Aerospace Ltd., Weston (Ontario). Space and Electronics Group.
TESTING OF FLEXIBLE DEPLOYED SOLAR ARRAY (L-SAT)
P. A. MCINTYRE, A. S. JONES, J. RENSHALL, and G. W. MARKS *In* AGARD Environ. Effects on Mater. for Space Appl. 16 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01

The L-SAT solar array subsystem was subjected to qualification testing at both the integrated system, subassembly and component level. In addition, development testing was carried out on critical items of the design, specifically that associated with blanket behavior during deployment and Apogee Engine and RCS firing, L-SAT being the first flexible array to be operational during Apogee Engine firing. The test philosophy being adopted is similar to that used on the Communications Technology Satellite (Hermes), however, due to the size of the array and facilities available, array natural frequencies will be predicted by analysis and modal test methods. Electrical component subsystem testing covering solar cell, array blanket pyro-techniques and other electrical items are discussed and the status of development tests completed to date is reviewed. Author

N83-30494# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
THE MBB COMBINED EFFECTS CHAMBER FOR REAL TIME AND ACCELERATED TESTS UNDER SIMULATED SPACE ENVIRONMENT
O. K. HUSMANN *In* AGARD Environ. Effects on Mater. for Space Appl. 8 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01

The MBB Space Division solar radiation simulation test facility is described. This test equipment is fully automated and runs without interruption 24 hours a day, as long as specified, with its radiation sources operating simultaneously or alone. The test chamber provides clean vacuum. The sample temperatures are adjustable between -30 C and +100 C. The UV - radiation exposures may be accelerated up to 6 solar constants. The electron and the proton current densities can be selected from 10 to the -10 power amps/sq cm to 10 to the -8 power amps/sq cm. Their energies may range from 5 KeVolts to 60 KeVolts. Eight samples size 11 x 11 mm are exposed simultaneously, or four samples 20 x 20 mm. For assessment of damages inflicted a spectrometer is mated to the vacuum chamber for in situ measurement of sample spectral reflectances from 240 nm to 2.5 um. Author

N83-30495# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
THE EFFECT OF COMBINED U.V. RADIATION AND HIGH ENERGY ELECTRONS ON THE BEHAVIOUR OF POLYMER MATRIX COMPOSITES IN HARD VACUUM
R. C. TENNYSON, B. A. W. SMITH, and L. P. HEBERT *In* AGARD Environ. Effects on Mater. for Space Appl. 12 p (SEE N83-30479 19-12) Mar. 1983 refs Sponsored in part by Natural Sciences and Engineering Research Council of Canada (Contract AF-AFOSR-3694-78)
Avail: NTIS HC A10/MF A01

A description of a space simulator capable of thermal-vacuum testing of samples subject to combined UV and high energy electron radiation is presented. Particular attention is given to the use a natural beta emitting Sr90 source to simulate space conditions. In-situ thermal and mechanical loading capabilities are also described together with test results obtained on selected polymer matrix composites. Specifically, graphite/epoxy and Kevlar/epoxy laminates have been employed to assess the combined effects of hard vacuum, thermal cycling and radiation on the change in stiffness, creep compliance and coefficient of thermal expansion. Author

N83-30496# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).
THERMAL CYCLING TESTS ON MATERIALS AND COMPONENTS FOR SPACE APPLICATIONS
H. HAMACHER, W. LEY, and K. V. REHMANN *In* AGARD Environ. Effects on Mater. for Space Appl. 9 p (SEE N83-30479 19-12) Mar. 1983 refs
Avail: NTIS HC A10/MF A01

Thermal cycling tests were performed on materials and components under high vacuum conditions. The purpose of these tests was to investigate changes in properties by thermal fatigue due to microcracking, delamination, etc. The test facility used was developed with respect to the need of true simulation of the strong temperature gradients to be expected in space flight. Tests were performed on carbon fiber composite materials which are candidates for large space structures use and on solar cell panel samples. The description of the facility, a presentation and discussion of the results is given. Author

N84-24603# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GUIDANCE AND CONTROL TECHNIQUES FOR ADVANCED SPACE VEHICLES
Loughton, England Jan. 1984 348 p refs In ENGLISH and FRENCH Symp. held in Florence, 27-30 Sep. 1983
(AGARD-CP-350; ISBN-92-835-0349-X; AD-A141969) Avail: NTIS HC A15/MF A01

This symposium dealt with spacecraft problems, the topic being guidance and control techniques for advanced space vehicles. Military applications of space for navigation, communication and intelligence impose increasing requirements on spacecraft capacity, orbit control and pointing accuracy. To meet the requirements for future spacecraft the performance of existing components, such as actuators and sensors, is improved or new concepts are developed. In particular the use of microprocessors and other data distribution systems permits multifunctional use of various sensors or information sources to produce effective, survivable systems at low cost. Increasing on-board computing capacity enables the use of sophisticated software for effective complex spacecraft control. A unique aspect of large spacecraft is the control of the structural configuration in order to achieve a specific pointing accuracy. Large structures, with their mechanical flexibility, present particular problems to the control engineer and control/structure interaction (CSI) is a driving force in many current

programs and figured largely in the papers presented. For individual titles, see N84-24604 through N84-24626.

N84-24604*# National Aeronautics and Space Administration, Washington, D.C.
SPACECRAFT CONTROL RESEARCH AT NASA
J. B. DAHLGREN and L. W. TAYLOR, JR. (NASA. Langley Research Center) *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 14 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01 CSCL 22B

Future missions is space will require controlling spacecraft which are both large and flexible. The limited inherent damping and the uncertain and changing dynamic characteristics of many of these vehicles, such as manned space stations and large antennas, will revolutionize spacecraft control requirements. In preparation for the time that such control systems are required, considerable research and technology development is necessary. A program is in place at NASA for the development of active control technology to support major initiatives for space station and advanced spacecraft. A number of key control technology program needs are cited in the paper as required for these and other future NASA missions together with an integrated controls/structures technology flight experiment to demonstrate and validate technology for large flexible structures. Author

N84-24605# Engins Matra, Toulouse (France).
THE ROLE OF ONBOARD INTELLIGENCE AND OF ORBITAL SERVICING IN THE INCREASE OF SATELLITE LIFETIME [ROLE DE LINTELLIGENCE DE BORD ET DE LENTRETIEN EN ORBITE DANS LACCROISSEMENT DE LA DUREE DE VIE DES SATELLITES]
P. C. COUGNET and J. P. SOTTA *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 14 p (SEE N84-24603 15-12) Jan. 1984 In FRENCH
Avail: NTIS HC A15/MF A01

The continued increase in satellite lifetime is now or is going to become critical with respect to the maintenance of system reliability and the risk of mission obsolescence. Resource to redundant equipment becomes more and more penalizing particularly because of the limited capacities of the launch methods. Futhermore, the classic satellite concept does not permit avoiding mission obsolescence or long duration life. To remedy these problems, two possible complementary methods are presented. One involves the use of satellite onboard intelligence to enable better management of its configuration and platform subsystems in order to assure a high level of availability to he satellite. The other solution is orbital servicing which permits periodic adjustment of reliability and platform autonomy as well as the eventual exchange of the payload. This solution calls for new techniques: rendezvous, assembling, and the space robot. Transl. by A.R.H.

N84-24606# Societe Anonyme d'Etudes et Realisations Nucleaires, Limeil-Brevannes (France).
IMAGE DISSECTOR TUBE STAR TRACKERS PERFORMANCE: ADVANTAGES AND DRAWBACKS AS COMPARED TO THOSE OF CHARGE TRANSFER DEVICE STAR TRACKERS
H. BOURCIER and M. VITE *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 18 p (SEE N84-24603 15-12) Jan. 1984 In FRENCH and ENGLISH
Avail: NTIS HC A15/MF A01

Performance characteristics which can be achieved with image dissector tube star trackers are given based on equipment manufactured for IPS/Spacelab and Exosat satellite. The advantages and disadvantages of such instruments are discussed with respect to equipment based on solid state devices of charge transfer type. The analysis of the performances is presented versus the intrinsic characteristics of the detectors and the technological constraints related to their use. A.R.H.

N84-24607# Raytheon Co., Sudbury, Mass. Equipment Div
FAULT TOLERANT SPACEBORNE COMPUTER
D. R. BATES, JR., J. E. SCHELL (Army Communications-Electronics Command, Fort Monmouth, N.J.), and G. R. COURANZ *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 14 p (SEE N84-24603 15-12) Jan. 1984
Avail: NTIS HC A15/MF A01

A method of utilizing present integrated circuit componentry with future technology insertion has been developed on the FTSC Program. The FTSC is designed to support a variety of spaceborne missions with a 95% probability of surviving, unattended and without degradation in performance, for five to seven years. Besides easing the ground station scheduling requirements, this capability increases the overall satellite survivability. The purpose of this paper is to present a concept of achieving the survivability by the utilization of various fault tolerant techniques. These concepts of fault tolerance, as well as technology insertion, are also being incorporated in the Military Computer Family Program currently under development. B.W.

N84-24608# Teldix Luftfahrt-Ausruestungs G.m.b.H., Heidelberg (West Germany). Engineering Dept. for Gyroscopic and Space Products.
A DOUBLE GIMBALLED MOMENTUM WHEEL FOR PRECISION 3-AXIS ATTITUDE CONTROL
W. AUER *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 8 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01

For precision three-axis attitude control of space vehicles, a Double Gimballed Momentum Wheel (DGMW) as attitude actuator is a favorable approach. A high reliability DGMW of modular design with two momentum wheels and two direct drive ultra high resolution stepper motors plus pick-offs per gimbal axis (full redundancy; no caging during launch) was designed, built and qualification tested, together with an associated wheel and gimbal drive electronics. In addition, extensive system tests were performed on a three-axis air bearing table which proved the excellent control capabilities of this DGMW. Besides the measurement under stationary conditions with an accuracy of 18 sec of arc, also the transient behavior was studied. Due to the high torque capability (up to 0.2 Nm around the momentum wheel axis and up to 1 Nm around the gimbal axes) rapid and accurate pointing and repointing of spacecraft are possible. Therefore, the DGMW system can be designed into tracking loops to assure continuous pointing of spacecraft instruments with a rapid assignment capability. Author

N84-24609# Ferranti Ltd., Edinburgh (Scotland). Navigation Systems Dept.
CURRENT WORK ON HIGH-GRADE SPACE GYROS AT FERRANTI IN THE UK
J. WELBURN *In* AGARD Guidance and Control Tech. for Advan Space Vehicles 4 p (SEE N84-24603 15-12) Jan. 1984
Avail: NTIS HC A15/MF A01

Certain satellite missions require gyroscopes of very high accuracy for attitude measurement. Formerly, floated rate integrating gyros have been widely used. More recently in the USA, 2-axis DTG's have been used, and agencies are now beginning to consider what type of instrument to use in the future. Features such as fluid dissociation, which are rumoured to occur in floated gyros over a long period of time, can be controlled and minimized by care in design, assembly techniques, and cleanliness. In any event, the phenomena caused by fluid effects generally only affect g sensitive performance aspects, which are of no relevance in orbital applications. The feasibility of using ball-bearing gyros for long-life satellite applications is discussed B.W.

N84-24610# Societe Nationale Industrielle Aerospatiale, Cannes (France).
OVERCOMING UNOBSERVABILITY IN 3-AXIS STABILIZATION OF SATELLITES
L. PASSERON and C. BOZZO (Compagnie de Signaux et d'Entreprises Electriques, Paris) *In* AGARD Guidance and Control Tech. for Advan Space Vehicles 21 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01

An optimal solution is provided to the problem of attitude estimation for a three-axis stabilized satellite devoid of yaw sensor

and undergoing significant disturbing torques. Influence of such torques on expectable system performance is analysed via a geometric approach. Estimation of satellite attitude is demonstrated to be systematically impaired by an error resulting from the system's torque-induced unobservability. The said error is then explicitly assessed as a function of the disturbing torques. Furthermore, assuming a priori knowledge of the disturbing torque amplitudes, an optimal observability canonical form is derived. Optimal attitude estimation is finally provided, together with the expression of the relative, thus minimized, systematic error. Author

N84-24611# MATRA Espace, Paris-Velizy (France). Space Branch.
MULTIFUNCTION SPACECRAFT ATTITUDE ESTIMATION AND NAVIGATION SYSTEM
J. C. AMIEUX and B. CALUDINON *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 17 p (SEE N84-24603 15-12) Jan. 1984
Avail: NTIS HC A15/MF A01

The primary function of a spacecraft attitude control subsystem is the attitude determination and, more generally, the state estimation (attitude of the main body, appendages and flexible modes). The so-called optico-inertial concept is first described with application to a number of modern spacecraft; an example of implementation using space-qualified microprocessors is given in detail; the state estimation of a flexible spacecraft is then considered, a technique which can be readily implemented on existing hardware. The extension of this concept to autonomous orbit control of an orbiting spacecraft is then considered for future development. Author

N84-24612# British Aerospace Dynamics Group, Bristol (England). Space and Communications Div.
A FILTERED ATTITUDE DETERMINATION SYSTEM FOR SPACECRAFT MEASUREMENT AND CONTROL
M. NOTON *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 21 p (SEE N84-24603 15-12) Jan. 1984 refs Sponsored in part by RAE, Farnborough, Engl.
Avail: NTIS HC A15/MF A01

This paper refers to a collaborative project to develop an accurate attitude determination system based on the combined use of gyros and star-crossing detectors. The latter are attractive for Earth-pointing satellites but the intermittent nature of the data introduces complications, compared to star tracker systems. Background is given on the hardware, but the emphasis is on formulation of the estimating algorithm (suitable for limited wordlength microprocessors), characterization of gyro drift, and estimation of overall performance both for low-Earth and geostationary orbits. Author

N84-24613# National Aerospace Lab., Emmeloord (Netherlands).
INERTIAL-OPTICAL ATTITUDE DETERMINATION AND MODEL FOLLOWING CONTROL OF MANEUVERING SPACECRAFT
T. ZWARTBOL and A. P. TERPSTRA *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 16 p (SEE N84-24603 15-12) Jan. 1984 refs Sponsored in part by Netherlands Agency for Aerospace Programs NIVR
Avail: NTIS HC A15/MF A01

The paper presents an approach to on-board commanding, estimation, and control of the attitude motion of maneuvering spacecraft, based on modern control principles. Firstly the control algorithms are discussed. The control law is based on explicit model following. It comprises single-axis models of the spacecraft motion, which generate a target trajectory and associated target control. The spacecraft tracks the target trajectory by means of the target control which is fed forward to the spacecraft, and by means of state feedback control. A spacecraft state estimator provides for the estimates of the spacecraft state (attitude, angular velocity), and provides for the estimate of the disturbance torque which is used for disturbance torque compensation. Secondly an algorithm for inertial-optical attitude determination and estimation of gyro parameters (drift rate bias and scale factor error) is presented. The algorithms were validated in software simulations of an attitude control system of the type as used in the Infra Red Astronomical Satellite (IRAS). The control law and state estimator were tested inflight, in an on-board experiment with the IRAS spacecraft. The considered control system comprises a strapdown rate-integrating gyro and a slit-type star sensor for optical-inertial attitude sensing, a reaction wheel actuator, and a 16-bit on-board computer. The estimation and control algorithms are described, design trade-offs are discussed, simulation results and in-flight results are presented. Author

N84-24614# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
DOCKING MECHANISM FOR IN-ORBIT ASSEMBLY AND SPACECRAFT SERVICING
F. GAMPE *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 12 p (SEE N84-24603 15-12) Jan. 1984
Avail: NTIS HC A15/MF A01

Future in-orbit infrastructure requires the usage of a Docking Mechanism Subsystem (DMS) for in-orbit assembly and spacecraft servicing. As a first entry for European applications unmanned, autonomous docking missions are foreseen as well in low Earth orbit (processing platforms) as in geostationary orbit (communication satellite clustering). The Rendezvous and Docking (RVD) operation is a key technology to realize such type of mission. The DMS is imbedded in a system performing the 'last meters' problem, where specially the Attitude and Orbit Control Subsystem (AOCS) closely cooperates with the DMS. The DMS itself is composed of the Docking Mechanism itself and the Docking Mechanism Electronics. Dependent on the initial separation conditions two docking concepts are considered: the DMS- and the AOCS - controlled closure. A first docking demonstration is envisaged during the EURECA-2 mission in 1989/90. Author

N84-24615# Aeritalia S.p.A., Torino (Italy). Space Systems Div.
THE INFLUENCE OF SENSOR AND THRUSTER IMPERFECTIONS ON THE ATTITUDE AND POSITION OF A SPACECRAFT PERFORMING A RENDEZVOUS
R. ANCILLOTTI and C. CASSI *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 13 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01

The operational conditions of two spacecraft performing a rendezvous in geostationary orbit are given with the relative motion equation and the relevant control law. The concept of position, velocity and attitude measurement of the chaser vehicle with respect to the target one is given in order to allow the evaluation of the measurement errors. Simulations show the effect of the errors sources on the flight path of the approaching vehicle and point out the necessity of a good matching between the sensor accuracy and the minimum impulse level of the actuation system. Author

N84-24616# Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany).
CONTROL ASPECTS AS ELABORATED IN SPACE RENDEZVOUS SIMULATIONS
P. NATENBRUK and D. RANGNITT *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 10 p (SEE N84-24603 15-12) Jan. 1984
Avail: NTIS HC A15/MF A01

The European Space Agency's system technology study effort related to in-orbit operations, covers rendezvous and docking between two spacecraft one of which is actively doing the rendezvous while the other passively waits. Unlike the US missions, RVD to be done without any man in space. The chaser does its operations to some extent automatically, having on board the degree of autonomy needed. Otherwise, it is steered from the ground by real-time or time tagged commands depending upon the contact opportunities. A program which simulates the homing phase and final approach control is described. A.R.H.

N84-24617# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
OPTIMIZING THE MANEUVERS OF AN OBSERVATION SATELLITE FOR RAPID OVERFLIGHT OF A PRECISE POINT ON EARTH [OPTIMISATION DES MANOEUVRES DUN SATELLITE DOBSERVATION EN VUE DUN SURVOL RAPIDE DUN POINT DU GLOBE]
A. M. MAINGUY, C. AUMASSON, and S. LAFFY *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 1 p (SEE N84-24603 15-12) Jan. 1984 In FRENCH
Avail: NTIS HC A15/MF A01

For the purpose of heightened surveillance, it may be necessary to modify the quasipolar circular orbit of an Earth observation satellite and place it in a geosynchronous circular orbit in order to observe repeatedly a precise point on Earth once a day over a given time period. This maneuver should be effected as rapidly as possible, in less than two days. Because the altitudes of the orbits are close, it is possible to get rid of the constraints of heliosynchronism and solve the problem by considering the two orbits to have the same inclination. The difficulty of the problem lies in the fact that the maneuver must be accomplished in a short time period, with limited reserve capacity, and with an engine with a low power level. The maneuver must proceed by stages. Three studies are described in an effort to solve the generalized problem. One uses simplified hypotheses on the physical constraints and mathematical equations. The second, with more realistic hypotheses, accounts for the low thrust level and establishes the propulsive arc. The third study addresses the problem without simplification. It is a functional optimization in which the controls to be determined are the power module and its orientation in the local orbital reference. Transl. by A.R.H.

N84-24618# Hughes Aircraft Co., El Segundo, Calif. Space and Communications Group
AN APPROACH TO ATTITUDE CONTROL MANEUVERS WHICH HELPS MAINTAIN ORBIT INCLINATION
W. M. BOWLES and M. R. ALTOBELLI *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 8 p (SEE N84-24603 15-12) Jan. 1984
Avail: NTIS HC A15/MF A01

An algorithm for attitude control is presented that derives a benefit for orbit inclination. This algorithm is useful for a spinning satellite using an offset axial thruster to perform attitude maneuvers. Depending on the circumstances of the mission, significant fuel savings may be derived by the use of this algorithm. Author

N84-24619# Honeywell, Inc., Minneapolis, Minn. Systems and Research Center.
CHARACTERIZATION OF UNCERTAINTY FOR LARGE SPACE STRUCTURE CONTROL PROBLEMS
J. C. DOYLE and J. E. WALL *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 19 p (SEE N84-24603 15-12) Jan. 1984 refs Sponsored in part by Honeywell Internal Research and Development Funding
(Contract F49620-82-C-0090)
Avail: NTIS HC A15/MF A01

A new formulation of the feedback control problem that captures both its performance and robustness aspects is reviewed. The basic analysis tool in this formulation is the structured singular value. The methods are potentially applicable to Large Space Structure Control Problems since they allow for uncertainty in a very natural way. Author

N84-24620# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
ATTITUDE CONTROL ON LARGE FLEXIBLE SPACECRAFT
G. THIEME *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 15 p (SEE N84-24603 15-12) Jan. 1984 refs Sponsored in part by ESA
Avail: NTIS HC A15/MF A01

Some results found during the investigation of control problems of large flexible spacecraft are presented. A triple plate configuration of such a spacecraft is defined and studied. The model is defined by modal data derived from finite element modelling. The order reduction methods applied are briefly described and results of order reduction are presented. An attitude control concept with low and high authority control was used to design an attitude controller for the reduced model. The stability and response of the original system together with the reduced controller is analyzed. Author

N84-24621# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Inst. fuer Dynamik der Flugsysteme.
LOW AUTHORITY CONTROL OF FLEXIBLE SPACECRAFT VIA NUMERICAL OPTIMIZATION
G. SCHULZ *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 16 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01

For the design of low authority controllers for attitude control of flexible spacecraft a new method based on numerical optimization is presented. Thereby a dominant criterion to be optimized is determined, and the design requirements are formulated as constraints. Two different criteria are investigated: first a dissipation energy criterion is maximized and second a control energy criterion is minimized. The method is applied for attitude controller design of two models, the 'Draper Model No. 1 and the Purdue Model'. The first represents a flexible tetrahedral truss structure while the latter can be considered as model of a solar power satellite. Damping requirements for these models are formulated as design objectives and the controllers are determined using the proposed method. The achieved results show that due to the now existing efficient optimization software, controller design via numerical optimization is a useful and flexible tool for system design. This flexibility arises from the fact that arbitrary design criteria can be implemented. Author

N84-24622# Rome Univ. (Italy). Dept. of Aerospace.
A DECENTRALIZED ACTIVE CONTROL SYSTEM FOR A LARGE FLEXIBLE STRUCTURE IN SPACE
A. DANESI *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 15 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01

A new strategy in controlling the modal shapes of large structure in space is presented. An active low authority modal control system, consisting of a discrete number of servo system units (M.C.U.) distributed along flexible masts supporting RF radiators, is provided to measure and control the local structural deformations in order to obtain a modal shapes resulting in acceptable pointing error for the RF radiators. Each servo unit is conceived as a model following control system implementing a strategy based on fast fourier transformation (F.F.T.) pairs computations. The control efforts applied by the M.C.U.s to the mast control points are made proportional to the spectral error function generated by a real time F.F.T. dedicated microprocessor as the difference between the measured and desidered modal spectra relative to the antenna angular deflections in respect to a fixed set point. The decentralized control system organized by a central controller residing in the master M.C.U., will force the antenna to match the model dynamical behavior which is expected to improve the antenna pointing accuracy within the large space structure design requirements. Author

N84-24623# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Flight Dynamics Lab.
DESIGN AND ROBUSTNESS ANALYSIS OF REDUCED ORDER CONTROLLERS FOR LARGE FLEXIBLE SPACE VEHICLES
S. S. BANDA, D. B. RIDGELY, H. H. YEH, and D. V. PALMER *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 25 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01

In the control design of a large flexible space vehicle, a finite element model is truncated and the control system is designed on the basis of the reduced order model. The step-by-step application of frequency-shaped Linear - Quadratic - Gaussian methodology is discussed, as well as payoffs and costs of this method. The procedure for choosing and forming both state and control frequency - weightings is shown. Treating the unmodelled dynamics of the structure as a source of plant uncertainty, stability robustness evaluation is discussed. Practical usefulness of the singular-valued closed-loop performance analysis and its possible improvement are also discussed. Author

N84-24624# Singer Co., Wayne, N. J.
THE DESIGN, SIMULATION AND DEVELOPMENTAL TESTING OF THE SPACE SHUTTLE DATA BUS SYSTEM
A. J. SHAPIRO *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 22 p (SEE N84-24603 15-12) Jan. 1984 refs
Avail: NTIS HC A15/MF A01

A suggested sequence to be followed in the design, development analysis and simulation of a digital data bus system is discussed. Also discussed are the computer modeling/simulations performed and the hardware verification test results obtained on elements of the Space Shuttle Orbiter data bus. A number of specific modules developed for the Space Shuttle are described as well as MIL-STD-1553 Remote Terminal Bus Controllers (RT/BC) in operational use by the U.S.A.F. R.J.F.

N84-24625# *Dassault (E. M.) Co., St. Cloud (France).*
CERTIFYING ONBOARD SOFTWARE: A TOTAL PROGRESSIVE APPROACH [LA CERTIFICATION DES LOGICIELS EMBARQUES: UNE APPROCHE GLOBALE ET PROGRESSIVE]
G. BRACON *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 10 p (SEE N84-24603 15-12) Jan. 1984 refs *In FRENCH*
Avail: NTIS HC A15/MF A01

The complexity and growing criticality of functions assured by software in systems vital for safety engender a difficult problem in computer program certification. Until the present, the method and tools (particularly tests) used at ESD in a project such as the Mirage 2000, permitted the attainment of a high level of quality in software products. However, the continued growth of the volume of programs and the ever more vital functions they exercise, requires effort in the quality assurance domain. Techniques actually used for verification and validation are described. Current studies and developments are examined including a system for helping define software needs, a system for helping in dynamic tests of real time programs, the definition of measurements of quality which can be selected by application to a structured development, and the formalized products which are issued from them.
Transl. by A.R.H.

N84-24626# Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
VERIFICATION AND VALIDATION TECHNIQUES APPLIED TO THE RECONFIGURABLE BLOCK 5D SATELLITE SOFTWARE
W. C. DINIAK *In* AGARD Guidance and Control Tech. for Advan. Space Vehicles 12 p (SEE N84-24603 15-12) Jan. 1984 refs
(Contract F04701-74-C-0020; F04701-78-C-0018)
Avail: NTIS HC A15/MF A01

The U.S. Air Force Defense Meteorological Satellite Program (DMSP) Block 5D satellite uses two general purpose digital flight computers for control of the satellite and launch vehicle. During the life of six satellites, various reconfigurations of the flight software were accomplished to achieve improvements or to compensate for problems. An independent verification and validation (IV&V) process was conducted on that flight software prior to launch and prior to uplink of major software changes. To accomplish this, a closed-loop digital simulation of the mission to exercise the actual flight software in a realistic environment was developed and used. This experience, focusing on how both the simulation and the IV&V process evolved as a consequence of the flight history is described. R.J.F.

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LAUNCH VEHICLES AND SPACE VEHICLES

Includes boosters; manned orbital laboratories; reusable vehicles; *and space stations.*

N84-31248# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ADVANCED TECHNOLOGY FOR SAM SYSTEMS ANALYSIS SYNTHESIS AND SIMULATION
Loughton, England May 1984 119 p refs Lecture Series held in Porz-Wahn, West Germany, 25-26 Jun. 1984, Rome, 28-29 Jun. 1984, and London, 2-3 Jul. 1984
(AGARD-LS-135; ISBN-92-835-0353-8; AD-A145365) Avail: NTIS HC A06/MF A01

The introduction of new technologies and techniques in the analysis, synthesis and simulation of SAM systems seen from the point of view of guidance and control are considered. Topics covered include: methodology for conception of advanced systems; new concepts for missile control, and in particular for terminal control; present capability and future technology for seeker systems simulation; warhead technologies; homing head imperfections altering missile guidance; and terrain bounce countermeasures against monopulse seeker system. For individual titles, see N84-31249 through N84-31257.

N84-31249# Thomson-CSF, Bagneux (France). Div. Systemes Electroniques.
ADVANCED TECHNOLOGY FOR SAM SYSTEMS ANALYSIS, SYNTHESIS AND SIMULATION
M. PAULET *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 6 p (SEE N84-31248 21-15) May 1984 In FRENCH and ENGLISH
Avail: NTIS HC A06/MF A01

An overview is presented of techniques and technologies being used in the development of defensive weapons with emphasis on the analysis, synthesis, and simulation of surface to air weapon missiles. Improvements in guidance, control, and warheads are also discussed. A.R.H.

N84-31250# MATRA Service Aerodynamique, Velizy-Villacoublay (France). Dept. d'Analyse de Systemes Militaires.
METHOD FOR DESIGNING FUTURE WEAPONS SYSTEMS: EXAMPLE OF THE VERY SHORT DISTANCE GROUND-AIR SYSTEMS [METHODOLOGIE DE LA CONCEPTION DES SYSTEMES D'ARMES FUTURS. EXEMPLE DES SYSTEMES SOL-AIR TRES COURTE PORTEE]
J. F. GONDET *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 23 p (SEE N84-31248 21-15) May 1984 In FRENCH
Avail: NTIS HC A06/MF A01

The assemblage and series of studies that it is desirable to perform before launching the development of a new weapon system are described. Focus is on the important steps in this approach made up of multicriteria-based comparative studies of the system being considered in order to address operational problems posed. To illustrate these methods, a parametric study is presented of very short distance surface to air missiles from which certain conclusions were considered in defining the Mistral system.
Transl. by A.R.H.

N84-31251# Royal Military Coll. of Science, Shrivenham (England).
SOME ASPECTS OF GUIDANCE LOOP DESIGN FOR SAM SYSTEMS
D. J. EAST *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 14 p (SEE N84-31248 21-15) May 1984 refs
Avail: NTIS HC A06/MF A01

The basic structure of guidance loops for SAM systems is considered and two important practical problems associated with their design and implementation if optimum performance is to be achieved are discussed. The nature of the switching transients that occur when loop parameters are changed is examined and the fundamental requirements for transient free operation are

presented. A computer aided design procedure for synthesizing a minimum bandwidth system which satisfies a stringent sensitivity specification despite large uncertainty in the plant being controlled is illustrated by means of a significant autopilot design example.
Author

N84-31252# CETA, Angouleme (France).
TERMINAL CONTROL FOR COMMAND TO LINE OF SIGHT GUIDED MISSILE
J. L. DURIEUX *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 14 p (SEE N84-31248 21-15) May 1984 refs
Avail: NTIS HC A06/MF A01

The implementation of terminal control guidance laws on line of sight, radio commanded missiles is discussed. Specific problems examined include: rangefinding accuracy, effects of tracker filtering, and switching from stationary to terminal controller. Performance is compared with active homing guidance for the case of medium-range, surface to air missiles. The parameters compared are: missile path curvature, agility, and effects of sensor noise. Both conventional and optimal control laws are considered.
E.A.K.

N84-31253# Societe Nationale Industrielle Aerospatiale, Paris (France). Div. des Engins Tactiques.
A NEW CONCEPT FOR GUIDING MISSILES WITH AN APPLICATION TO THE GROUND-AIR SYSTEM [UN NOUVEAU CONCEPT DE PILOTAGE DES MISSILES APPLICATION AUX SOL-AIR]
G. SELINCE *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 12 p (SEE N84-31248 21-15) May 1984 refs In FRENCH
Avail: NTIS HC A06/MF A01

The PIF,PAF system associates to conventional control surfaces the action of gas jets creating lateral forces applied near the missile center of gravity. The advantages of the two devices are then cumulated, leading to very short response time and large lateral accelerations, even at low speed or high altitude, as the PIF rapidity makes up for the PAF dynamic error. The result is a notable decrease of miss distance against highly maneuvering targets. General principles of such a guidance system and examples of possible applications to surface to air missiles with antimissile capability are presented.
Transl. by A.R.H.

N84-31254# Army Missile Command, Redstone Arsenal, Ala. Systems Simulation and Development Directorate.
SEEKER SYSTEMS SIMULATION, PRESENT CAPABILITY AND FUTURE TECHNOLOGY
K. V. GRIDER *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 10 p (SEE N84-31248 21-15) May 1984
Avail: NTIS HC A06/MF A01

The missile command's use of seeker in the loop real time simulation in the development of surface to air missile systems is discussed. Material is presented to show that seeker in the loop simulation makes a very positive contribution in the context of the current constraints on weapon system development, such as limited resources, the requirement for convincing system demonstrations, and the requirement for evaluation in a realistic environment including electromagnetic countermeasures and counter-countermeasures. The present facilities and capabilities for such simulation in the radiofrequency, nonimaging infrared and electro-optical bands are described and discussed. Examples of simulation results and their contribution to cost effective system development are presented. Developing technology in this simulation area and plans for future increased simulator capability are addressed. The development of multimode or multispectrum, imaging infrared, and millimeter wave simulators are discussed.
E.A.K.

N84-31255# Selenia S.p.A., Rome (Italy). Defence Systems Div.
MISSILE SYSTEM FOR LOW ALTITUDE AIR DEFENCE
R. BROWN and G. SANTI *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 8 p (SEE N84-31248 21-15) May 1984 refs
Avail: NTIS HC A06/MF A01

Simulation techniques adopted in the design and development phases of the low altitude surface to air missile system SPADA are described. Two distinct areas are examined: one as a tool to validate system concepts, the other in conjunction with field tests to complete operational evaluation. The defense of high value targets (typically airports), within friendly territory, from low level, high speed air raids is examined. The location of such defended targets which is known to the enemy, and attacks are preplanned to take advantage of terrain contours and of electronic countermeasures (screening and deception) to avoid or to delay detection by the defence systems and therefore narrow in to the target, reaching useful weapon release distances. A missile system which is specifically designed for airport defence and considers identification and integrity of friendly A/C was developed. The system named SPADA enchances system survivability to attacks and adapts to the change of objective which are to be defended.
E.A.K.

N84-31256# Thomson-CSF, Malakoff (France). Div. Avionique.
HOMING HEAD IMPERFECTIONS ALTERING MISSILE GUIDANCE
M. DESMERGER *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 6 p (SEE N84-31248 21-15) May 1984
Avail: NTIS HC A06/MF A01

The electromagnetic homing head imperfections which alter the missile guidance were analyzed. Problems connected with detection of the targets such as detection time, parasitic signals rejection, and phenomena introducing errors on target parameters such as thermal noise, parasitic signals, nature of the target, radome aberrations are discussed.
E.A.K.

N84-31257# Messerschmitt-Boelkow-Blohm G.m.b.H., Schrobenhausen (West Germany). Research and Future Programmes for Warheads and Fuzes Dept.
WARHEADS FOR SAM SYSTEMS
M. HELD *In* AGARD Advan. Technol. for SAM Systems Anal. Syn. and Simulation 18 p (SEE N84-31248 21-15) May 1984
Avail: NTIS HC A06/MF A01

The effectiveness of surface to air missiles (SAM) warheads are to be described with the use of lethality models. Missile hits are divided in direct hits and near pass. In the near pass the fragmenting warheads transfer the HE-energy to the target much more effectively than blast warheads. With high hit densities special synergistic or cumulative effects is accomplished. Synergetic or cumulative effects are discussed. Special high fragment beam densities are obtained by aimable warheads.
E.A.K.

N86-27350# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). FMP Working Group WG-12.
VALIDATION OF MISSILE SYSTEM SIMULATION Final Report
Nov. 1985 114 p
(AGARD-AR-206 ISBN-92-835-1514-5) Avail: NTIS HC A06/MF A01

A survey of missile simulation facilities in 1982 indicated that very little was devoted to the validation of missile system simulations. The validation techniques that are used are not standardized, often ill defined, and generally undocumented. In an attempt to rectify this situation, missile simulation procedures were examined and techniques for the validation and universalization of the results were recommended. A simulation terminology that, if adopted, should simplify the validation process is recommended. A hierarchical model representation called, Confidence Level in Model Behavior (CLIMB), is also recommended to organize the simulation process. A standardized documentation procedure is emphasized which both simplifies the orderly use of simulation and insures confidence in the final simulation results. Examples of using CLIMB are included. Computer languages and how they can benefit the simulation process are discussed. Software verification, validation, and assessment methods are exemined.

Recommendations were made to enhance the validation of the simulation. Author

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SPACECRAFT DESIGN, TESTING AND PERFORMANCE

Includes spacecraft thermal and environmental control; and attitude control.

N86-27224# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics and Flight Mechanics Panel.
UNSTEADY AERODYNAMICS-FUNDAMENTALS AND APPLICATIONS TO AIRCRAFT DYNAMICS
Loughton, England Nov. 1985 620 p In ENGLISH and FRENCH Symposium held in Goettingen, West Germany, 6-9 May 1985
(AGARD-CP-386; ISBN-92-835-0382-1; AD-A165045) Avail: NTIS HC A99/MF A01

Recent advances in the methods for experimentation and computational prediction of nonlinear flow phenomena in unsteady aerodynamics and of stability parameters required to describe adequately the dynamic behavior of aircraft with special emphasis on high angle-of-attack were examined. Topics addressed include: unsteady boundary layers; unsteady separation and stall; buffeting; unsteady airloads; wind tunnel and flight test techniques, with emphasis on the measurement of nonlinearities, aerodynamic cross-coupling, hysteresis, and time dependent effects; mathematical modeling; bifurcation theory; prediction of wing rock; and advanced control systems. For individual titles see N86-27225 through N86-27266.

N86-27225# Technische Univ., Brunswick (West Germany). Inst. fuer Stroemungsmechanik.
UNSTEADY FLOWS: FUNDAMENTALS AND APPLICATIONS
B. LASCHKA *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 21 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

An introductory overview about the fundamental equations describing the special features of unsteady flows is presented. Starting with the full Navier-Stokes equations different stages of reductions down to linear potential theory are evaluated. Their scope of validity is discussed. For viscous flows attention is given to the incompressible case whereas for inviscid flows compressibility was retained. Author

N86-27226# United Technologies Research Center, East Hartford, Conn.
DYNAMIC STALL OF SWEPT AND UNSWEPT OSCILLATING WINGS
F. O. CARTA *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 15 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

Recent unsteady tests on oscillating tunnel-spanning wings (representative of full scale helicopter blades) have shown that the dynamic stall phenomena for a swept wing model is significantly different from that for an unswept wing. Several critical measurements and calculations relative to the behavior of the surface flow were made, including chordwise wave speed of the stalling vortex, the degree of pitch rate dependence of the vortex inception angle, and the ability of the cosine law for sweep to normalize unsteady poststall behavior, even after reattachment occurs. Finally, an examination of hot-film response data shows that the stagnation flow along the swept wing leading edge significantly alters the unsteady surface flow behavior in a narrow region along the leading edge when compared with data from the unswept wing. However, from approximately 15 percent chord and aft there appears to be no sweep effect, and the results from both wings are nearly indistinguishable. Author

N86-27227# Centre National de la Recherche Scientifique, Orsay (France).
UNSTEADY VISCOUS FLOW OF AN INCOMPRESSIBLE FLUID AROUND A PROFILE: A COMPARISON OF THEORY AND PRACTICE [ECOULEMENT INSTATIONNAIRE DECOLLE D'UN FLUIDE INCOMPRESSIBLE AUTOUR D'UN PROFIL: UNE COMPARISON THEORIE-EXPERIENCE]
O. DAUBE, T. P. LOC, P. MONNET (Poitiers Univ., France) and M. COUTANCEAU *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 14 p (SEE N86-27224 18-02) Nov. 1985 In FRENCH
Avail: NTIS HC A99/MF A01

The results of numerical and experimental studies of the unsteady flow of a viscous incompressible fluid around a profile of high incidence were presented. Numerical simulation and experimental tests were used to analyze the correlation of the Navier-Stokes equation and Reynolds number at the transition phase. Transl. by T.R.

N86-27228# Vrije Universiteit, Brussels (Belgium). Dept. of Fluid Mechanics.
VELOCITY AND TURBULENCE MEASUREMENTS IN DYNAMICALLY STALLED BOUNDARY LAYERS ON AN OSCILLATING AIRFOIL
J. DERUYCK and C. HIRSCH *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 13 p (SEE N86-27224 18-02) Nov. 1985 Sponsored in part by Belgian National Research Funds (NFWO)
(Contract DAJA45-83-C-0021)
Avail: NTIS HC A99/MF A01

Detailed velocity and turbulence properties in the dynamically stalled boundary layer of an oscillating NACA 0012 airfoil were measured. The airfoil oscillated around an axis at 25% distance from the leading edge with a sinusoidal motion. Measurements are performed at eight chordwise positions, in non-stalled, stall onset, and deep stalled flow conditions. Instantaneous detailed flow and turbulence patterns of the periodic separation vortex are presented and discussed. Corresponding terms of the turbulent energy balance are derived and compared with flat plate boundary layer data. In particular, negative turbulent energy production is observed during vortex development. Author

N86-27229# Centre National de la Recherche Scientifique, Marseilles (France). Inst. de Mecanique des Fluides.
WING PROFILE IN STALLED POSITION SUBJECT TO A FLOW OF ALTERNATING POTENTIAL AND STRONG VORTEX [PROFIL D'AILE EN DECROCHAGE SOUMIS A UN ECOULEMENT ALTERNATIVEMENT POTENTIEL ET A FORT VORTICITE]
C. MARESCA and D. FAVIER *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 15 p (SEE N86-27224 18-02) Nov. 1985 In FRENCH
Avail: NTIS HC A99/MF A01

The aerodynamic behavior of a wing profile subject to a flow of alternating potential and strong vortex is examined. The simulation experiment consisted of placing a fixed wing profile in the wake of a profile that oscillated at stalling incidence parallel to the flow. The results show that the effects on the fixed profile may be theoretically approximated by considering the profile as isolated in the flow while the amplitude of the speed and the incidence are simultaneously variable with the pre-established values. Transl. by T. R.

N86-27230# Lockheed Missiles and Space Co., Sunnyvale, Calif.
A CRITICAL LOOK AT DYNAMIC SIMULATION OF VISCOUS FLOW
L. E. ERICSSON *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 11 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

A critical examination is made of the classic role of the wind tunnel as a tool for simulation of the free flight aerodynamics. That the equivalence concept established for steady flow is not valid for unsteady flow is no great surprise. More surprising, probably, is the fact that simulation of the relative velocity time history, which assures simulation of the inviscid unsteady aerodynamics, will in many cases not assure simulation of the

unsteady viscous flow. In the case of flow separation and associated hysteresis the lack of simulation of the transient viscous flow can sometimes even generate the incorrect final steady state flow condition. Only close attention to the simulation of the unsteady boundary condition at the vehicle surface can assure the utility of experimental and numerical results for prediction of full scale unsteady viscous flow characteristics. Author

N86-27231# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Aeroelastik.

UNSTEADY BOUNDARY-LAYER SEPARATION ON AIRFOILS PERFORMING LARGE-AMPLITUDE OSCILLATIONS: DYNAMIC STALL

W. GEISSLER *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 12 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01

Experimental investigations have exposed a strong dependency of unsteady separation characteristics in the regime of dynamic stall on airfoil shape, Reynolds and Mach number, and frequency and time dependence incidence. A suitable prediction method should be able to account for these various parameters. Coupling procedures between two-dimensional unsteady boundary layers and inviscid surface singularity methods (panel methods) were developed for analytical investigation of unsteady turbulent separation. The influence of various parameters on unsteady separation is discussed in detail and comparison with experimental data is made. The results show that, even for weak coupling between boundary layer and inviscid boundary condition, good correspondence exists between theory and experiment with respect to the development of unsteady separation. Author

N86-27232*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

COMPUTATIONAL ASPECTS OF UNSTEADY FLOWS

T. CEBECI (Douglas Aircraft Co., Inc., Long Beach, Calif.), L. W. CARR, A. A. KHATTAB, and S. M. SCHIMKE *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 25 p (SEE N86-27224 18-02) Nov. 1985

(Contract F496720-82-C-0055)

Avail: NTIS HC A99/MF A01 CSCL 01A

The calculation of unsteady flows and the development of numerical methods for solving unsteady boundary layer equations and their application to the flows around important configurations such as oscillating airfoils are presented. A brief review of recent work is provided with emphasis on the need for numerical methods which can overcome possible problems associated with flow reversal and separation. The zig-zag and characteristic box schemes are described in this context, and when embodied in a method which permits interaction between solutions of inviscid and viscous equations, the characteristic box scheme is shown to avoid the singularity associated with boundary layer equations and prescribed pressure gradient. Calculations were performed for a cylinder started impulsively from rest and oscillating airfoils. The results are presented and discussed. It is concluded that turbulence models based on an algebraic specification of eddy viscosity can be adequate, that location of translation is important to the calculation of the location of flow separation and, therefore, to the overall lift of an oscillating airfoil. Author

N86-27233*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

UNSTEADY TURBULENT BOUNDARY-LAYER EXPERIMENTS WITH RAPIDLY CHANGING FREE-STREAM CONDITIONS

G. J. BRERETON (Stanford Univ., Calif.), L. W. CARR, and W. C. REYNOLDS *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 9 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01 CSCL 01A

Selected data sets produced by the Stanford Unsteady Turbulent Boundary Layer Program are compared to analytic solutions of the Stokes equations for different kinds of imposed, organized unsteadiness. Good agreement is found, qualifying the facility as one that faithfully produces flows of different prescribed unsteady conditions. Data sets from the facility are therefore considered especially suitable for comparison with predictions of turbulence models for unsteady flows. New data describing the development of an unsteady separation bubble are presented. Author

N86-27234# Centre National de la Recherche Scientifique, Grenoble (France). Inst. de Mecanique.

EXPERIMENTAL STUDY OF UNSTEADY TURBULENT BOUNDARY LAYERS SUBJECT TO MEAN PRESSURE GRADIENTS OF ZERO OR POSITIVE [ETUDE EXPERIMENTALE DE COUCHES LIMITES TURBULENTES INSTATIONNAIRES SOUMISES A DES GRADIENTS DE PRESSION MOYENS NULS OU POSITIFS]

G. BINDER, S. TARDU, R. BLACKWELDER, and J. L. KUENY *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 13 p (SEE N86-27224 18-02) Nov. 1985 In FRENCH

Avail: NTIS HC A99/MF A01

The results of tests on turbulent flows in a fluid cycle, at the frequency and amplitude of the audible frequency range were presented. The results include velocity measurements using laser velocimeter equipment, as well as friction measurements using the hot film method. Transl. by T. R.

N86-27235# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Etudes et Recherches en Aerothermodyn.

UNSTEADY TURBULENT BOUNDARY LAYERS: EXPERIMENTAL AND NUMERICAL INVESTIGATIONS [COUCHE LIMITE TURBULENTE INSTATIONNAIRE: INVESTIGATIONS EXPERIMENTALE ET NUMERIQUE]

J. COUSTEIX and R. HOUDEVILLE *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 12 p (SEE N86-27224 18-02) Nov. 1985 In FRENCH

Avail: NTIS HC A99/MF A01

The results of an experimental study of turbulent boundary layers subject to periodic external fluctuations of the flow are presented. Two cases are studied, one a flat plate and the other a pipe with a positive pressure gradient viscous flow. The unsteady boundary layer equations and their relationship with viscous flow is analyzed using integral equations. Transl. by T. R.

N86-27236# Mykytow (Walter J.), Weymouth, Mass.

REVIEW OF SMP 1984 SYMPOSIUM ON TRANSONIC UNSTEADY AERODYNAMICS AND ITS AEROELASTIC APPLICATIONS

W. J. MYKYTOW *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 45 p (SEE N86-27224 18-02) Nov. 1985.

Avail: NTIS HC A99/MF A01

The latest methods of predicting transonic unsteady airloads for oscillating surfaces and flutter were discussed. Also considered were aerolelastic applications, many of which were made to standard AGARD configurations. The 16 papers and the round table discussion were summarized for coordination with the Fluid Dynamics Panel and the Fluid Mechanics Panel. B.G.

N86-27237*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

TRANSONIC AERODYNAMIC AND AEROELASTIC CHARACTERISTICS OF A VARIABLE SWEEP WING

P. M. GOORJIAN, G. P. GURUSWAMY (Informatics, Inc., Palo Alto, Calif.), H. IDE (Rockwell International Corp., Los Angeles, Calif.), and G. MILLER *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 15 p (SEE N86-27224 18-02) Nov. 1985 Previously announced as N85-25203

Avail: NTIS HC A99/MF A01 CSCL 01A

The flow over the B-1 wing is studied computationally, including the aeroelastic response of the wing. Computed results are compared with results from wind tunnel and flight tests for both low-sweep and high-sweep cases, at 25.0 and 67.5 deg., respectively, for selected transonic Mach numbers. The aerodynamic and aeroelastic computations are made by using the transonic unsteady code ATRAN3S. Steady aerodynamic computations compare well with wind tunnel results for the 25.0 deg sweep case and also for small angles of attack at the 67.5 deg sweep case. The aeroelastic response results show that the wing is stable at the low sweep angle for the calculation at the Mach number at which there is a shock wave. In the higher sweep

case, for the higher angle of attack at which oscillations were observed in the flight and wind tunnel tests, the calculations do not show any shock waves. Their absence lends support to the hypothesis that the observed oscillations are due to the presence of leading edge separation vortices and are not due to shock wave motion as was previously proposed. Author

N86-27238# National Aerospace Lab., Amsterdam (Netherlands).
UNSTEADY AIRLOAD COMPUTATIONS FOR AIRFOIL OSCILLATING IN ATTACHED AND SEPARATED COMPRESSIBLE FLOW
R. HOUWINK *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 8 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

Recent developments in coupled inviscid flow-boundary layer computations are discussed for airfoils in unsteady motion in attached and separated subsonic and transonic flow. The applicability of quasi-simultaneous strong interaction coupling procedures for transonic small perturbation theory and boundary layer integral methods is illustrated for oscillating airfoils with shock-induced separation. The relevance of the predicted airloads for aeroelastic applications is illustrated using the analysis of an aeroelastic instability of a supercritical wing wind tunnel model. Author

N86-27239# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
WIND TUNNEL AND FLIGHT TEST ANALYSIS AND EVALUATION OF THE BUFFET PHENOMENA FOR THE ALPHA JET TRANSONIC WING
H. BUERS and V. SCHMITT (Office National d'Etudes et de Recherches Aeronautiques, Paris, France) *In* AGARD Unsteady Aerodynamics-Fundamentals and Application to Aircraft Dynamics 11 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

In addition to previous presentations of wind tunnel and flight test data of the Dornier Transsonischer Tragfluegel (TST) program, results of local flow surveys on the wing in the buffeting region are presented. The vibration levels on the wing and at the pilot's seat are also shown. The separated effects of the slats in use both with and without trailing edge flaps as maneuver flaps up to the transonic flight regime are presented. Author

N86-27240# Max-Planck-Institut fuer Stroemungsforschung, Goettingen (West Germany).
UNSTEADY VORTEX AIRFOIL INTERACTION
G. E. A. MEIER and R. TIMM *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 10 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

The unsteady flow in the vicinity of an airfoil in a subsonic flow with strong vortices is investigated for a two-dimensional problem. Emphasis was placed on the interaction of the passing vortex flow field with the steady flow field of the airfoil. Unsteady flow separation and generation of new vortices of the airfoil occurs depending on vortex strength and core path. Inviscid calculations of vortex paths and sound generation are compared with the experimental results. The associated pressure waves have a strong directivity. The vortices used for the interaction experiments are generated by different vortex shedding cylinders in a stationary duct flow or by airfoils in the starting flow of a shock-tube. High speed interferometric flow recording and wall pressure measurement are the main experimental techniques. Author

N86-27241# Westland Helicopters Ltd., Yeovil (England).
UNSTEADY AERODYNAMICS APPLICATION TO HELICOPTER NOISE AND VIBRATION SOURCES
T. S. BEDDOES *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 10 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

The feasibility of producing aerodynamic loads of sufficient fidelity to enable a realistic acoustic signal to be derived was studied. The need arises from the excessive blade/slap noise which results from blade/vortex interaction. A tool is required to investigate the influence of design and operational parameters as a routine procedure. For this purpose a simplified two dimensional model was developed and validated against a more sophisticated analysis. The model is extended to the rotor application where the complex wake geometry is the determining factor in the character of the loading. From the distributed transient loading an acoustic signal was derived which was compared with experimental data. A comprehensive correlation was not yet performed but the preliminary results are encouraging. Author

N86-27242*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
RECENT DEVELOPMENTS IN ROTARY-BALANCE TESTING OF FIGHTER AIRCRAFT CONFIGURATIONS AT NASA AMES RESEARCH CENTER
G. N. MALCOLM and L. B. SCHIFF *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 25 p (SEE N86-27224 18-02) Nov. 1985 Previously announced as N85-32090
Avail: NTIS HC A99/MF A01 CSCL 01A

Two rotary balance apparatuses were developed for testing airplane models in a coning motion. A large scale apparatus, developed for use in the 12-foot Pressure Wind Tunnel primarily to permit testing at high Reynolds numbers, was recently used to investigate the aerodynamics of 0.05-scale model of the F-15 fighter aircraft. Effects of Reynolds number, spin rate parameter, model attitude, presence of a nose boom, and model/sting mounting angle were investigated. A smaller apparatus, which investigates the aerodynamics of bodies of revolution in a coning motion, was used in the 6-by-6 foot Supersonic Wind Tunnel to investigate the aerodynamic behavior of a simple representation of a modern fighter, the Standard Dynamic Model (SDM). Effects of spin rate parameter and model attitude were investigated. A description of the two rigs and a discussion of some of the results obtained in the respective tests are presented. Author

N86-27243# Royal Aircraft Establishment, Bedford (England). Aerodynamics Dept.
NEW ROTARY RIG AT RAE AND EXPERIMENTS ON HIRM
C. O. OLEARY and E. N. ROWTHORN *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 14 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

A rig for measurement of forces and moments due to continuous rate of roll was commissioned at Royal Aircraft Establishment, Bedford. Tests were made on a High Incidence Research Model (HIRM) in two wind tunnels at M $\approx$ 0.2, 0.4, and 0.7. At present models can be tested up to 40 deg angle of attack at rotational speeds up to 350 rpm. Tests on HIRM included an investigation of configuration and Reynolds number effects. Results are compared with similar data from tests with another rolling rig and from small amplitude oscillatory tests. Author

N86-27244# Aeronautical Research Inst. of Sweden, Bromma.
NEW DYNAMIC TESTING TECHNIQUES AND RELATED RESULTS AT FFA
T. JANSSON and L. TORNGREN *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 14 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

Extraction of dynamic derivatives from wind tunnel testing was emphasized in recent years. This is shown from the number of different rigs developed and in use, both in the subsonic and transonic wind tunnels. Brief descriptions of the different rigs, testing procedures and data handling were given. A wide survey of the different rigs used for dynamic derivative testing and the corresponding testing capability are presented. B.G.

N86-27245# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Aeroelastik.
STANDARD DYNAMICS MODEL EXPERIMENTS WITH THE DFVLR/AVA TRANSONIC DERIVATIVE BALANCE
E. SCHMIDT *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 16 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

A slender high-load forced-oscillation measuring system for dynamic derivatives of aircraft and missile models in a transonic

wind tunnel is presented together with typical test results of the significant aerodynamic coefficients and stability derivatives of the Standard Dynamics Model, a simplified fighter aircraft model with a wing span of 0.345 m. The measurements in the rotational modes pitch, yaw, and roll encompass Mach numbers from 0.6 to 1.2, angles of attack from 0 to 30 degrees, and excitation frequencies from 2 to 20 Hz at a constant Reynolds number of 7.8 Mio/m. Most of the stiffness and damping derivatives gathered show substantial nonlinear dependence on Mach number and angle of attack, whereas the influence of reduced frequency is less prominent. The results are closely related to published measurements on Standard Dynamic Models performed in other NATO countries. Author

N86-27246# Institut de Mecanique des Fluides de Lille (France).

RECENT DEVELOPMENTS IN TECHNIQUES FOR DYNAMIC SIMULATION FOR THE IDENTIFICATION OF STABILITY PARAMETERS [RECENTS DEVELOPPEMENTS DES TECHNIQUES DE SIMULATION DYNAMIQUE APPLIQUEES A L'IDENTIFICATION DES PARAMETRES DE STABILITE]

D. TRISTRANT and O. RENIER *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 14 p (SEE N86-27224 18-02) Nov. 1985 In FRENCH

Avail: NTIS HC A99/MF A01

In the aircraft dynamic behavior prediction context, experimental methods and analytical procedures which allow mathematical linear modeling parameters to be identified, using a test apparatus located at the Institut de Mecanique des Fluides de Lille is presented. The rig characteristics, the experimental procedures, the identification methods, and results from different aircraft models will be described. Emphasis is put on the interest of a specific lambda degree of freedom angle formed by the rotational vector and velocity vector. Effectively, it is shown that rotational tests with a non zero value of lambda offer interesting possibilities for identification and allow the estimation of linear model parameters in the case of a quasi-linear path. A different degree of freedom, called gyration radius, was obtained by fixing a special mechanism onto the test apparatus. By carrying out a carefully selected test program, this degree of freedom allows the whole set of stability parameters to be identified, given the structure of the linear mathematical model. Finally, dynamic measures obtained during oscillatory coning using a complete aircraft model produced in evidence the large amplitude of unsteady aerodynamic phenomena at high angles of attack, which could not be ignored if prediction of post stall evolutions is sought. Author

N86-27247# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany) Inst. fuer Flugmechanik.

GENERATION OF TWO-DIMENSIONAL GUST FIELDS IN SUBSONIC WIND-TUNNELS

B. KRAG and W. WEGNER (Technische Univ., Brunswick, West Germany) *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 12 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01

For a variety of flight vehicles, problems during flight in turbulence at subsonic speeds are expected: mainly slow flying helicopters, tilt rotorcraft, aircraft maneuvering at high angles of attack, wing in ground effect vehicles, and aircraft with active controlled wings. The investigation of these problems posses large difficulties. The analyst rapidly enters domains where computational methods fail and where wind tunnel experiments are necessary. This raises the problem of stimulating atmospheric turbulence in a wind tunnel. Until now, no fundamental investigations of the problem of gust generation in wind tunnels were undertaken. Investigations of gust generations were started in a model subsonic wind tunnel. In order to recognize the influence of the main parameters, like number of lift generating wings, chord length, trailing edge-flap or jet-flap, constant chord wing or side-wall mounted winglets, four different types of gust generators were investigated. The gust field was harmonically oscillating. Frequency response measurements of the gust angle of attack were made, covering the complete volume of the test section. Additionally the flow field in the wind tunnel behind harmonically oscillating gust generator flaps was calculated. The results were compared with the measurements. Author

N86-27248*# National Aeronautics and Space Administration Dryden (Hugh L.) Flight Research Center, Edwards, Calif.

EXTRACTION OF AERODYNAMIC PARAMETERS FOR AIRCRAFT AT EXTREME FLIGHT CONDITIONS

K. W. ILIFF *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 21 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01 CSCL 01A

The maximum likelihood estimator was used to extract stability and control derivatives from flight data for many years. Most of the literature on aircraft estimation concentrates on new development and applications, assuming familiarity with basic concepts. The maximum likelihood estimator and the aircraft equations of motion that the estimator uses are discussed. The current strength and limitations associated with obtaining flight-determined aerodynamic coefficients in extreme flight conditions are assessed. The importance of the careful combining of wind tunnel results (or calculations) and flight results and the thorough evaluation of the mathematical model is emphasized. The basic concepts of minimization and estimation are examined for a simple computed aircraft example, and the cost functions that are to be minimized during estimation are defined and discussed. Graphic representations of the cost functions are given to help illustrate the minimization process. Finally, the basic concepts are generalized, and estimation of stability and control derivatives from flight data is discussed. Author

N86-27249*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.

NONLINEAR PROBLEMS IN FLIGHT DYNAMICS INVOLVING AERODYNAMIC BIFURCATIONS

M. TOBAK and G. T. CHAPMAN *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 15 p (SEE N86-27224 18-02) Nov. 1985 Previously announced as N85-25206

Avail: NTIS HC A99/MF A01 CSCL 01A

Aerodynamic bifurcation is defined as the replacement of an unstable equilibrium flow by a new stable equilibrium flow at a critical value of a parameter. A mathematical model of the aerodynamic contribution to the aircraft's equations of motion is amended to accommodate aerodynamic bifurcations. Important bifurcations such as, the onset of large-scale vortex shedding are defined. The amended mathematical model is capable of incorporating various forms of aerodynamic responses, including those associated with dynamic stall of airfoils. E.A.K.

N86-27250*# National Aeronautics and Space Administration Ames Research Center, Moffett Field, Calif.

BIFURCATION THEORY APPLIED TO AIRCRAFT MOTIONS

W. H. HUI (Waterloo Univ., Ontario) and M. TOBAK *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 14 p (SEE N86-27224 18-02) Nov. 1985 Previously announced as N85-23705

Avail: NTIS HC A99/MF A01 CSCL 01A

The bifurcation theory is used to analyze the nonlinear dynamic stability characteristics of single-degree-of-freedom motions of an aircraft or a flap about a trim position. The bifurcation theory analysis reveals that when the bifurcation parameter, e.g., the angle of attack, is increased beyond a critical value at which the aerodynamic damping vanishes, a new solution representing finite-amplitude periodic motion bifurcates from the previously stable steady motion. The sign of a simple criterion, cast in terms of aerodynamic properties, determines whether the bifurcating solution is stable (supercritical) or unstable (critical). For the pitching motion of a flap-plate airfoil flying at supersonic/hypersonic speed, and for oscillation of a flap at transonic speed, the bifurcation is subcritical, implying either that exchanges of stability between steady and periodic motion are accompanied by hysteresis phenomena, or that potentially large aperiodic departures from steady motion may develop. On the other hand, for the rolling oscillation of a slender delta wing in subsonic flight (wing rock), the bifurcation is found to be supercritical. This and the predicted amplitude of the bifurcation periodic motion are in good agreement with the experiments. Author

N86-27251# National Research Council of Canada, Ottawa (Ontario).
DYNAMIC NONLINEAR AIRLOADS: REPRESENTATION AND MEASUREMENT
E. S. HANFF *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 14 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

A new representation of aerodynamic reactions (in terms of the motion variables), which does not rely on assumptions of linearity, is proposed. This representation is, therefore, indicated for extreme flight conditions where a locally linearized model is usually of questionable value. The significance within the present context of stability derivatives is discussed with the intention of pointing out their range of applicability. A wind tunnel technique, capable of efficiently obtaining the bulk of the data required for the effective use of the representation is briefly described. Author

N86-27252*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RECENT EXPERIENCES OF UNSTEADY AERODYNAMIC EFFECTS ON AIRCRAFT FLIGHT DYNAMICS AT HIGH ANGLE OF ATTACK
L. T. NGUYEN, R. D. WHIPPLE, and J. M. BRANDON *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 25 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

Recent research is highlighted which was conducted at the NASA Langley Research Center on two high angle-of-attack flight dynamic phenomena which are dominated by unsteady aerodynamic effects: wing rock and tumbling. Studies of wing rock induced by strong vortical flows and tumbling characteristics observed on an advanced configuration are reviewed. Results of wind tunnel experiments are summarized and the aerodynamic mechanisms involved in the phenomena were discussed. Author

N86-27253# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Avionics Lab.
UNSTEADY AERODYNAMICS AND DYNAMIC AIRCRAFT MANEUVERABILITY
J. D. LANG and M. S. FRANCIS (Air Force Space Div., Los Angeles, Calif.) *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 19 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

A forecast of future aerial combat predicated on anticipated technological advances and weapons developments suggests a need for supermaneuverable aircraft possessing greatly enhanced turning and virtually instantaneous point-and-shoot capabilities. The potential advantage of exploiting this unique flight environment was discussed along with a detailed description of expected vehicle dynamic behavior. An emerging picture of the unsteady aerodynamic behavior which will be experienced during these violent maneuvers dictates a need for greater vehicle and flow field control capabilities far in excess of any previously employed in application. However, the successful implementation of advanced control techniques may well beneficially exploit the unusual flow phenomena associated with this nonclassical method of flight. The research discoveries and developmental ideas generated during the next decade will likely alter the concept of maneuvering flight as it is known and lead to a new generation of aircraft with vastly improved combat capabilities. Author

N86-27254# London Univ. (England). Dept. of Aeronautical Engineering.
ON THE INTERFACE BETWEEN UNSTEADY AERODYNAMICS, DYNAMICS AND CONTROL
G. J. HANCOCK and R. VEPA *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 12 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

The problems of interfacing the mathematical representation of linearized unsteady aerodynamics with dynamic response such that the eigenvalue of the dynamic response are correctly obtained. These eigenvalues are then used in control synthesis. Particular attention is paid to C sub M2 (lag effect between the main wing and tail) in the context of aircraft dynamics. The concept of quasi-steady aerodynamics is clarified. Author

N86-27255# Royal Aircraft Establishment, Farnborough (England).
CORRELATION OF PREDICTED AND FREE-FLIGHT RESPONSES NEAR DEPARTURE CONDITIONS OF A HIGH INCIDENCE RESEARCH MODEL
A. J. ROSS and G. F. EDWARDS *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 13 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

The mathematical model of aerodynamic forces and moments is described, based on results from various wind tunnel experiments with the Royal Airforce Establishment High Incidence Research Model (HIRM). Simulations of the responses due to longitudinal and lateral control inputs at high angles of attack are compared with the responses measured on free-flight models of the configuration. The main features of the flight behavior are reproduced, in particular such phenomena as roll-off, wing rock, and nose slice. Author

N86-27256# Kansas Univ., Lawrence. Dept. of Aerospace Engineering.
THEORETICAL PREDICTION OF WING ROCKING
C. E. LAN *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 13 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

Wing rock is primarily a rolling oscillation about the longitudinal body axis at high angles of attack. It involves nonlinear interaction between flight dynamics and aerodynamics. A nonlinear aerodynamic model was proposed earlier to predict the wing rock frequency and amplitude of low aspect-ratio configurations with good accuracy. The theory is applied to a twin-jet fighter aircraft of moderate aspect ratio and to a low-speed configuration of high aspect ratio. For the purpose of predicting necessary aerodynamic derivatives, a lifting surface method coupled with nonlinear airfoil section data is developed. The results show that wing rock can be predicted with the present wing-rock and aerodynamic theories. It is also found that for configurations of high aspect ratio, the one degree of freedom dynamic model in the present wing rock theory should be used. For other configurations, the three degrees of freedom model is more appropriate. Author

N86-27257# Technische Hogeschool, Delft (Netherlands). Dept. of Aerospace Engineering.
EFFECTS OF AERODYNAMIC LAGS ON AIRCRAFT RESPONSES
J. C. VANDERVAART *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 11 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

Results of a theoretical study on the effects of unsteady aerodynamics on symmetric aircraft responses due to elevator and vertical turbulence imputs, are presented. Several linear models were developed to describe unsteady lift and downwash and delays due to horizontal tail length. Results for three example aircraft types show that calculated normal acceleration levels due to turbulence are very little affected by including unsteady wing lift and downwash. However, there appears to be a noticeable influence on plunging acceleration and pitch rate response to elevator or vertical turbulence inputs. Author

N86-27258# Smith Associates Consulting System Engineers Ltd., Cobham (England).
A SELF-ORGANISING CONTROL SYSTEM FOR NON-LINEAR AIRCRAFT DYNAMICS
C. EVANS *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 12 p (SEE N86-27224 18-02) Nov. 1985
Avail: NTIS HC A99/MF A01

At high angles of attack (AOA) flow separations can produce nonlinear and time varying aerodynamic loads, which cannot be predicted with great certainty. Such loads make control system development extremely difficult. A control system was developed which can accomplish on-line reduction of the a priori uncertainties pertaining to the effective control of the aircraft. The self-organizing

control system was developed to suppress unacceptable pitch-up tendencies of an aircraft at high AOA, without the use of AOA measurement. The final control system demonstrated good performance for a variety of inputs although performance was not as good in turbulence. Author

N86-27259# Messerschmitt-Boelkow G.m.b.H., Munich (West Germany). Hubschrauber und Flugzeuge.

GUST ALLEVIATION ON A TRANSPORT AIRPLANE

J. BECKER, F. WEISS, E. CAVATORTA (Aeritalia S.p.A., Naples, Italy), and C. CALDARELLI *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 9 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01

A Gust Alleviation System on a preliminary configuration of a commuter aircraft was analyzed. The analysis takes into account the influence of the elasticity of the aircraft, unsteady aerodynamic effect, and mechanical nonlinearities such as backlash-deadzone, control surface rate, and deflection limitations. A relatively simple model shows that ride comfort can be improved by at least 50%. Author

N86-27260# Waterloo Univ. (Ontario). Dept. of Applied Mathematics and Mechanical Engineering.

UNSTEADY THREE-DIMENSIONAL FLOW THEORY VIA MATERIAL FUNCTIONS

W. H. HUI and H. J. VANROESSEL *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 3 p (SEE N86-27224 18-02) Nov. 1985

(Contract NAGW-575)

Avail: NTIS HC A99/MF A01

A new Lagrangian formulation for unsteady three dimensional supersonic inviscid flow over rigid bodies is developed. The continuity equation is eliminated by the use of material functions, a generalization of the stream functions for steady flow. This is followed by a transformation to new independent variables, three of which are these material functions. The fourth variable is a Lagrangian time distinct from the Eulerian time. This simultaneous use of both Langrangian and Eulerian time allows the problem of flow with shock wave to be reduced to a fixed boundary one. In the Newtonian limit it is found possible to obtain analytic solutions for various body shapes. Author

N86-27261*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

UNSTEADY INTERACTIONS OF TRANSONIC AIRFOILS WITH GUSTS AND CONCENTRATED VORTICES

W. J. MCCROSKEY and G. R. SRINIVASAN (JAI Associates, Mountain View, Calif.) *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 13 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01

Unsteady interactions of strong concentrated vortices, distributed gusts, and sharp-edged gusts with stationary airfoils were analyzed in two-dimensional transonic flow. A simple and efficient method for introducing such vortical disturbances was implemented in numerical codes that range from inviscid, transonic small-disturbance to thin-layer Navier Stokes. The numerical results demonstrate the large distortions in the overall flow field and in the surface air loads that are produced by various vortical interactions. The results of the different codes are in excellent qualitative agreement, but, as might be expected, the transonic small-disturbance calculations are deficient in the important region near the leading edge. Author

N86-27262# Hellenic Air Force Technology Research Center, Athens (Greece).

MODELLING OF THE VORTEX-AIRFOIL INTERACTION

A. G. PANARAS *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 16 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01

A modeling of the vortex-airfoil interaction is presented in which the finite-area of the real vortices is taken into consideration. Two vortex models are used. In the first, a disturbed piece of vorticity layer is simulated by four rows of discrete vortices of small strength. In the second, a number of discrete vortices is arranged within a circle. The first model may simulate a shear layer or a wake, while the second, a well-formed vortex. The method was applied to the calculation of the pressure induced on the surface of the airfoil by the interacting vortex. Both models give similar results. It was found that for large distances of the vortex from the surface of the airfoil, the consideration or not of the finite-area of the vortex is not a significant factor in determining the induced pressure field. However, when the distance of the vortex from the surface is reduced, its shape is distorted and the induced pressure pulses have lower amplitude than the ones induced by an equivalent point vortex. In the limit, where the vortex impinges on the leading edge of the airfoil, it is split into two and the time dependent pressure coefficient takes even negative values at some time intervals. Author

N86-27263# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Flugmechanik.

IDENTIFICATION OF AIRCRAFT CHARACTERISTICS INCLUDING GUST INDUCED DYNAMIC EFFECTS

D. ROHLF *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 8 p (SEE N86-27224 18-02) Nov. 1985

Avail: NTIS HC A99/MF A01

For the investigation of unsteady aerodynamic effects at low Mach numbers, dynamic tests using controllable models of a light transport aircraft were performed in wind tunnels in the Dynamic Simulation Facility (Germany) and the Free Flight Catapult Facility (France). These model test techniques have the advantage of laboratory conditions with the possibility of generating reproducible gusts. The achieved flight test data were analyzed in detail applying method of system identification. This included the determination of the discrete gust disturbance from onboard measured signals. An approach was presented which used the measured angle of attack and additional calculated dynamic terms, which become essential in the presence of fast flow changes due to short-wave gusts or high-frequency control deflection. Measured time histories of model flight tests with excitation by control inputs and gusts are presented and compared with identification results obtained from the multi-run evaluation. Author

N86-27264# Sherbrooke Univ. (Quebec). Dept. de Genie Mecanique.

EXPERIMENTAL STUDY OF THE EFFECT OF TURBULENCE ON DYNAMIC STALLING [ETUDE EXPERIMENTALE DE L'EFFET DE LA TURBULENCE SUR LE DECROCHAGE DYNAMIQUE]

A. LANEVILLE, P. VITTECOQ, and J. COTE *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 7 p (SEE N86-27224 18-02) Nov. 1985 In FRENCH

Avail: NTIS HC A99/MF A01

The results of a study of dynamic stalling for different intensities of turbulence in the flow of a wind tunnel are presented. The test was conducted on a NACA 0018 profile with sinusoidal oscillation. The results show that turbulence modifies both static and dynamic stall phenomena. It is shown that turbulence stabilizes the boundary layer at the leading edge, while allowing the profile to attain larger angles of incidence before stalling. In addition, turbulence alters the formation of vortices at the leading edge. Transl. by T. R.

N86-27265*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

APPLICATION OF CFD TECHNIQUES TOWARD THE VALIDATION OF NONLINEAR AERODYNAMIC MODELS

L. B. SCHIFF and J. KATZ *In* AGARD Unsteady Aerodynamics-Fundamentals and Applications to Aircraft Dynamics 15 p (SEE N86-27224 18-02) Nov. 1985 Previously announced as N85-26671

Avail: NTIS HC A99/MF A01 CSCL 14B

Applications of computational fluid dynamics (CFD) methods to determine the regimes of applicability of nonlinear models describing the unsteady aerodynamic responses to aircraft flight motions are described. The potential advantages of computational methods over experimental methods are discussed and the concepts underlying mathematical modeling are reviewed. The economic and conceptual advantages of the modeling procedure over coupled, simultaneous solutions of the gas dynamic equations and the vehicle's kinematic equations of motion are discussed. The modeling approach, when valid, eliminates the need for costly

repetitive computation of flow field solutions. For the test cases considered, the aerodynamic modeling approach is shown to be valid. Author

N86-27266# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
STUDY OF THE TRANSITION BEHAVIOR OF AN AIRPLANE IN THE VICINITY OF BIFURCATION POINTS [ETUDE DU COMPORTEMENT TRANSITOIRE D'UN AVION AU VOISINAGE DE POINTS DE BIFURCATION]
P. GUICHETEAU *In* AGARD Unsteady Aerodynamics-Fundamentals and applications to Aircraft Dynamics 7 p (SEE N86-27224 18-02) Nov. 1985 In FRENCH
Avail: NTIS HC A99/MF A01

The transition behavior of an aircraft in the vicinity of bifurcation points, using a differential system method to analytically determine nonlinearities is discussed. The method proposed does not require the reduction of the differential system. Primary applications for this method include studies on fighter aircraft. Transl. by T. R.

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SPACECRAFT PROPULSION AND POWER

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

N85-15809# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
RAMJET AND RAMROCKET PROPULSION SYSTEMS FOR MISSILES
Loughton, England Oct. 1984 241 p refs In ENGLISH and FRENCH Lectures held in Monterey, Calif., 5-6 Sep. 1984, in London, 10-11 Sep. 1984, and in Neubiberg, West Germany, 13-14 Sep. 1984
(AGARD-LS-136; ISBN-92-835-0360-0; AD-A154081) Avail: NTIS HC A11/MF A01

An introduction is given to modern Ramjet technology. Applications to missiles are especially emphasized. Various types of Ramjets are surveyed and characterized and Ramjet components are discussed, as well as the main types of subsonic combustion Ramjets and supersonic combustion Ramjets. For individual titles see N85-15810 through N85-15817.

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CHEMISTRY AND MATERIALS (GENERAL)

Includes biochemistry and organic chemistry.

N84-33465# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
MATERIALS SUBSTITUTION AND RECYCLING
Loughton, England Apr. 1984 298 p refs In ENGLISH and FRENCH Meeting held in Vimeiro, Portugal, 14-19 Oct. 1983
(AGARD-CP-356; ISBN-92-835-0352-X; AD-A148598) Avail: NTIS HC A13/MF A01

The rarity of several metals such as cobalt, chromium, tantalum and niobium, which are used in high temperature materials for jet turbine induces a need for stock-piling, conservation, substitution and recycling. This meeting was focused on the last two aspects, with special reference to superalloys with low critical element contents and substitutes to superalloys on one side, the identification of the sensitive impurities, the problems related to the increase of their concentration, and the possible ways to solve them on the other. For individual titles, see N84-33466 through N84-33488.

N84-33466# Rutgers - The State Univ., Piscataway, N. J. Center for Ceramic Research.
THE NATURE OF THE CRITICAL AND STRATEGIC MATERIALS PROBLEM
J. B. WACHTMAN, JR. *In* AGARD Mater. Substitution and Recycling 11 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The economics and national defense systems of the industrialized, market economy countries depend on many imported raw materials. Some of these materials are vital to the performance of advanced weapons or to basic production capacity such as machine tools. While no present shortage exists, the potential of supply interruptions requires national preparedness as a form of insurance. Adequate preparedness requires a multifaceted strategy including the capability of short term response, such as stockpiling, and longer term responses such as emergency substitution. Development of substitutes occurs normally only when a price or performance advantage is foreseen. Some substitutes are being developed through this natural economic motivation exists. Technically promising substitution development which could reduce vulnerability may require more deliberate and better organized government support. Author

N84-33467# Durham Univ. (England). Dept. of Geography.
FACTORS AFFECTING THE SUPPLY OF STRATEGIC RAW MATERIALS WITH PARTICULAR REFERENCE TO THE AEROSPACE MANUFACTURING INDUSTRY
E. W. ANDERSON *In* AGARD Mater. Substitution and Recycling 20 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The political and strategic factors affecting the supply of certain raw materials critical to the European NATO aerospace industry are analyzed. For various reasons, including potential political instability, concentration of sources, small scale of production and technological industrial problems, chromium, cobalt, hafnium, manganese, niobium, titanium, tungsten and vanadium are all considered to a degree at risk. R.J.F.

N84-33468# Motoren- und Turbinen-Union Muenchen G.m.b.H. (West Germany).
MEASURES FOR MATERIALS CONSERVATION IN AERO-ENGINE CONSTRUCTION
H. HUFF, R. GRAETER, and R. FROEHLING *In* AGARD Mater. Substitution and Recycling 9 p (SEE N84-33465 23-23) Apr. 1984
Avail: NTIS HC A13/MF A01

Based on the minimization of critical raw materials input the production of as little scrap (machining wastes, parts out of service) as possible, concepts for reducing the use of materials and the associated dependence upon raw materials imports are explained. With reference to aeroengine components, the following possibilities are shown as examples: Very different materials can be combined by means of modern joining techniques. Components built up in this way contain expensive materials only where they are indispensable. The blank contour can be approximated to the final contour of the component (thus reducing machining losses) by contour forging, flow turning and powder metallurgy. Run parts can be reusable. It is shown that a considerable economy of materials is obtainable and has partly been achieved already. Attention is drawn to problems which may follow from the application; e.g., material deposition or joining of dissimilar materials results in a tendency to render the recycling of such engine components more difficult. R.J.F.

N84-33469# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (West Germany).
TOWARDS A CYCLE WITHOUT LOSS: COBALT IN THE AIRCRAFT INDUSTRY
C. VOIGT *In* AGARD Mater. Substitution and Recycling 7 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The flow cycle of cobalt in products used in the aircraft industry was investigated. The manufacturing processes, uses and ultimate destinations of the materials containing cobalt (superalloys, ultrahigh strength steels, tool steels and special alloys) were quantitatively analyzed. The ways in which cobalt is lost within the material cycle were determined. Cobalt recovery rates for process scrap and obsolete scrap are presented. It turns out that,

ultimately, the dilution of cobalt in iron is to a degree that it is improved scrap separation at all steps of the material cycle. The influence of no scrap technologies is discussed. R.J.F.

N84-33470# General Electric Co., Cincinnati, Ohio. Engineering Materials Technology Labs.
GAS TURBINE ENGINE DESIGN CONSIDERATIONS AS RELATED TO ALLOYS OF HIGH CRITICAL ELEMENT CONTENT
R. A. SPRAGUE *In* AGARD Mater. Substitution and Recycling 6 p (SEE N84-33465 23-23) Apr. 1984
Avail: NTIS HC A13/MF A01

The trade offs that a designer must make in the selection of materials for specific component applications are reviewed. Emphasis is placed on discussion of what options are available in reducing the strategic material content of the engine system while still achieving performance and cost objectives. The primary payoff is selection of wrought/cast alloys containing strategic elements is performance, not cost. For example, in commercial engines, the temperatures that parts are exposed to have increased steadily in an effort to improve specific fuel consumption. In military engines, higher operating temperatures are usually governed by efforts to improve thrust to weight ratio. R.J.F.

N84-33471*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
UNDERSTANDING THE ROLES OF THE STRATEGIC ELEMENT COBALT IN NICKEL BASE SUPERALLOYS
J. B. STEPHENS and R. L. DRESHFIELD *In* AGARD Mater. Substitution and Recycling 15 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

Research progress in understanding the effects of cobalt and some possible substitute on microstructure, mechanical properties, and environmental resistance of turbine alloys is discussed. The United States imports over 90 percent of its cobalt, chromium, tantalum and columbium, all key elements in high temperature nickel base superalloys for aircraft gas turbine disks and airfoils. NASA, through joint government/industry/university teams, undertook a long range research program aimed at reducing or eliminating these strategic elements by examining their basic roles in superalloys and identifying viable substitutes. R.J.F.

N84-33472# Wiggin Alloys Ltd., Hereford (England).
OXIDE DISPERSION STRENGTHENED ALLOYS
G. A. J. HACK *In* AGARD Mater. Substitution and Recycling 16 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The principle of oxide dispersion strengthening was applied to precious metals, nickel, ferritic steels, aluminum alloys and superalloys. Conventional melting processes are unsuitable for the production of ODS alloys and alternative methods are required to incorporate oxides, etc., various base compositions. One of these methods, mechanical alloying is particularly appropriate to large scale commercialization and readily accommodate reactive alloying elements. The commercial production, properties and applications of ODS superalloys are described. The strength contribution of the oxides gives the alloy designer more freedom to optimize for oxidation and sulphidation resistance to minimize the use of strategic metals; for example, the alloys described are all cobalt free. R.J.F.

N84-33473# Vanderbilt Univ., Nashville, Tenn. Dept. of Metallurgy and Management of Technology.
SUBSTITUTION AND CONSERVATION TECHNOLOGY FOR CHROMIUM
A. G. GRAY *In* AGARD Mater. Substitution and Recycling 11 p (SEE N84-33465 23-23) Apr. 1984
Avail: NTIS HC A13/MF A01

Information is given on application areas where substitution conservation appear feasible in a supply crisis based on present available technology. Likewise, applications where research is needed to expand the substitution potential are indicated. Opportunities for conservation and displacement with emerging technologies are discussed. Finally, the value of an organized effort on substitution preparedness to gather and develop information on chromium substitution and conservation technology and have it ready as a contingency plan are presented. Chromium is a highly strategic and critical metal because of its significant import dependence and its essential uses for defense, energy and industrial products. It is used in such diversified applications as stainless steels and tool steels; alloy steels to provide hardenability in heat treatment, in air frames, and in landing heat and corrosion resistant alloys; superalloys for jet engines; alloy cast iron; electroplating; and corrosion treatment for aluminum alloys. R.J.F.

N84-33474# National Physical Lab., Teddington (England).
POTENTIAL OF METAL-MATRIX COMPOSITES AS SUPERALLOY SUBSTITUTES
M. MCLEAN and T. KHAN (ONERA) *In* AGARD Mater. Substitution and Recycling 10 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

A review of metal-matrix composites for high temperature applications was made in order to identify materials that are insensitive to the supply of critical elements. The potential of metal-matrix composites as gas-turbine blade materials was largely judged on the increased temperature capabilities they offer over the strongest current superalloys. However, several composites that were rejected on this basis are either independent of or have low concentrations of critical alloying elements. Consequently they should be reassessed as reserve materials matching the performance of existing widely used superalloys that depend on strategically vulnerable constituents. An alternative approach might be to consider the potential of regenerating the original creep performance of certain monocarbide reinforced nickel based composites such as Cotac 744 developed at ONERA - after service exposure. In this context the combination of perfectly elastic fibers in a creeping matrix would imply that high temperature deformation of these materials is almost completely recoverable. Hence, one should judge the potential of these materials in the light of total life expectancy through both the processing and regeneration conditions rather than from their simple creep behavior alone. R.J.F.

N84-33475# Pratt and Whitney Aircraft Group, West Palm Beach, Fla. Government Products Div.
MANUFACTURING DEVELOPMENTS TO REDUCE STRATEGIC MATERIALS USAGE
M. M. ALLEN, D. S. HALFPAP, and M. A. SIEGEL *In* AGARD Mater. Substitution and Recycling 8 p (SEE N84-33465 23-23) Apr. 1984
Avail: NTIS HC A13/MF A01

Manufacturing development programs to reduce the usage in gas turbine engines are examined. Several programs which provided significant of cobalt, titanium, and tantalum results in reducing raw materials requirements, that have been reduced to practice are described. The programs include forging and casting complex parts to near net shape, recycling of machining scrap and used parts, repair and refurbishment of damaged or worn parts, and component retirement for cause. In addition to reduction of strategic material usage, the programs resulted in lower cost parts due to reduced material input requirements and less machining. E.A.K.

N84-33476# GEC Turbine Generators Ltd., Whetstone (England). Central Metallurgical Labs.
PRACTICAL IMPLICATIONS OF THE USE OF ALUMINIDE COATINGS FOR THE CORROSION PROTECTION OF SUPERALLOYS IN GAS TURBINES
A. STRANG, E. LANG (Commission of the European Communities), and R. PICHOIR (ONERA) *In* AGARD Mater. Substitution and Recycling 35 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The difficulties incurred in the pack aluminizing of superalloys, especially in prolonging component life without emphasis on performance, integrity and safety of the engine are considered. The objectives and requirements of using aluminide coatings, the processes currently commercially available, the compatability of aluminide coatings with various superalloys substrates and quality control of both the coating and the coated component are reviewed. The properties of coatings themselves are considered for corrosion resistance, overall thermal and structural stability, and effect on the mechanical properties of the substrate. Long term corrosion protection is examined for the practicalities of reclaiming and

recoating of exservice turbine parts to extend component life and conservation of critical materials. E.A.K.

N84-33477# Atomic Energy Research Establishment, Harwell (England). Materials Development Div.
COATINGS FOR FUEL ECONOMY OR MATERIALS SUBSTITUTION
J. P. COAD and K. T. SCOTT *In* AGARD Mater. Substitution and Recycling 11 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The application of three coatin techniques in fuel economy or materials substitution is described. The coating techniques are plasma spraying, sputter ion plating (SIP) and plasma assited vapor deposition (PAVD), ad the applications range from thin coatings for nuclear and aerospace use to free standing furnace elements. E.A.K.

N84-33478# Naval Material Command, Washington, D. C.
THE NAVY PROGRAM TO DEVELOP REPLACEMENTS FOR CRITICAL AND STRATEGIC MATERIALS
J. J. KELLY and M. A. KINNA (Naval Sea Systems Command) *In* AGARD Mater Substitution and Recycling 10 p (SEE N84-33465 23-23) Apr. 1984
Avail: NTIS HC A13/MF A01

The development of design options for critical and strategic materials (CSM) in future weapon and platform systems is discussed. Key objectives of the program are: development of a data base, fabrication of materials and components, demonstration of hardware, and establishment of manufacturing processes to provide reproducible materials and components. Four materials thrusts are addressed, they are: utilization of domestically abundant materials, development of domestic high temperature materials, evaluation of new materials and alloys, and conservation of critical materials E.A.K.

N84-33479# Army Materials and Mechanics Research Center, Watertown, Mass.
CERAMICS AS SUBSTITUTES FOR SCARCE METALS
R. N. KATZ *In* AGARD Mater. Substitution and Recycling 8 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

Opportunities for the use of ceramics as substitutes in several example applications, were explored. Lack of domestic availability of critical industrial metals, such as chromium and cobalt make the U.S. economy vulnerable to supply disruption. These critical metals are primarily used as high temperature, corrosion resistant or metal cutting alloys. Modern high performance ceramics are attractive substitutes for critical metals in many of these applications. E.A.K.

N84-33480# Bureau of Mines, Washington, D. C. Div. of Materials and Recycling.
NEW DEVELOPMENTS IN MATERIALS RECYCLING BY THE US BUREAU OF MINES
R. C. HORTON and C. B. KENAHAN *In* AGARD Mater. Substitution and Recycling 24 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The mineral based waste products generated by industry and the consuming public as potential secondary mineral resources to be used for recycling materials are considered. Technical solutions are presented to complex recycling problems, such as: recovery of cobalt, nickel, and chromium from superalloy scrap; the separation, recovery, and reuse of nickel and chromium from stainless and specialty steel wastes; precious metal recovery from electronic scrap; an environmentally acceptable method for recycling lead acid batteries; recovery of nonferrous metals from scrap automobiles; and rapid scrap identification methods suitable for today's modern alloys. E.A.K.

N84-33481# Imphy S.A. (France). Etudes et Recherches.
VACUUM RECYCLING EFFECT ON MINOR ELEMENTS IN SUPERALLOYS [EFFET DES TRAITEMENTS SOUS VIDE SUR L'EVOLUTION ES TENEURS EN ELEMENTS TRACES DANS LES SUPERALLIAGES]
J. F. WADIER and J. MORLET *In* AGARD Mater. Substitution and Recycling 12 p (SEE N84-33465 23-23) Apr. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A13/MF A01

Superalloy recycling is an economical and strategical necessity. Scrap recovery is examined from a thermodynamical and technological point of view with emphasis on air melting with oxygen blowing to remove titanium and aluminum before vacuum treatment; and non reactive melting of conditioned scraps in vacuum induction melting. The vacuum effect on the carbon/oxygen reaction, desulfurization and nitrogen removal, and heavy metal distillation is examined. Further reactions during remelting in VAR or ESR are taking account to assure the quality of the final product. Author

N84-33482# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris (France).
PROBLEMS PRESENTED TO ENGINE BUILDERS BY THE RECYCLING OF METALLIC MATERIALS [PROBLEMES POSES AUX MOTORISTES PAR LE RECYCLAGE DES MATERIAUX METALLIQUES]
Y. HONNORAT and J. NOUAILLES *In* AGARD Mater. Substitution and Recycling 7 p (SEE N84-33465 23-23) Apr. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

Fabrication of the principal parts of aircraft engines implies assurance of a safe life that is not always completely verifiable by nondestructive quality control. Besides, the products of fabrication are often very weak and the cost of parts is greatly influenced by the economy of the material. The engine builder must then recycle scrap which is even more profitable since the recycling circuit is much shorter. Recycling is apt to generate problems of quality for which precautions should be taken. Examples from using forged titanium alloys and heat resistant nickel base alloys in the lost process illustrate the mechanisms by which recycling of scrap influences the quality of parts. The respective roles of different partners, the alloyist, the coarse part fabricator, the engine builder, and the recyclist are delineated. This means that acceptance control techniques offer the engine builder to master the problem are explained. Transl. by A.R.H.

N84-33483# Pratt and Whitney Aircraft Group, West Palm Beach, Fla. Government Products Div.
COATING DEVELOPMENTS TO RESTRICT STRATEGIC MATERIALS USAGE
R. J. HECHT and D. S. HALFPAP *In* AGARD Mater. Substitution and Recycling 7 p (SEE N84-33465 23-23) Apr. 1984
Avail: NTIS HC A13/MF A01

The development of protective coatings that enabled the implementation of less environmentally stable alloys with no loss, and sometimes an increase, in component capability and life is described. Development of tailored MCrAly overlay coatings, improved diffusion aluminides, thermal barriers, and alternate wear resistant coatings allows the coating corrosion and oxidation life to be more independent of the base superalloy composition and hence allow more latitude in alloy selection. The resulting coating developments and their effects on reducing strategic element use are presented. E.A.K.

N84-33484# National Physical Lab., Teddington (England). Div. of Materials Applications
TRACE ELEMENTS IN SUPERALLOYS AND THE IMPLICATIONS FOR RECYCLING
P. N. QUESTED, T. B. GIBBONS, and G. L. R. DURBER (Glossop Superalloys Ltd.) *In* AGARD Mater. Substitution and Recycling 17 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The general problem of control and specification of impurity elements with emphasis on the situation related to recycled alloys and the influence of certain impurities on microstructure and properties are considered. It is shown that there is scope for the improvement of specifications for impurity elements and that a better understanding of the relationship between casting conditions

and microstructure is required for conventionally cast alloys.
E.A.K.

N84-33485# Ecole des Mines, Paris (France). Centre des Materiaux.
THE EFFECT OF RECYCLING ON CAST STRUCTURES AND THE INTERNAL CHARACTER OF IN100 ALLOY: A LABORATORY STUDY [EFFET DU RECYCLAGE SUR LES STRUCTURES DE FONDERIE ET LA SANTE INTERNE DE L'ALLIAGE IN 100: ETUDE DE LABORATOIRE]
S. RUPP, J. MASSOL, Y. BIENVENUU, and G. LESOULT (Ecole des Mines, Nancy) *In* AGARD Mater. Substitution and Recycling 14 p (SEE N84-33465 23-23) Apr. 1984 refs In FRENCH
Avail: NTIS HC A13/MF A01

Some lots of virgin and recycled IN 100 alloys were selected by two European superalloy founderies (united European research). A laboratory study attempted to interpret in terms of solidification, the more marked tendency to microporosity observed by smelters in the recycled lots. Differential thermal analysis does not show the characteristic variations in the temperature of solidification except for those imputable to the slight variation in composition. Wetting during directional solidification permits measurement of the magnitude of morphology which governs the circulation of liquid in the viscous zone which comes to compensate for contraction during solidification. Differences in the precipitation kinetics in solid phases are observed between virgin and recycled alloys. Preliminary results of a study on Mar-M-002 alloy are also presented. Transl. by A.R.H.

N84-33486# Centre de Recherches Metallurgiques, Liege (Belgium). Div. Formetal.
USING RECYCLED SUPERALLOYS IN PRECISION CASTING [MISE EN OEUVRE DE SUPERALLIAGES DE REEMPLOI EN FONDERIE DE PRECISION]
M. LAMBERGTS and J. M. DRAPIER *In* AGARD Mater. Substitution and Recycling 12 p (SEE N84-33465 23-23) Apr. 1984 refs *In* FRENCH
Avail: NTIS HC A13/MF A01

The recycling of cast scrap is not uniquely justified by fear of difficulties in supplying primary metals or by care to preserve the relationship limited natural supplies of certain of these materials: it is imperative that the smelter minimize costs. Recyling can, however, lead to a deterioration of the metallurgical properties of precision cast superalloys and to a certain chemical contamination that can affect the service life of cast parts. Recycling can be introduced only after careful control of all the consequences. The influence of recycling on composition (trace elements), solidification behavior, microstructure, and mechanical properties was investigated in various nickel alloys such as IN 100, IN 728, and Mar-M-002. Cobalt alloys such as X45 and W152 were also studied. Particular emphasis is given to inclusion content and to the tendency to microporosity. The technical occurrence and economics of an eventual hot isostatic compression cycle is evaluated. Transl. by A.R.H.

N84-33487# National Aeronautical Establishment, Ottawa (Ontario). Structures and Materials Lab.
TRACE ELEMENTS AND RESIDUAL ELEMENTS IN SUPERALLOYS
R. T. HOLT *In* AGARD Mater. Substitution and Recycling 14 p (SEE N84-33465 23-23) Apr 1984 refs
Avail: NTIS HC A13/MF A01

Impurities and trace elements in nickel base superalloys were studied Improvements in refinement technology are discussed, including evaluation of refactory materials to ensure minimal accumulation of inclusions. The section on detrimental elements covers: (1) residual gases and porosity; (2) nonmetallic inclusions; and (3) residual elements sulfur, phosphorus and other tramp elements which segregate to grain boundaries. This segregation leads to intergranular fracture and the elements were studied by auger electron spectroscopy (AES). Beneficial elements, which are added in small amounts to counteract the effect of the tramp elements are described. Some of those beneficial elements in small residual amounts may also help with grain size control. The processing of scrap with emphasis on minimizing the inclusion and trace element content of the alloys. E.A.K.

N84-33488# Paderborn Univ. (West Germany).
RECYCLING CONFORM DESIGN
W. JORDEN *In* AGARD Mater. Substitution and Recycling 5 p (SEE N84-33465 23-23) Apr. 1984 refs
Avail: NTIS HC A13/MF A01

The flow of materials in a real recycling system was demonstrated by a recycling model system. The analysis of this system results in additional new goals and guide lines for design. The guide lines are interpreted by examples which show how a product can be designed in a recycling conform manner. Each product should be prepared in an optimal way for the eventual reuse of the whole product and, after the end of product life, for regaining the residue materials. E.A.K.

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COMPOSITE MATERIALS

Includes laminates.

N84-10203# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
CHARACTERIZATION, ANALYSIS AND SIGNIFICANCE OF DEFECTS IN COMPOSITE MATERIALS
Loughton, England Jul. 1983 309 p refs In ENGLISH and FRENCH Conf. held in London, 12-14 Apr. 1983
(AGARD-CP-355; ISBN-92-835-0333-3; AD-A134058) Avail: NTIS HC A14/MF A01

The effects of damage and manufacturing defects on the structural properties of composite materials are addressed. The general characterization of these defects, their analysis by nondestructive evaluation, and fatigue and static testing are also discussed. For individual titles, see N84-10204 through N84-10224.

N84-10204# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
FRACTOGRAPHIC ANALYSIS OF FAILURES IN CFRP
D. PURSLOW *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 11 p (SEE N84-10203 01-24) Jul. 1983
Avail: NTIS HC A14/MF A01

Work on unidirectional carbon fiber reinforced plastics (CFRP) test coupons in which a known mode of failure had been produced, the modes being longitudinal and transverse tension, compression and shear is discussed. From a fundamental understanding of the character of the different modes and of the mechanisms of fracture propagation it is shown how the qualitative significance of micro-defects occurring in good quality laminates may be assessed. The defects considered are fiber faults, fiber matrix bond strength, fiber distribution, fiber alignment and voids and inclusions; these are illustrated and their individual and collective significance discussed. M.G

N84-10205# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
NDE TECHNIQUES FOR COMPOSITE LAMINATES
G. P. SENDECKYJ *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 22 p (SEE N84-10203 01-24) Jul. 1983 refs
Avail: NTIS HC A14/MF A01

Destructive and nondestructive evaluation (NDE) techniques for documenting defects and damage in resin-matrix composite materials are described and assessed from the viewpoint of a researcher studying the damage accumulation process. The results show that deplying, a destructive evaluation technique, provides the most detailed information on the spatial distribution of damage in resin-matrix composite materials. Of the NDE techniques, penetrant enhanced stereo X-ray radiography is the best one Ultrasonic, holographic, and edge replication NDE techniques provide much less information than X-ray radiography. Acoustic emission, thermographic and stiffness change monitoring provide valuable information on when to conduct more thorough evaluations using one of the other NE techniques M.G

N84-10206# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Strukturmechanik.

MONITORING OF DEFECT PROGRESSION BY ACOUSTIC EMISSION

J. BLOCK *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 11 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

Acoustic emission (AE) is a suited technique for the characterization of damage in composite materials, as also in metallic structures. A lot of tests with different carbon fiber reinforced plastics (CFRP) specimens make sure that there are correlations between certain AE parameters, respectively their variation, and characteristics of defects, which are typical for composites. The damage history of the test specimens can be analyzed with a very good chronological resolution. This includes an exact correlation between acoustic and mechanical parameters, such as load, cycle number etc. The present results demonstrate a potential for distinguishing between some dominant failure mechanisms, as fiber failure and matrix cracking, and noise generated by internal friction. Locating existing defects and tracking spatial damage progression is another field of application. All AE data are being monitored continuously in situ during loading of the specimen. Post-test-analysis of the stored data with suited computer programs enables a more sophisticated evaluation.

M.G.

N84-10207# Societe Europeene de Propulsion, Saint-Medard-en-Jalles (France). Div. Propulsion a Poudre et Composites.

DISSECTING COMPOSITE PARTS: A VALUABLE AID IN CONCEPT DESIGN AND NONDESTRUCTIVE CONTROL [LA DISSECTION DES COMPOSITE: UNE AIDE PRECIEUSE A LA CONCEPTION ET AU CONTROLE NON DESTRUCTIF]

M. BOURGEON *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 2 p (SEE N84-10203 01-24) Jul. 1983 In FRENCH

Avail: NTIS HC A14/MF A01

Specific examples are given to demonstrate the importance that must be given to dissecting parts made of composite materials. Such dissection is helpful in concept definition by bringing complementary information by calculations of fiber orientation and quality of functional liaisons etc., and in nondestructive control by real signification of flaws evidenced by different techniques and the effect this can have on the choice of methods.

Transl. by A.R.H.

N84-10208# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Strukturmechanik.

GROWTH OF DELAMINATIONS UNDER FATIGUE LOADING

R. PRINZ *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 27 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

In order to determine the nature of failure mechanisms a number of fatigue tests were performed. The test specimens partly have artificial delaminations between different layers of the multidirectional laminates made from T300/914C prepregs. For better understanding of the strength degradation in fatigue a damage model, based on the delamination propagation, starting from the free edges between the plies of a multidirectional laminate, was developed. These defects propagate due to interlaminar stresses up to an area, which is critical in the case of tension-compression fatigue against buckling or shearing of parts of the delaminated test specimen. Author

N84-10209# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Aircraft Div.

EXPERIMENTAL INVESTIGATION OF DELAMINATIONS IN CARBON FIBRE COMPOSITE

W. GEIER, J. VILSMEIER, and D. WEISGERBER *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 11 p (SEE N84-10203 01-24) Jul. 1983

Avail: NTIS HC A14/MF A01

Results concerning the effect of delaminations on static and fatigue strength of carbon fiber composites are presented. The delaminations were introduced artificially into solid laminates and sandwich structures by means of folded teflon patches. The effects of delaminations caused by low energy impact were also investigated. The tests were carried out both at room temperature and at 120 C in the as received as well as in the wet condition. For the sandwich structure design no loss in fracture strength could be found even in the case of fatigue and built-in delaminations. The same results are valid for the shear angle specimens. No significant loss in compression strength caused by 6 x 6 mm delaminations was found, although 12 x 12 and 12 x 25 mm delaminations showed a considerable reduction in strength. The effect of delaminations caused by low energy impact was found to be no greater than that of a 6 mm open hole. M.G.

N84-10210# Army Materials and Mechanics Research Center, Watertown, Mass.

CHARACTERIZATION OF CUMULATIVE DAMAGE IN COMPOSITES DURING SERVICE

M. E. ROYLANCE, W. W. HOUGHTON, G. E. FOLEY, R. J. SHUFORD, and G. R. THOMAS *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 14 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

The nature of cumulative damage occurring in glass epoxy composite test coupons and sub-structures during fatigue loading was investigated and the extent of this damage was correlated with remaining useful lifetime. Changes of stiffness in composite laminate specimens loaded in tension-tension fatigue at various load levels were shown to reflect the extent of accumulated damage and the magnitude of the stiffness change was used to predict the remaining life fraction of the specimens. Dynamic structural analysis techniques can be used to follow these stiffness changes in substructures, and should be useful as a field technique for following stiffness losses in composite structures. The nature of the damage which occurs during fatigue loading was characterized by a number of nondestructive evaluation techniques including ultrasonics and infrared thermography. M.G.

N84-10211# Westland Helicopters Ltd., Yeovil (England). Materials Lab.

AN EMPIRICAL APPRAISAL OF DEFECTS IN COMPOSITES

N. PARSLOW *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 18 p (SEE N84-10203 01-24) Jul. 1983

Avail: NTIS HC A14/MF A01

The development of a helicopter tail rotor blade from fiber reinforced materials is discussed. Rotor blades were manufactured from pre-preg material in the form of uni-directional glass fiber, uni-directional carbon fiber, and woven glass fabric (two weave styles) all impregnated with epoxy resin. An expanding mandrel technique was used to manufacture the tail rotor blade. All the development blades were subjected to a non-destructive evaluation to develop a technique capable of assessing the size and location of defects in the component, while maintaining a degree of convenience to ensure rapid inspection of the component. During the development of the tail rotor blade, various defects and discontinuities were produced. These are categorized and discussed in reference to their effect on blade performance.

M.G.

N84-10212# Aeritalia S.p.A., Torino (Italy). Materials Technology Research.

CORRECTION BETWEEN NONDESTRUCTIVE INSPECTION RESULTS AND PERFORMANCE OF GRAPHITE/EPOXY STRUCTURAL PARTS

F. CIPRI *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 7 p (SEE N84-10203 01-24) Jul. 1983

Avail: NTIS HC A14/MF A01

During production of advanced composite structural parts, because of material or manufacturing process anomalies, some typical defects, such as porosity and/or delaminations, may become embodied into the final product. In order to improve the accept/reject criteria for typical defects, a static/fatigue test program was on specimens in which various porosity levels were simulated. Further, an attempt was made to correlate mechanical performances with the ultrasonic energy absorption measures.

M.G.

N84-10213# Royal Aircraft Establishment, Farnborough (England). Materials Structures Dept.

THE EFFECT OF DAMAGE ON THE TENSILE AND COMPRESSIVE PERFORMANCE OF CARBON FIBRE LAMINATES

S. M. BISHOP and G. DOREY *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 10 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

The type of defect or flaw produced when carbon fiber reinforced plastics (CFRP) is damaged in service depends on the structural design and the conditions of damage such as the energy and momentum of an impact. These defects are stress raisers which may reduce the strength of the structure. There is a need, following non-destructive inspection, to be able to predict the residual performance so that decisions can be made on whether to monitor, repair or replace the component. Various types of damage produced by typical impact situations were assessed non-destructively and the effect on strength determined in tension and compression under both static and fatigue loading. For example areas of delamination, shown by sectioning to be multiple delamination between the plies, reduce the compressive strength by local buckling processes. Detailed examination of the fracture mechanisms at machined notches emphasizes the importance of effects in neighboring plies influencing the stress concentrations in the load carrying 0 deg fibers. M.G.

N84-10214# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (West Germany). Inst fuer Bauweisen- und Konstruktionsforschung.

BEHAVIOR OF IDEALIZED DISCONTINUITIES AND IMPACT DAMAGES IN CFRP UNDER FATIGUE LOADING

R. M. AOKI *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 10 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

Results of an ongoing experimental program concerning the behavior of impact damaged carbon fiber reinforced plastic (CFRP) specimens are presented. The purpose is to determine the characteristics resulting from localized low-energy impact damage and also the behavior of the damaged specimens under harmonic fatigue loading. Damage simulating a dropped medium weight (300 g) tool was introduced by drop weights with various geometry impactors. Also circular defects were built into specimens as idealized discontinuities. The damage propagation under static and fatigue loading (R = 0.1, R = -1) was monitored using US-C-scan, temperature measurements and acoustic emission. The basic parameters included the influence of stacking sequence and impactor tip radius, as well as the degree of local discontinuity in the outer layers of the specimens. The straight sided specimens with quasi-isotropic lay-up are manufactured from T300/Code 69. The feasibility of simulating impact damages with this form of built-in idealized discontinuities is shown. M.G.

N84-10215# Societe Nationale Industrielle Aerospatiale, Suresnes (France).

THE INFLUENCE OF FABRICATION FLOWS ON THE STATIC AND DYNAMIC BEHAVIOR OF STRUCTURES MADE OF CARBON-RESIN COMPOSITES [INFLUENCE DE DEFAUTS DE FABRICATION SUR LE COMPORTEMENT STATIQUE ET DYNAMIQUE DES STRUCTURES EN COMPOSITE CARBON-RESINE]

J. CUNY and G. BRIENS *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 9 p (SEE N84-10203 01-24) Jul. 1983 In FRENCH

Avail: NTIS HC A14/MF A01

The types of flaws appearing in the fabrication of carbon-resin composites are examined as well as methods adopted for their detection. The influence of defects affecting only the resin or the fiber-resin interface are studied. Emphasis is on high resistance carbon fibers impregnated with epoxy resins. Transl by A.R.H.

N84-10216# Costruzioni Aeronautiche Giovanni Agusta S.p.A., Gallarate (Italy). Technological Development Dept.

ADVANCED ND TECHNIQUES FOR COMPOSITE PRIMARY STRUCTURES

M. FARIOLI, F. PORRO, G. SAMANNI, and V. WAGNER *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 18 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

One of the weakest points in composites and adhesives technology is that there is no one N.D. method useful and valid for all kinds of defects. A variety of N.D. methods is needed in order to achieve good results in the inspectability of configurations. Some of the most popular techniques for maximum sensitivity determination of standard defects using proof specimen are reviewed. These include X-ray radiography and in-line radioscopy electronically supported; X-ray xeroradiography; neutron radiography; and U.S. investigation methods. The application of these techniques and results obtained on the main rotor spar and blade main rotor blade grip are discussed. A.R.H.

N84-10217# Toronto Univ. (Ontario). Inst. for Aerospace Studies.

COMPUTATION OF INFLUENCE OF DEFECTS ON STATIC AND FATIGUE STRENGTH OF COMPOSITES

R. C. TENNYSON, J. S. HANSEN, G. R. HEPPLER, G. MABSON (Engineering Research Associates, Toronto, Ontario), G. WHARRAM (Engineering Research Associates, Toronto, Ontario), and K. N. STREET (Defence Research Establishment Pacific, Victoria, B.C.) *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 17 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

A combined analytical and experimental investigation has been undertaken to determine the effects of flaws on the static strength and fatigue life of graphite/epoxy (AS1/3501-6) laminates. Both bond-line defects in sandwich beam construction and interlaminar disbond flaws were studied. Up to present, compressive strength test data were obtained from ambient and elevated temperature, moisture-saturated conditions, including results from thermal-spike cycling simulating supersonic flight. In addition, baseline data were obtained to define the strength parameters associated with the tensor polynomial lamina failure criterion. Although this model was originally derived for static 'unflawed' strength predictions, it is being extended to include the effect of holes and flaws. In the latter case, a finite element approach is described to illustrate the methodology for computing the influence of flaws. A formulation for predicting the fatigue life of laminates is presented based on the experimental evaluation of fatigue functions which are utilized in a form of the tensor polynomial failure criterion. Author

N84-10218# Drexel Univ., Philadelphia, Pa. Dept. of Mechanical Engineering.

FRACTURE MECHANICS OF SUBLAMINATE CRACKS IN COMPOSITE LAMINATES

A. S. D. WANG *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 19 p (SEE N84-10203 01-24) Jul. 1983 refs

Avail: NTIS HC A14/MF A01

An overview is presented of a fracture mechanics approach to some of the most frequently encountered matrix dominated, sub laminate cracks in epoxy based composite laminates. By "sub-laminate", it is meant that the cracks are internal to the laminate, generally invisible macroscopically; but are much larger in size than those microcracks considered in the realm of micromechanics. The origin of sub-laminate cracks is assumed to stem from the coalescence of natural material flaws (also microcracks) which occur under a certain favorable laminate stress condition. Thus, the modelling of the mechanisms of sub-laminate crack initiation and propagation is essentially mechanistic and probabilistic in nature. Some specific results from several analytical/experimental investigations using graphite-epoxy laminates are presented and discussed. Author

N84-10219# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
THE SIGNIFICANCE OF DEFECTS AND DAMAGE IN COMPOSITE STRUCTURES
R. T. POTTER *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 10 p (SEE N84-10203 01-24) Jul. 1983 refs
Avail: NTIS HC A14/MF A01

The significance of defects and damage in fiber composite structures depends upon a wide range of decisions taken at every stage of the life of each particular structure, from the initial design conception, through detailed design and manufacture, to inspection, maintenance and repair procedures. Since many of these decisions interact, there is a need for a coherent overall philosophy for the management of defects and damage if fiber composite structures are to be efficient and cost effective. The general requirements of such a philosophy are considered and it is seen that further research is required particularly on the interaction of defects and damage with structural features. Some initial results and observations from the RAE program devised to study such interactions are presented. Author

N84-10220# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
IN-SERVICE NDI OF COMPOSITE STRUCTURES: AN ASSESSMENT OF CURRENT REQUIREMENTS AND CAPABILITIES
D. E. W. STONE and B. CLARKE *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 14 p (SEE N84-10203 01-24) Jul. 1983 refs
Avail: NTIS HC A14/MF A01

Practical design criteria and the structural significance of defects and damage in carbon fiber composite components are reviewed. The principal sources of in-service damage and the possibility of the interaction of damage mechanisms are considered. The concept of providing a map of damage acceptability for a given structure is then discussed. The probable current requirements for in-service NDI are assessed. The capabilities and limitations of currently available NDI techniques are reviewed, and some recent developments are described. Author

N84-10221# McDonnell Aircraft Co., St. Louis, Mo.
EFFECT OF DEFECTS ON AIRCRAFT COMPOSITE STRUCTURES
R. A. GARRETT *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 34 p (SEE N84-10203 01-24) Jul. 1983 refs
Avail: NTIS HC A14/MF A01

Seven manufacturing defects associated with mechanical fasteners for aircraft composite structures were investigated; out-of-round holes; broken fibers on the exit side of drilled holes; porosity; improper fastener seating depth; tilted countersinks; interference fit; and multiple fastener installation and removal cycles. Both static and fatigue test results are described, along with correlation with analysis techniques. The interaction of the effects of these defects on hole wear, measured in fatigue tests of structural joints, is considered. The effects of two types of service-induced damage are also described; low energy impact damage and 23mm HEI ballistic damage. The relative sizes of visible and non-visible damage as determined by visual and non-destructive inspection techniques are compared. Stitching and the inclusion of glass or Kevlar fiber buffer strips to improve the damage tolerance of carbon/epoxy structures are evaluated. Results of tests of carbon/epoxy panel structures are discussed. Correlation of experimental results with predicted residual static strength is good. Author

N84-10222# General Dynamics Corp., Fort Worth, Tex.
THE ENGINEERING SIGNIFICANCE OF DEFECTS IN COMPOSITE STRUCTURES
D. J. WILKINS *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 11 p (SEE N84-10203 01-24) Jul. 1983 refs
Avail: NTIS HC A14/MF A01

The significance of defects in composite aircraft structures is described from a broad, practical viewpoint. Three generic defect types (cut fibers, matrix cracks, and delaminations) and simple load components that can be generalized to the most complex loading cases are considered. Methods for evaluating manufacturing and in-service damage in terms of the resulting local damage are reviewed and the possible benefits of more damage tolerant forms of composite materials are explored. Author

N84-10223# British Aerospace Public Ltd. Co., Preston (England). Aircraft Group.
DEFECT OCCURRENCES IN THE MANUFACTURE OF LARGE CFC STRUCTURES AND WORK ASSOCIATED WITH DEFECTS, DAMAGE AND REPAIR OF CFC COMPONENTS
C. S. FRAME and G. JACKSON *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 17 p (SEE N84-10203 01-24) Jul. 1983
Avail: NTIS HC A14/MF A01

Current activities in a research investigation into the effects of defects and damage, and their repair, are reviewed. Future work in this field is also discussed. The occurrences of defects and damage in large CFC structures (eg. Tornado tailleron, Jaguar wing etc) are presented and experience gained from flight and ground testing is reported. The NDT detection and characterization methods are given together with an outline of the work proposed to overcome existing problem areas and limitations. Author

N84-10224# Rockwell International Corp., Los Angeles, Calif.
DELAMINATION GROWTH IN COMPOSITE STRUCTURES UNDER INPLANE COMPRESSION LOADING
D. Y. KONISHI *In* AGARD Characterization, Anal. and Significance of Defects in Composite Mater. 10 p (SEE N84-10203 01-24) Jul. 1983 refs
Avail: NTIS HC A14/MF A01

An approximate solution to the stress field causing delamination under biaxial loading, where the principal load is compressive, was developed. It utilizes a Raleigh-Ritz approach for the finite amplitude deflection analysis of a rectangular or elliptical plate which has bending/membrane coupling terms and clamped boundary conditions. The solution determines the complete stress field on the boundary, including the short transverse stress field. This leads to delamination growth trajectories which can be analyzed to determine constant gradient da/dt growth configurations. These results can be analyzed to establish design criteria to be used to minimize the impact of delamination growth considerations by stacking sequence selection, etc., as well as to maximize the residual strength capabilities of the structure. Author

N84-31300# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
COMPOSITE STRUCTURE REPAIR
L. G. KELLY (AFWAL) Feb. 1984 24 p refs Presented at the 57th Meeting of the Structures and Materials Panel, Vimeiro, Portugal, 9-14 Oct. 1983
(AD-A141456; AGARD-R-716; ISBN-92-835-1466-1) Avail: NTIS HC A02/MF A01 CSCL 11D

The technology for advanced composite structure repair is presently in a developing stage. The boundaries and limitations of bolted versus bonded repairs and precured patches versus cocured in place patches and their applicability to various types of hardware has yet to be clearly established. This paper does not discuss step by step repair procedures for specific aircraft components, such as defined in repair technical orders, but rather provides general guidelines for repair concepts and discusses two repair configurations that are generic in nature; an external patch and a near flush repair and the extent to which they have been verified in the U.S. These repairs are applicable to a wide variety of light to moderately bonded (up to 25,000 lb/inch) stiffened and honeycomb sandwich structure sustaining damage over a reasonably large area (up to 100 sq. in.) Also provided are references to documents containing step by step procedures for these repair techniques and identification of organizations in the U.S. actively engaged in advanced composite structure repair. GRA

N85-17057# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
COMPOSITE STRUCTURE REPAIR, ADDENDUM
Loughton, England Aug. 1984 26 p refs Presented at the 58th Meeting of the Struct. and Mater. Panel, Sienna, Italy, 2-6 Apr. 1984 Addendum to AGARD-R-716; N84-31300
(AGARD-R-716-ADD; ISBN-92-835-1476-9; AD-A148800) Avail: NTIS HC A03/MF A01

Programs are presented in which bonded and bolted composite repair techniques were validated. The repair of specific military and commercial aircraft components is addressed. Composite repair of flat laminates, integral stiffened panels, and honeycomb sandwich structures on aircraft is discussed. For individual titles see N85-17058 through N85-17059.

N85-17058# Naval Air Development Center, Warminster, Pa.
REPAIR OF COMPOSITES
T. M. DONNELLAN, E. L. ROSENZWEIG, R. E. TRABOCCO, and J. G. WILLIAMS (Aeronautical Research Labs., Melbourne) *In* AGARD Composite Struct. Repair, Addendum 10 p (SEE N85-17057 08-24) Aug. 1984 refs
Avail: NTIS HC A03/MF A01

Developments in composite repair technology are discussed. The planned use of composites in primary aircraft structure has necessitated the development of a specialized repair technology. The types of damage seen in composites differs from conventional materials. Delamination is the most serious composite defect since it can exist without causing surface damage. The two techniques used to repair composites are bonded and bolted approaches. A number of programs have been performed which have evaluated repair techniques under simulated operating conditions. Programs are discussed in which bonded and bolted repair techniques were validated. Generic repair development programs are described in which the repairs were performed with equipment and techniques possible in the service environment. The results of these studies show that the repairs restored the component structural integrity. Repair programs on specific military and commercial aircraft are also described. The components studied included an AHI rotor blade, a S-3A *spoiler* and a L-1011 fin. R.S.F.

N85-17059# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
COMPOSITE REPAIR OF AIRCRAFT STRUCTURES
J. W. VILSMEIER *In* AGARD Composite Struct. Repair, Addendum 9 p (SEE N85-17057 08-24) Aug. 1984
Avail: NTIS HC A03/MF A01

The repair of composite and metallic aircraft structures with composite materials has become a matter of world wide interest and activity. Activities in the field of composite repair of flat laminates, honeycomb sandwich structures, and integral stiffened panels are presented. Composite repair problems, aircraft battle damage repair, bonding on wet laminates, environmental effects, and problems associated with nondestructive testing of repaired structures and repair of joints are discussed. R.S.F.

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INORGANIC AND PHYSICAL CHEMISTRY

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

N84-24732# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
COMBUSTION PROBLEMS IN TURBINE ENGINES
Loughton, England Jan. 1984 434 p refs In ENGLISH and FRENCH Symp. held in Cesme, Turkey, 3-6 Oct. 1983
(AGARD-CP-353; ISBN-92-835-0346-5; AD-A140700) Avail: NTIS HC A19/MF A01

With ever increasing emphasis on improving gas turbine cycle efficiency, reducing engine development time/cost, reducing cost of ownership, minimizing pollutant emissions, and more recently the need to develop fuel tolerant combustion systems, the combustion problems in gas turbine engines require special considerations. Alternative fuels, fuel preparation, kinetics, soot, liner cooling, and combustion modeling are among the topics discussed. For individual titles see N84-24733 thru N84-24768

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METALLIC MATERIALS

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

N85-33238# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
MANAGEMENT OF CORROSION
Loughton, England May 1985 168 p refs Lectures held in Ankara, 17-18 Jun. 1985, in London, 20-21 Jun 1985, and in Ottawa, 2-3 Jul. 1985
(AGARD-LS-141; ISBN-92-835-1500-5; AD-A158935) Avail: NTIS HC A08/MF A01

Papers submitted for AGARD Lecture Series No 141 (Management of Corrosion), concerning the management of corrosion in the aerospace field, are presented. Among the subjects covered are the superiority of corrosion resistance of low alloy steel containing 0.5 wt% copper over plain carbon steel, some theoretical aspects of corrosion and practical implications for aircraft, the effect of the microenvironment on corrosion, corrosion protection by means of various coatings, the special susceptibility of aircraft components to corrosion, aircraft corrosion preventive measures, experimental methods used to monitor corrosion, and the effect of road salt and a marine environment on thin-gage metals used in vehicle and aircraft manufacture. For individual titles see N85-33239 through N85-33247.

N85-33239# Michigan State Univ., East Lansing. Dept. of Metallurgy, Mechanics and Materials Science.
CORROSION MANAGEMENT STRATEGIES FOR AIRCRAFT AND RELATED SYSTEMS
R. SUMMITT *In* AGARD Management of Corrosion 3 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

Unlike the automobile, which is considered a throwaway item in the U.S. economy, in the case of the aircraft, demands for safety and reliability, coupled with enormous replacement costs, force an anitcorrosion strategy which centers on timely and effective maintenance, regardless of cost. The operational life of an aircraft is greatly prolonged by a complex hierarchy of inspection and repairs, the costs of which never could be justified for a truck or automobile. Even more important than economics in aircraft, is the requirement for safety and reliability. The emphasis in aircraft anticorrosion tactics now lie in the fields of linear elastic fracture mechanics, damage-tolerant design, and reliability-centered maintenance. F.M.R.

N85-33240# Technische Hogeschool, Delft (Netherlands). Metallurgy Lab.
THEORETICAL ASPECTS OF CORROSION AND PRACTICAL IMPLICATIONS FOR AIRCRAFT AND RELATED SYSTEMS
W. A. SCHULTZE *In* AGARD Management of Corrosion 24 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

The basic phenomena of corrosion, the nature of the operational environment, and the response of typical aerospace materials to corrosion are reviewed. Among the topics discussed are single electrode reactions, the dynamic equilibrium of an electrode reaction, the redox electrode, electrode potential, polarization, and reaction rates. Also discussed are corrosion reactions, i.e., corrosion of a homogeneous metal in an acid solution, Pourbaix diagrams, kinetic aspects of corrosion, the effect on corrosion of inhomogeneities in metal or environment, and the corrosion kinetics of a passive metal. F.M.R.

N85-33241# Sereda (P. J.), Ottawa (Ontario).
ENVIRONMENTAL FACTORS IN CORROSION AND DETERIORATION OF MATERIALS
P. J. SEREDA *In* AGARD Management of Corrosion 11 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

The state-of-the-art in monitoring techniques and the importance of temperature, moisture (precipitation and relative humidity), solar radiation, and pollution as factors related to the microenvironment assisting in corrosion are reviewed. The effect of this microenvironment on the specific processes of corrosion and deterioration, and this on the performance of materials, is examined. Methods of monitoring the environment are reviewed, especially in connection with measurement of time-of-wetness, UV radiation, and pollution by sulfur dioxide. Areas where information is lacking, i.e., the effects of some pollutants (including acid rain), are identified. Author

N85-33242# Lehigh Univ., Bethlehem, Pa. Center for Surface and Coatings Research.
RATIONALE IN THE SELECTION OF CORROSION PROTECTIVE COATING SYSTEMS
H. LEIDHEISER, JR. *In* AGARD Management of Corrosion 17 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

Corrosion protection by coatings is a growing area of science and technology. This method of protection permits the design of a substrate with the desired physical and mechanical properties resistant to the environment to which the part is to be exposed. Protective coatings largely used at temperatures below 200C will be emphasized. Coatings are broken down for convenience into four types: metallic, polymeric, conversion, and comentitious. Each is discussed separately since the principles governing the performance of each type are different. Author

N85-33243# Middle East Technical Univ., Ankara (Turkey).
MAINTENANCE AND THE MILITARY ENVIRONMENT
M. DORUK and A. TUEFEKCIOGLU (Turkish Air Force Supply and Maintenance Center, Eskisehir) *In* AGARD Management of Corrosion 21 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

Corrosion and maintenance problems are discussed from a military point of view. The general characteristics of aircraft corrosion and the environment to which military aircraft are exposed with typical examples of type and location of corrosion are given. Corrosion damage is evaluated in terms of dominant environmental factors. Consideration is also given to the role of alloys, heat treatment of metals, and design in corrosion prevention. Elements of a corrosion prevention maintenance program are briefly described with special emphasis on nondestructive inspection (NDI) methods of corrosion detection. Author

N85-33244# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
CURRENT REQUIREMENTS FOR THE DESIGN AND MAINTENANCE AGAINST CORROSION OF UK MILITARY AIRCRAFT
C. J. E. SMITH *In* AGARD Management of Corrosion 13 p (SEE N85-33238 22-26) May 1985
Avail: NTIS HC A08/MF A01

The protection of new aircraft against corrosion depends initially on the careful selection of materials, good design, and well applied protective schemes. The corrosion control measures which must be applied to UK military aircraft are given in Defence Standard 00-970 Chaper 801, Precautions against Corrosion and Deterioration, and the philosophy behind these measures is outlined. Regular corrosion maintenance is essential to ensure the continued operation of the aircraft once in service. The use and scheduling of maintenance procedures such as aircraft washing, the application of corrosion preventative compounds and the rectification of corrosion damage is discussed. Author

N85-33245# Naval Air Development Center, Warminster, Pa.
PROTECTIVE SYSTEMS AND MAINTENANCE POLICIES FOR MARINE ENVIRONMENTS
I. S. SHAFFER and C. T. LYNCH (ONR, Arlington, Va.) *In* AGARD Management of Corrosion 13 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

The degradation of U.S. Navy systems performance is related to humidity and pollutants characteristic of the environment in which they operate. Several studies have correlated corrosion damage with these environmental factors. Moreover, experimental methods have been developed and used to monitor corrosion and to supplement environmental severity rating methods. The results of these studies and others provide a basis for development programs for alloys, protective coatings and corrosion inhibitors. This paper reviews current maintenance strategies - procedures, materials, and techniques - used by fleet personnel to minimize life-cycle costs of aircraft systems in an especially severe corrosive environment. Author

N85-33246# General Motors Corp., Warren, Mich.
LAND VEHICLE CORROSION MANAGEMENT
R. F. STEINMAYER *In* AGARD Management of Corrosion 19 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

The history of U.S. motor vehicle industry anti-corrosion measures is related. Prior to World War II corrosion was not a major concern for vehicles, which were made of heavy-gage steel, and deicing materials were seldom used. Following the war, major design innovations permitted the use of thinner gage metals. Also, increased, all weather highway use required the use of salt in freezing conditions. Vehicle corrosion became endemic. During the 60's rust-proofing became a must. Since then corrosion resistance has been further enhanced by better design, pre-coated metals, improved paint systems, good sealing techniques, and special augmentation coatings. Improved laboratory and proving ground test procedures, field survey and fleet evaluations provide reliable and accurate data on the corrosion performance of specific materials and test vehicles. F.M.R.

N85-33247# Michigan State Univ., East Lansing. Dept. of Metallurgy, Mechanics and Materials Dept.
RELATING CORROSION MAINTENANCE TO ENVIRONMENTAL FACTORS
R. SUMMITT *In* AGARD Management of Corrosion 15 p (SEE N85-33238 22-26) May 1985 refs
Avail: NTIS HC A08/MF A01

Aircraft inspections and maintenance should be timely based upon risk of damage, in order to minimize life cycle costs, and to maximize reliability. From the basis of Linear Elastic Fracture Mechanics, Damage-Tolerant Design, and Reliability-Centered Maintenance, optimum intervals have been developed with respect to fatigue and wearout failure. Such, however, is not the case for corrosion. Studies of maintenance in USAF aircraft systems have shown, nonetheless, that corrosion is a stochastic-failure process and can be described by standard models. Moreover, corrosion is predictable from: (1) the probability of initiation, and (2) the kinetics of propagation, both of which are functions of material corrodibility and environmental corrosivity. Some success has been achieved in describing environmental corrosivity in terms of ambient conditions. Thus, although the state of the art in corrosion-failure prediction lags that of fatigue-failure prediction by some two decades, the necessary foundation has been developed from which corrosion can be rapidly integrated into inspection/maintenance scheduling. Author

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

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PROPELLANTS AND FUELS

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

N86-20580# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PRODUCIBILITY AND COST STUDIES OF AVIATION KEROSENE
C. C. ROSEN, III, ed. Jul. 1985 51 p refs
(AGARD-AR-227; ISBN-92-835-1504-8; AD-A162764) Avail: NTIS HC A04/MF A01

A computer analysis conducted by Exxon Research and Engineering Company and NASA used standard refinery planning methods to determine the optimum processing path within model refineries to achieve minimum cost for various product outputs. Crude feedstock types were combined and refinery configurations selected to create regional calculation models. Principal objectives were: to determine the effect of jet fuel quality variations on the maximum yield of jet fuel; to determine the effect of jet fuel quality variations on refining costs for regional models based on future supply and demand; and to determine, for the United States Air Force, the effect of changing from wide cut (naptha) to kerosene jet fuels on refining cost and production yield in the United States and Europe. B.G.

31

ENGINEERING (GENERAL)

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

N83-34095# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
BEHAVIOUR OF SHORT CRACKS IN AIRFRAME COMPONENTS
Loughton, England Apr. 1983 203 p refs Meeting held in Toronto, 19-24 Sep. 1982
(AGARD-CP-328; ISBN-92-835-1444-0; AD-A131159) Avail: NTIS HC A10/MF A01

The accuracy and applicability of methods based on linear elastic fracture mechanics currently available for predicting short crack behavior are discussed. Emphasis is on the behavior of short cracks in airframe components. R.J.F.

N85-15086# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PROCESS MODELING APPLIED TO METAL FORMING AND THERMOMECHANICAL PROCESSING
Loughton (England) Sep. 1984 161 p refs Lectures held in Oslo, 15-16 Oct. 1984, in Paris, 18-19 Oct. 1984, and in Lisbon, 22-23 Oct. 1984
(AGARD-LS-137; ISBN-92-835-1477-7; AD-A149027) Avail: NTIS HC A08/MF A01

New perspectives to advance metal forming and thermomechanical processing were discussed. Working and forming processes are viewed as systems which integrate component behavior such as workpiece flow, heat flow and friction at the workpiece, tooling interface, and microstructural evolution. These are combined to form a system process model using deformation mechanics. Extrusion, forging, rolling, and sheet forming processes are examined and specific results for light metals, steels and superalloys, finite element methods and related aspects of computer-aided process design are presented. For individual titles see N85-15087 through N85-15096.

N85-29116# National Aerospace Lab., Amsterdam (Netherlands). Technical Group ETW.
CRYOGENIC TEST TECHNOLOGY, 1984
R. J. NORTH, D. SCHIMANSKI, and J. P. HARTZUIKER, ed. Apr. 1985 28 p refs
(AGARD-AR-212; AD-A157055) Avail: NTIS HC A03/MF A01

This report reviews the new information available on cryogenic test technology since the report of the Converters' Group on Cryogenic Test Technology was written in 1981. The present position is summarized. The major events since the Converters' report have been the completion and commissioning of the National Transonic Facility (NTF), the suspension of further work on the Douglas 4-WT blowdown tunnel, the conversion of ONERA T2 for cryogenic operation, the steady progress with the DF-LP KKK, and the slow but positive progress with the ETW project, including installation of the pilot tunnel PETW. B.W.

32

COMMUNICATIONS

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

N83-30862# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
MODERN HF COMMUNICATIONS
Loughton, England May 1983 177 p refs Lecture series presented at Athens, 30-31 May 1983, Rome, 2-3 Jun. 1983 and Fort Monmouth, N.J., 14-15 Jun. 1983
(AGARD-LS-127; ISBN-92-835-1450-5; AD-A131163) Avail: NTIS HC A09/MF A01

Real time channel evaluation; system design; and advances in equipment, in propagation, and in coding and modulation techniques are discussed. For individual titles, see N83-30863 through N83-30872.

N83-30863# York Univ. (England). Dept. of Electronics.
HF SYSTEM DESIGN PRINCIPLES
M. DARNELL *In* AGARD Modern HF Commun. 15 p (SEE N83-30862 19-32) May 1983 refs
Avail: NTIS HC A09/MF A01

The general principles of HF communication system design, using as a framework a generalized communication system comprising: propagation path, information source and sink, source encoder/decoder, channel encoder/decoder, and RF equipment. The basic properties of the medium relevant to the design, control and operation of HF systems are considered. In particular, the problems of HF system control are examined in depth. Author

N83-30864# Norwegian Defence Research Establishment, Kjeller.
PROPAGATION 1. STATE OF THE ART OF MODELLING AND PREDICTION IN HF PROPAGATION
E. V. THRANE *In* AGARD Modern HF Commun. 21 p (SEE N83-30862 19-32) May 1983 refs
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

N83-30865# York Univ. (England). Dept. of Electronics.
REAL-TIME CHANNEL EVALUATION
M. DARNELL *In* AGARD Modern HF Commun. 20 p (SEE N83-30862 19-32) May 1983 refs
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

N83-30866# Harvard-Smithsonian Center for Astrophysics, Cambridge, Mass.
INTRODUCTION TO CODING FOR HF COMMUNICATIONS
M. D. GROSSI *In* AGARD Modern HF Commun. 13 p (SEE N83-30862 19-32) May 1983 refs
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 adoption 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

N83-30867# Signatron, Inc., Lexington, Mass.
MODERN HF COMMUNICATIONS, MODULATION AND CODING
P. MONSEN *In* AGARD Modern HF Commun. 13 p (SEE N83-30862 19-32) May 1983 refs
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

N83-30868# Petrie Telecommunications, Nepean (Ontario).
EQUIPMENT: ANTENNA SYSTEMS
L. E. PETRIE *In* AGARD Modern HF Commun. 7 p (SEE N83-30862 19-32) May 1983 refs
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 an 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 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 or both mobile and fixed service operations. The application of adaptive antenna arrays and active antennas in modern HF communication systems are briefly reviewed. Author

N83-30869# Mitre Corp., Bedford, Mass.
HF EQUIPMENT: RECEIVERS, TRANSMITTERS, SYNTHESIZERS, AND PERIPHERALS
Q. C. WILSON *In* AGARD Modern HF Commun. 15 p (SEE N83-30862 19-32) May 1983
Avail: NTIS HC A09/MF A01

Although long distance communications via satellites has dominated the last two decades of radio equipment development, high frequency (HF) radio equipment is experiencing a high technology renaissance. Satellite systems now transmit quality low data rate communications and navigation aids to mobile users, but the low cost and surviability attributes of HF radio are again being recognized. Emerging new systems automate network operations while adapting to propagation conditions. However, neither new replacement radios nor new systems furnish the potential capability of state-of-the-art components. The advances in equipment, systems, and components are summarized. Author

N83-30870# Norwegian Defence Research Establishment, Kjeller.
PROPAGATION 2. PROBLEMS IN HF PROPAGATION
E. V. THRANE *In* AGARD Modern HF Commun. 17 p (SEE N83-30862 19-32) May 1983 refs
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 discusses 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

N83-30871# Harvard-Smithsonian Center for Astrophysics, Cambridge, Mass.
HF PROPAGATION MEASUREMENTS FOR REAL-TIME CHANNEL EVALUATION (RTCE) SYSTEMS
M. D. GROSSI *In* AGARD Modern HF Commun. 16 p (SEE N83-30862 19-32) May 1983 refs
Avail: NTIS HC A09/MF A01

Recent advances in microprocessor technology, in frequency-agile HF equipment and in the understanding of the propagation medium make it feasible and practical the adoption of adaptivity approaches in HF communications. Signal-to-Noise ratio, multipath spread and Doppler spread are the basic parameters to which the link has to adapt itself. A necessary prerequisite for adaptivity is Real Time Channel Evaluation (RTCE). Measurements of these parameters 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 emphasize the measurement of signal amplitude

and noise levels (inclusive of interference) at several frequencies in specific HF paths of interest, with a few instances of inclusion sof multipath spread measurement. There is little doubt that, at the end of the R&D phase, RTCE and link adaptivity will enter the practice of modernized HF communications. Author

N83-30872# Petrie Telecommunications, Nepean (Ontario).
ADAPTIVE SYSTEMS IN OPERATION
L. E. PETRIE *In* AGARD Modern HF Commun. 4 p (SEE N83-30862 19-32) May 1983 refs
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 interconnect. Also described is a HF message terminal which automatically requests, repeats and confirms message status for sender and receiver. Author

N83-30873# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PROPAGATION ASPECTS OF FREQUENCY SHARING, INTERFERENCE AND SYSTEM DIVERSITY
H. SOICHER (Army Communications Electronics Command, Fort Monmouth, N.J.) Loughton, England Mar. 1983 401 p refs Conf. held at Issy-les-Moulineaux, France, 18-22 Oct. 1982 (AGARD-CP-332; ISBN-92-835-0329-5; AD-A130833) Avail: NTIS HC A18/MF A01

Frequency spectrum management is an extremely important activity that facilitates the orderly use of the electromagnetic spectrum for many telecommunications purposes. Frequency assignment, radio frequency interference, propagation effects on practicability of frequency sharing between services, mechanisms responsible for, and limits posed by interference from strong signals, and techniques available for control of such interference and for increase in channel capacity were discussed. For individual titles, see N83-30874 through N83-30909.

N83-30874# Dartmouth Coll., Hanover, N.H. School of Engineering.
FUNDAMENTAL LIMITATIONS CAUSED BY RF PROPAGATION
R. K. CRANE *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 19 p (SEE N83-30873 19-32) Mar. 1983 refs Previously announced in IAA as A81-22880
Avail: NTIS HC A18/MF A01

Propagation phenomena affect the design of radio frequency (RF) transmission systems. Propagation phenomena limit the suitability of portions of the frequency band for some applications, limit the reliability of RF transmission systems, and provide a means of coupling unwanted signals from one system to another with the potential of producing interference. The possibility of interference is the fundamental limitation to the unrestricted use of the frequency band. Author

N83-30875# Institute for Telecommunication Sciences, Boulder, Colo. Applied Electromagnetic Science Div.
SOME PROPAGATIONAL ASPECTS OF FREQUENCY ALLOCATION AND FREQUENCY SHARING
H. T. DOUGHERTY and C. M. RUSH *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 11 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

The propagation phenomena of importance to the allocation and sharing of frequency bands are briefly summarized. Those aspects most significant for the various frequency bands are highlighted, illustrated, and referenced. Systems normally achieve their required grade of telecommunications service (service fields) by reliance upon standard modes of electromagnetic propagation. However, both standard modes (so-called) and anomalous modes of propagation must be considered when describing interference phenomena (interference fields). Further, these standard modes are described for any specific service as tending to be stable (relatively) and predictable. The anomalous modes, however, are described as involving some degree of uncertainty; they tend to be less stable and less predictable/anomalous, can involve different selections across the spectrum and with various services. Hence, for interference fields, the categorization is described herein as essentially by geometry. That is, interference situations are terrestrial Earth to space, or space to space propagational situations. Author

N83-30876# Department of the Army, Washington, D. C.
OVERVIEW OF FREQUENCY SHARING
E. J. HOLLIMAN *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 6 p (SEE N83-30873 19-32) Mar. 1983
Avail: NTIS HC A18/MF A01

Frequency engineering is the process of sharing spectrum space among many requirements in a manner which attempts to control potential operational interference. In most cases, the point that operational degradation occurs is identified by technical parameters. All frequencies are shared. In the case of the United States Army, the communication requirements exceed all possible spectrum space by approximately 8 times. The individual user of the radio spectrum would like to be unconcerned with sharing. However, this is not practicable for two reasons. First, the user must share his frequency with noise which is intrinsically involved with his system's design and environment. It influences his own design approaches and establishes limiting conditions of performance for the proposed operation. Secondly, the sharing environment forces him to recognize the presence of other users. In the assignment process, sharing is considered in one or more variations of four concepts. Author

N83-30877# Directorate of Radio Technology, London (England).
RADIO REGULATORY ASPECTS OF FREQUENCY SHARING
L. W. BARCLAY *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 6 p (SEE N83-30873 19-32) Mar. 1983
Avail: NTIS HC A18/MF A01

The requirement for communications, civil and military, analogue and digital, continues to expand and advances in technology have facilitated the expansion. Although much of the demand for data transmission in connection with information technology may be met by the provision of cable and optical fiber links, the pressure for expansion of radio communication continues. Some of the regulatory aspects of the use of the radio frequency spectrum are discussed and one or two of the problems associated with frequency re-use are highlighted. Author

N83-30878# Leicester Univ. (England). Dept. of Physics.
ANOMALOUS ABSORPTION EFFECTS PRODUCED BY HIGH POWER RADIO WAVES IN THE HIGH LATITUDE IONOSPHERE
T. B. JONES, T. ROBINSON, P. STUBBE (Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau, West Germany), and H. KOPKA (Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau, West Germany) *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

High power HF radio waves can produce plasma instabilities in the ionosphere which induce major changes in the propagation characteristics of other HF signal propagating through the disturbed region. Experiments to investigate some of these disturbance effects were undertaken using the Max Planck Institut fur Aeronomie, Lindau heating facility at Tromso, Norway. Particular attention is given to the anomalous absorption effects discovered and to the induced phase changes observed in the diagnostic signals. The observations are interpreted in terms of the plasma instabilities generated and are of interest in assessing the performance of HF communication systems when disturbances of this nature are produced in the ionosphere. Author

N83-30879# Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau (West Germany).
VHF-LONG-DISTANCE-PROPAGATION BY AURORAL BACKSCATTER
G. LANGE-HESSE *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 14 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Extended investigations of VHF auroral backscatter communications was carried out in Europe in the years from 1958 to 1969 using the results of the observation of beacon transmitters and of an extended network of amateur stations covering big parts of Europe. The frequency of occurrence of this kind of propagation as a function of geomagnetic activity and location, time of day, season and sunspot cycle is shown by several diagrams. The physical reasons for this backscatter phenomenon and especially for the typical daily variation in the frequency of occurrence are discussed. Proposals are made for special arrangements to suppress this kind of propagation in case of frequency sharing. Author

N83-30880# Federal Communications Commission, Washington, D. C.
INTERFERENCE AND SHARING AT MEDIUM FREQUENCY: SKYWAVE PROPAGATION CONSIDERATIONS
J. C. H. WANG *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 13 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

A considerable amount of work dealing with nighttime skywave propagation was done; however, some areas remain to be explored. For example, short term variation of field strengths was overlooked. Daytime propagation is far from being quantitatively understood. Also, it is not quite possible to determine interfering signal levels which are present for a small percentage of time with high accuracy. During sunspot cycles 18 and 19, the Federal Communications Commission conducted an extensive field strength measurement program in the midlatitude areas of North America. These and other data are revisited with a new emphasis, namely, interference and sharing. Determination of field strengths exceeded for different percentages of time (1 to 99%), diurnal variation of field strengths, favorable conditions for daytime skywave propagation, effect of magnetic storms, frequency dependence as observed at daytime and nighttime are discussed. Author

N83-30881# Science Research Council, Chilton (England).
SIGNAL AND NOISE VARIABILITY IN HIGH FREQUENCY SKYWAVE RADIO-SERVICE PLANNING
P. A. BRADLEY *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 14 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Procedures existing under the auspices of the International Telecommunication Union for allocating frequency blocks to radio services and for the assignment of specific frequencies to individual radio operators are explained. The compatibility analysis undertaken by the International Frequency Registration Board at high frequencies to test for harmful interference is described and the technical standards used in this analysis are discussed. Work in progress within the International Radio Consultative Committee in preparation for a forthcoming World Administrative Radio Conference on High Frequency Broadcasting concerned with improved standards for field strength estimation, fading, protection ratio and minimum usable field strength is reviewed. Author

N83-30882# Alaska Univ., Fairbanks. Geophysical Inst.
ANOMALOUS PROPAGATION BEHAVIOR OF RADIO SIGNALS AT HIGH LATITUDES
R. HUNSUCKER *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 15 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Signals in the 3 to 30 MHz (HF) band propagated through polar and auroral ionospheric regions sometimes undergo some unique and profound changes. The channel capacity, intelligibility and reliability of these signals are affected by multipath distortion, backscatter, nongreat circle propagation and other high latitude anomalies. Signals propagated in the very low frequencies (VLF), low frequencies (LF), medium frequencies (MF), very high frequencies (VHF)/ultrahigh frequencies (UHF) and microwave portions of the radio spectrum also undergo some very deleterious effects. Specifically, some of the newer results obtained include: ground constant measurements of tundra permafrost, MF skywave signals and precipitation depolarization of satellite downlink signals. Author

N83-30883# Hulburt (E. O.) Center for Space Research, Washington, D.C. Ionospheric Effects Branch.
THE APPLICATION OF REAL-TIME MODEL UPDATE BY OBLIQUE IONOSPHERIC SOUNDERS TO FREQUENCY SHARING
D. R. UFFELMAN, L. O. HARNISH, and J. M. GOODMAN *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 11 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Frequency management systems for the high frequencies (HF) currently in use by the US Department of Defense (DoD) rely heavily on manual selection of frequencies which were allocated on a circuit by circuit basis. There is no capability to anticipate frequency changes (QSY's) in advance in a manner such that a frequency being released by one user is utilized effectively and immediately by a second user. A scheme by which a small computer model of the maximum usage frequency (MUF) of the HF channel (MINIMUF 3.5) is made to perform very accurately to anticipate channel characteristics in a short term prediction mode was examined. It is proposed that this model be utilized to provide automated frequency management which would allow one to anticipate frequency availability and thereby sharing of frequencies between several users. Utilizing data obtained from an oblique sounder net on the East Coast of the United States, the manner in which this might be accomplished is demonstrated. Author

N83-30884# Hulburt (E. O.) Center for Space Research, Washington, D.C. Ionospheric Effects Branch.
THE DEVELOPMENT OF AN IONOSPHERIC MODEL THESAURUS AND USER'S GUIDE
J. M. GOODMAN *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 12 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

The preliminary progress on the development of a comprehensive survey of ionospheric models - both physical and empirical - which have, are, or would be employed to evaluate the operation of military radiowave systems. Also to be contained in the survey are forecasting/prediction techniques and propagation effects models together with an evaluation of each based upon available documentation. Author

N83-30885# Middle East Technical Univ., Ankara (Turkey). Dept. of Electrical Engineering.
MEDIUM WAVE GROUNDWAVE PROPAGATION MODEL-NUMERICAL AND EXPERIMENTAL RESULTS
A. F. FER and A. HIZAL *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Two computer models incorporating two different groundwave propagation analysis techniques are investigated. The first model is a perturbation technique based on the approach by King Maley and Wait and represents an extention of the previous results to take into account an n-section propagation path. The second model is the integral equation solution for irregular and inhomogeneous terrain based on the formulation by Ott (i.e. PROGRAM WAGNER). The results from the two approaches are compared with each other as well as the results from Millington formula for multisection paths and knife edge diffraction for mountainous regions. Limited amount of experimental data is also compared with computed values for ground wave propagation from Trabzon Broadcast transmitter over the Eastern Anatolian mountain ranges. Computer modelling for the study of ground wave propagation is seen to present an economically advantageous tool in the design of medium frequency (MF) communication links. Author

N83-30886# Institute for Telecommunication Sciences, Boulder, Colo.
A COMPUTATIONAL MODEL FOR MULTIPLE KNIFE-EDGE DIFFRACTION
L. E. VOGLER and P. M. MCMANAMON *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 7 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

The derivation of a multiple knife edge attenuation function is described. This exact multiple integral is transformed into a series suitable for numerical evaluation. The series solution is implemented as a computer program capable of calculating the attenuation over a path consisting of up to 10 knife-edges. Theoretical attenuation calculations are compared with observed measurements for a 15-km path containing 5 knife edges. The significance of atmospheric refractivity on multiple knife edge diffraction is discussed, and a means to use this to provide information about the statistical distribution of propagation loss over specific paths is suggested. E.A.K.

N83-30887# Maritime Telegraph and Telephone Co. Ltd., Halifax (Nova Scotia).
VHF/UHF PROPAGATION STUDIES ON LONG OVER THE HORIZON SALT WATER RADIO PATHS
R. E. GRANTHAM and W. P. LONC (Saint Mary's Univ.) *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 11 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

The nature of short term and long term path are outlined, and the preliminary observations of the data collected are described. Received Signal Levels were monitored and recorded over a number of long range (200 km) salt water radio paths. It is revealed that mean signal levels received are higher than anticipated and that a usable path can be established with 1 kW ERP levels. The propagation is characterized by short deep fades and there are only rare occasions when the signal drops below usable limits for extended periods. A strong seasonal effect was recorded. Path reliability approaches 100% during the summer and as low as 50% during the winter. The fast fading effect can be reduced significantly with space diversity reception and the reliability could exceed 95% with simple diversity arrangements. Space and frequency diversity, if required, would offer near 98% reliability for voice communications. Circular polarization appears to suffer less from fast fades than linear polarization. It is found that the differences in performance between UHF (400) and VHF (140) are not pronounced. E.A.K.

N83-30888# Technische Hogeschool, Eindhoven (Netherlands)
MODELLING ON INTERFERENCE DUE TO DUCTING AT FREQUENCIES ABOVE 1 GHZ
J. DIJK, J. VANTIGGELEN, and J. NEESEN (Neher Labs., Leidschendam, Netherlands) *In* AGARD Propagation Aspects of Freguency Sharing, Interference and System Diversity 13 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

A theoretical basis and the numerical tools for the calculation of the field strength due to ducting in beyond the horizon microwave links are presented. The purpose is a contribution to the understanding of the propagation phenomena involved and to provide some physical basis for the predictive techniques to be considered for the evaluation of mutual interference between radio communication systems, operating at frequencies above 1 GHz. E.A.K.

N83-30889# Service Meteorologique Metropolitan, Paris (France).
STATISTICAL STUDY OF ELEVATED DUCTS EXTENSION
B. STRAUSS and J. L. DUMAS *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 3 p (SEE N83-30873 19-32) Mar. 1983
Avail: NTIS HC A18/MF A01

The spatial extension of elevated ducts using meteorological radiosondes soundings were studied. A limited extension of a duct to the sounding station is found in about 85% of the cases. E.A.K.

N83-30890# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France)
MULTIPLE DIFFUSION BY HYDROMETEOROLOGY: A NUMERICAL SIMULATION [LA DIFFUSION MULTIPLE PAR LES HYDROMETEORES: UNE SIMULATION NUMERIQUE]
N. SPANJAARD and J. LAVERGNAT *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 6 p (SEE N83-30873 19-32) Mar. 1983 refs In FRENCH
Avail: NTIS HC A18/MF A01

The influence of hydrometeorology on millimeter wave propagation and those due to multiple diffusion was studied. It is found that at these frequencies the wavelength is near the characteristic dimensions of diffusing cores. Consequently the relationship between efficacious section of diffusion and of absorption is on more levels of higher magnitude, superior to those which concern waves with inferior frequencies at 10 GHz.
Transl. by E.A.K.

N83-30891# Essex Univ., Colchester (England). Dept. of Mathematics.
BISTATIC RADAR REFLECTIVITIES IN THE RANGE 11-30 GHZ
D. G. CHARLTON, A. R. HOLT, and B. G. EVANS *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Bi-static scattering cross sections and reflectivities for the scattering of microwaves by raindrops are presented. Exact results for spheroids were compared with exact results for spheres, and approximate calculations for spheroids using Rayleigh Theory. Results are given for several frequencies in the range 11-30 GHz, and for both a terrestrial and a satellite path. It is found that the Rayleigh approximation gives significant errors in certain cases. The results have implications or the calculation of interference between communication systems. E.A.K.

N83-30892# British Telecommunications Research Ltd., Martlesham Heath (England).
OVERSHOOT INTERFERENCE ON MICROWAVE RADIO LINKS DUE TO THE CO-EXISTENCE OF MULTIPATH FADING AND TRANS-HORIZON PROPAGATION
J. E. DOBLE *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 7 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Periods of meteorological conditions which lead to multipath effects on line of sight systems and which can also be those during which anomalous transhorizon propagation is present are outlined. The coexistence of these two effects cause increased system sensitivity to overshoot interference from one section of a microwave route into subsequent sections, or into other systems. Current overshoot interference calculations treat these two effects as uncorrelated and the degree to which this assumption is in error was estimated from independent measurements on transhorizon links and terrestrial links terminating in the same area. E.A.K.

N83-30893# Lockheed Missiles and Space Co., Sunnyvale, Calif.
SYSTEM ASPECTS OF CLEAR AIR PROPAGATION ABOVE 40 GHZ
D. M. THEOBOLD and J. D. HOPPONEN *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Communication links operating at frequencies above 40 GHz may be modeled by computer programs which treat both the atmosphere and communication hardware of the system in an integrated fashion. Absorption by atmospheric gases and turbulence effects are considered. Link degradations due to seasonal variations are treated. Absorption by molecular oxygen and water vapor causes dispersive signal attenuation, phase delay, and noise due to random atmospheric emission. These quantities may be predicted for specific frequency bands and atmospheric conditions by employing a computer program for ray tracing. The characteristics of the atmospheric transfer function are of importance to questions of modulation distortion in high data rate systems. The atmosphere is viewed as an additional signal filter

of the communication channel and the resultant signal distortion is quantified by predicting bit error rate degradation. E.A.K.

N83-30894# Essex Univ., Colchester (England).
PROPAGATION CONSTRAINTS IN THE MILLIMETRE WAVEBANDS DUE TO PRECIPITATION SCATTERING
B. G. EVANS and A. R. HOLT *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 10 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Theoretically derived forward and backward scattering calculations for precipitation up to 210 GHz. Simple scaling rules are investigated for forward and backward directions which allow scattering parameters at one frequency to be derived from other frequencies thus obviating the need for exhaustive and complex calculations. Predictions of propagation degradations for communication and radar systems operating in the millimeter wave bands are given. E.A.K.

N83-30895# AEG-Telefunken, Ulm (West Germany). Geschaeftbereich Hochfrequenztechnik.
A MM-WAVE COLLISION WARNING DEVICE FOR HELICOPTERS
B. REMBOLD, H. G. WIPPICH, M. BISCHOFF, and W. F. X. FRANK *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Using the frequency slot of maximum atmospheric attenuation around 60 GHz a short range collision warning device for helicopters was developed. The system consists of a pulsed radar sensor using semiconductors exclusively, a fast scanning mechanism and a display. First measurements show that high voltage transmission lines with diameters of about 20 mm can be detected at a distance of more than 400 m. E.A.K.

N83-30896# Massachusetts Inst. of Tech., Cambridge.
A PREDICTOR MODEL FOR EHF COMMUNICATION SATELLITE SYSTEM AVAILABILITIES IN THE PRESENCE OF RAIN
L. M. SCHWAB and A. J. SIMMONS *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 11 p (SEE N83-30873 19-32) Mar. 1983 refs Sponsored by Defense Communications Agency
Avail: NTIS HC A18/MF A01

Rain attenuation of millimeter waves has a major effect upon link availability which is the major element of system availability. A computer based tool for assessing the effect of rain attenuation upon availability was developed to aid in selecting fundamental MILSATCOM parameters such as satellite subpoint and operating frequency as well as secondary parameters such as design margin and antenna radiation patterns. E.A.K.

N83-30897# GTE Labs., Inc., Waltham, Mass.
DIVERSITY RECEPTION OF COMSTAR 19/29 GHZ SATELLITE BEACONS IN CONVECTIVE RAIN CLIMATE OF FLORIDA, 1978 - 1981
D. DAVIDSON, D. D. TANG, and S. C. BLOCH (Univ. of South Florida, Tampa) *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 12 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Tampa, Florida has about 90 thunderstorm days per year, nearly all in summer, dominated by events tending to occur in afternoon or early evening. Results of 19 GHz downlink rain attenuation diversity studies are reported for a period of 29 months, which includes three rainy seasons. Despite marked month to month differences, long term measurements with the two larger spacings indicates that for separations above about 15 km diversity performance is not sensitive to spacing or orientation. During a fourth rainy season, using a 29 GHz beacon and the 16 km spacing, performance was similar to that predicated by scaling the 19-GHz results of the previous seasons. For rain climates like Tampa's, some form of site diversity will be required for high reliability SHF satellite links. E.A.K.

N83-30898# Portsmouth Polytechnic (England). Dept. of Electrical and Electronic Engineering.
SCINTILLATION MODELLING AND MEASUREMENT. A TOOL FOR REMOTE-SENSING SLANT PATHS
E. VILAR and J. HADDON *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 13 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

The use of spectral analysis amplitude scintillations as a remote-sensing tool of a slanted path is investigated in order to derive values of c sub N(2), turbulent path L, and dominant eddy size. Relevant propagation aspects are reviewed nd extended, a layer model analyzed in detail, and experimental results are presented and discussed. The limitations of the remote-sensing technique are also discussed, particularly the use cross-path wind v sub t. The remote-sensing of v sub t is briefly outlined and relevant antenna aperture effects are also considered. Author

N83-30899# British Telecommunications Research Ltd., Martlesham Heath (England).
LONG TERM CROSS-POLAR STATISTICS AT 12 AND 14 GHZ ON A 30 DEG SLANT-PATH
R. G. HOWELL, J. THIRLWELL, and D. J. EMERSON *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Slant-path propagation measurements relevant to the design of dual-polar satellite systems are reported. The measurements were made on a 29.9 deg elevated slant-path during the period July 1978 to September 1981 using the Orbital Test Satellite (OTS) in conjunction with a 6.1 m off-set Cassegrain aerial located at Martlesham Heath near Ipswich (UK). Co-polar and cross-polar circularly polarized signals at a frequency of 14.5 GHz were transmitted to the satellite. These signals were down-converted to 11.8 GHz and re-transmitted to the ground together with a 11.8 GHz circularly polarized beacon signal. In addition measurements were made on an 11.6 GHz linearly polarized telemetry carrier transmitted by the satellite. Cumulative statistics of the cross-polar discrimination (XPD) for the 11.6 and 11.8 GHz signals are presented and the XPD statistics for the 14.5 GHz signal estimated. The statistical significance of the depolarization produced by high altitude ice crystals is discussed. The relationship XPD = U - V log CPA proposed by the CCIR to relate XPD to the co-polar attenuation (CPA) (dB) for rain is investigated and values for U and V obtained. The dependence of depolarization on the type of polarization (linear compared to circular) is studied and compared with theory. Author

N83-30900# Communications Satellite Corp., Clarksburg, Md. Propagation Studies Dept.
FADING STATISTICS OF C-BAND SATELLITE SIGNAL DURING SOLAR MAXIMUM YEARS (1978 - 1980)
D. J. FANG and C. H. LIU (Illinois Univ., Urbana) *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 14 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

From January 1978 to June 1980, scintillation experiments were conducted at the Hong Kong Earth station. INTELSAT satellite signals at 4 GHz were received via both the Pacific Ocean Region (POR) and Indian Ocean Region (IOR) satellite-Earth links. Severe intensity scintillations with peak-to-peak fluctuations up to 14 dB were observed on many evenings during the equinoctial period. This paper presents detailed statistics of the scintillating signals. The level of fluctuations based on the scintillation index is evaluated, and fading rates in terms of the coherence time are examined and correlated with the level of scintillation. Power spectrum densities are also assessed. The high-frequency asymptotes, i.e., the roll-off slopes at frequencies above the Fresnel frequency, as approximated by f(-n), are derived for different levels of fluctuations. For system applications, various cumulative statistics, including annual and worst-month statistics, diurnal variations, and sunspot cycle dependence are summarized. Author

N83-30901# Siemens A.G., Munich (West Germany).
NEW ASPECTS IMPROVING THE AVAILABILITY OF DIGITAL LOS-RADIO RELAY LINKS DEDUCED FROM WIDE-BAND MEASUREMENTS AT 5 AND 15 GHZ
M. NIEMEYER and W. SCHWARZ, B. *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 16 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

This paper will first describe a frequency sweep method based on recordings of broadband amplitude distortions which were continuously performed over a period of two years. Measurements have been carried out on a 60 km path in the 5 and 15 GHz frequency range. The relative measuring bandwidth was 2 and 3%, respectively. The analysis of the records revealed two important results: First, the statistical consideration of the long term experiments yields to a prediction about the availability of digital radio links as a function of the occupied bandwidth provided, that no additional diversity measures are used. Second, the analysis of the determined coherence bandwidth allows a physical interpretation of the interference phenomena. The model of a dominating 3 path propagation found by these experiments could be proved with the aid of a high directive, tracked antenna system (3 dB-beamwidth approximately 0.3 degree) in the 15 GHz frequency range. B.W.

N83-30902# Manchester Coll. of Science and Technology (England). Dept. of Electrical Engineering and Electronics.
OCCUPANCY MEASUREMENTS ACROSS THE ENTIRE HF SPECTRUM
G. F. GOTT, N. F. WONG, and S. DUTTA *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 13 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

The paper outlines the various aspects of a research program into the characteristics of interference at HF, and gives measured results of occupancy across the entire HF spectrum These occupancy values are given for several thresholds, and for the different HF user frequency allocations, as defined by ITU regulations. They are presented for day and night conditions, at times of the year corresponding to the winter and summer solstices, for a period of high sunspot activity. Author

N83-30903# Directorate of Radio Technology, London (England).
PROPAGATION DATA FOR VHF PLANNING IN THE UK AREA
K. A. HUGHES and J. A. LANE *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 10 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Demand for VHF spectrum in the UK requires sharing of frequency bands by different services. Fundamental to the planning of shared bands is the prediction of the potential interference between the services for small percentages of the time. The most well established prediction method at VHF is probably that given in CCIR Recommendation 370. As an aid to UK spectrum planning, the suitability of Recommendation 370-4 has been investigated for propagation paths within, or terminating in the UK. Comparisons have been made between long term measurements and predicted values of field strength using the Recommendation. For some categories of path, measured field strengths were found to exceed predicted values by some 10 dB; other categories however, show good agreement. the applicability of the Recommendation to current planning requirements is discussed in the light of the comparisons. Author

N83-30904# Operations Research, Inc., Silver Spring, Md.
IMPLICATIONS OF PROPAGATION UNCERTAINTIES IN FREQUENCY SHARING ANALYSES
T. M. SULLIVAN *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 6 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

Frequency sharing analyses are used for a variety of spectrum management purposes. These applications include procedures for identifying frequency assignment coordination requirements, the planning of telecommunication services, the derivation of frequency sharing criteria, and detailed Electromagnetic Compatibility (EMC) analyses. An examination of interfering signal power levels that are exceeded for no more than some specified percentage(s) of time is generally required in frequency sharing analyses. Also, depending on the application, an analysis of the desired signal power levels exceeded for at least some specified time percentage(s) is needed. These evaluations of the desired or interfering signal power levels are based on service quality objectives, equipment parameter values, and propagation predictions. The latter two factors embody uncertainties that affect not only service quality, but also spectrum utilization efficiency. The objectives of various frequency sharing analysis applications and the potential consequences of analytical uncertainties were considered. Analytical techniques used in frequency sharing analyses and the associated sources of analytical uncertainties were reviewed. Finally, the implications of propagation uncertainties in frequency sharing analyses were examined in light of other analytical uncertainties. The implications of propagation prediction uncertainties depend on the frequency sharing analysis application and can range from unacceptable interference to inefficient use of the spectrum. Author

N83-30905# Army Communications-Electronics Command, Fort Monmouth, N.J. Center for Systems Engineering and Integration.
PROPAGATION PREDICTION USAGE IN AUTOMATED FREQUENCY ASSIGNMENTS BASED ON COSITE AND REMOTE SYSTEM SPECTRUM SHARING
S. M. SEGNER *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

This paper covers the use of propagation predictions in the US Army (automated) Battlefield Spectrum Management and Engineering (ABSM&E) capability development program. This program is divided into nine tasks. The major task is the US Army (automated) Tactical Frequency Engineering System (ATFES) Pilot Program. This task will set up the experimental and test structure by fielding vertical slice of an integrated capability in US Army Europe. These ADP systems will initially spectrum manage LOS, TROPO, and HF systems. Eventually, all communications and electronic (radar, sensors and avionics) will be managed by new software now in development for these spectrum assests of command control and weapons systems. A major function of ABSM&E is to provide coordination of friendly force use of spectrum with friendly force ECM systems. The basic common interest here is the propagation aspect of each spectrum dependent system in each community. Author

N83-30906# Nova Scotia Technical Coll., Halifax. Dept of Electrical Engineering.
ON COMBATING MULTIPATH EFFECTS USING SPREAD-SPECTRUM SYSTEMS
C. P. TOU *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 11 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

This paper discusses briefly the origins of multipath propagation, their effects on radio communication systems, and schemes for suppressing these effects. Major attention is given to spread spectrum schemes to demonstrate their capacity to combat multipath effects, to examine conditions under which the schemes would be effective, and to assess the merits of the schemes. Multipath propagation can occur under various atmospheric and geographical conditions as illustrated by simple examples. The adverse effects of multipath propagation on communication systems can be described in terms of selective fading and intersymbol interference. Simple measures can be found if the multipath propagation is predictable, but sophisticated techniques are required to combat unpredictable multipath interference. It has been shown that spread spectrum systems are superior to other approaches in terms of effectiveness in combating multipath interference and other valuable features. However, the ability of spread spectrum systems to suppress interference depends on the process gain of the system and the system performance depends on the degree of synchronization which can be established by the system Author

N83-30907# Shape Technical Center, The Hague (Netherlands)
A SPECTRAL EMISSION MASK FOR DIGITAL TROPOSPHERIC SCATTER TRANSMISSION
R. K. P. GALPIN *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

A spectral emission mask definition for high power digital radio transmission is proposed. Developed for use in the specification of digitalized ACE high troposcatter links, it is offered for consideration by industry and frequency planning authorities. Similar in form to the FCC mask definition for digital LOS radio, the proposed definition is believed to be a reasonable compromise between minimizing interference into adjacent radio channel allocations and avoiding the imposition of costly constraints upon the manufacturers and operators. Computer simulations supported by spectral measurements at 10 kW have shown that well designed filtering (with negligible intersymbol interference) before the high power amplifier is very effective in reducing out of band emission, and that the proposed mask can be satisfied with a signal having a bandwidth utilization efficiency of 1.6 bit/s/Hz when operating at 2 dB below saturation of the klystron amplifier. Author

N83-30908# Technische Hogeschool, Eindhoven (Netherlands). Telecommunications Div.
INTERFERENCE REJECTION BY AUXILIARY FEEDS IN CASSEGRAIN EARTH TERMINALS
J. ARNBAK, M. H. A. J. HERBEN, and R. A. C. M VANSPAENDONK *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 10 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

This paper reviews progress in an ongoing study of interferometric sidelobe suppression by auxiliary feeds in Cassegrain antennas. The isolation improvements are explored and related to the feed geometry, orbital spacing between satellites, and required excitation levels. The system value of this modernization option is very relevant as an interference mitigation scheme in the various satellite networks now in widespread use. B.W.

N83-30909# Institute for Telecommunication Sciences, Boulder, Colo.
GAIN PATTERNS OF MICROWAVE COMMON CARRIER ANTENNAS
A. G. HANSON and P. M. MCMANAMON *In* AGARD Propagation Aspects of Frequency Sharing, Interference and System Diversity 9 p (SEE N83-30873 19-32) Mar. 1983 refs
Avail: NTIS HC A18/MF A01

This paper summarizes analytical expressions which describe the off-axis radiation characteristics of 924 transmit antenna models in use within the continental United States in the 2, 4, 6, and 11 GHz common carrier microwave terrestrial radio service. Data are presented in a uniform format which permits the user to determine power gain for any antenna identified, at any off-axis azimuthal angle. The primary application of these data is for interference prediction among microwave links and between microwave links and communication satellite Earth terminals sharing a common frequency band. B.W.

N83-34179# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SPEECH PROCESSING
Loughton, England May 1983 122 p refs Lecture held in Trondheim, Norway, 20-21 Jun. 1983, in Copenhagen, 23-24, and in Delft, Netherlands, 27-28 Jun. 1983
(AGARD-LS-129; ISBN-92-0331-7; AD-A132092) Avail: NTIS HC A06/MF A01

The following topics of speech processing were addressed: military applications, speech signal, automatic recognition, current equipment and research, assessment of speech systems, and voice technology in naval training systems. For individual titles, see N83-34180 through N83-34188.

N83-34180# Rome Air Development Center, Griffiss AFB, N.Y.
GENERAL REVIEW OF MILITARY APPLICATIONS OF VOICE PROCESSING
B. BEEK and R. S. VONUSA *In* AGARD Speech Process. 20 p (SEE N83-34179 22-32) May 1983 refs
Avail: NTIS HC A06/MF A01

Voice Interactive Systems and their role in military applications are introduced. The history and evolution of automatic speech recognition and synthesis is briefly explored and the current state of the art is reviewed. The term Voice Interactive Systems is defined and the advantages and disadvantages of Voice Interactive Systems are highlighted. Previous applications of speech systems to military problems are summarized, the major application areas are described and current development projects in the U.S. and other NATO countries are presented. Special attention is focused on the cockpit application. Several projects in this area are discussed along with a summary of important issues to consider when applying Voice Interactive Systems to the aircraft environment. Author

N83-34181# National Aeronautical Establishment, Ottawa (Ontario).
THE SPEECH SIGNAL
M. J. HUNT *In* AGARD Speech Process. 12 p (SEE N83-34179 22-32) May 1983 refs
Avail: NTIS HC A06/MF A01

An introduction to the speech signal with particular emphasis on the recognition of spoken messages is provided. In an attempt to clarify its nature, speech is compared with two other kinds of signal. Some properties of words and phenemes are considered, and unlike many artificial message bearing signals, speech cannot be considered as a simple sequence of independent message units. A speaker adjusts the amount of information in his speech to suit his listener, and the listener carries out an active reconstruction of the message from the information available to him. Turning to recognition by machine, the use of syntactic constraints is first discussed, followed by a look at three kinds of approach to the analysis and representation of speech for recognition purposes. A brief account of speech production is provided in order to explain the motivation for production based representations. Author

N83-34182# AEG-Telefunken, Ulm (West Germany).
ANALYSIS, SYNTHESIS AND TRANSMISSION OF SPEECH SIGNALS
H. MANGOD *In* AGARD Speech Process. 17 p (SEE N83-34179 22-32) May 1983 refs
Avail: NTIS HC A06/MF A01

Digital techniques have opened quite new possibilities for processing of speech signals. This is true for analysis and for transmission. These new methods are characterized by a strict adaptation to the very special peculiarities of speech. An overview about the mathematical possibilities and their relevance to the different parts of the speech signal is given. Efforts to represent speech in a digital and more or less redundancy free form gives good insight into all the characteristics of such a highly complex signal. Possibilities for representation of speech signals reach from the very simple pulse code modulation techniques (PCM) to sophisticated vocoders. The research work done for speech transmission and coding has prepared the way for methods to recognize and synthesize speech signals. Automatic speech synthesis is an important tool for the communication between man and machine. An additional introduction into the techniques of automatic speech synthesis is given. Author

N83-34183# Royal Signals and Radar Establishment, Malvern (England).
TECHNIQUES FOR AUTOMATIC SPEECH RECOGNITION
R. K. MOORE *In* AGARD Speech Process. 12 p (SEE N83-34179 22-32) May 1983 refs
Avail: NTIS HC A06/MF A01

A brief insight into some of the algorithms that lie behind current automatic speech recognition system is provided. Early phonetically based approaches were not particularly successful, due mainly to a lack of appreciation of the problems involved. These problems are summarized, and various recognition techniques are reviewed in the contect of the solutions that they provide. It is pointed out that the majority of currently available speech recognition

equipments employ a 'whole-word' pattern matching approach which, although relatively simple, has proved particularly successful in its ability to recognize speech. The concepts of time-normalizing plays a central role in this type of recognition process and a family of such algorithms is described in detail. The technique of dynamic time warping is not only capable of providing good performance for isolated word recognition, but how it is also extended to the recognition of connected speech (thereby removing one of the most severe limitations of early speech recognition equipment). Author

N83-34184# National Aeronautical Establishment, Ottawa (Ontario).
SPEAKER DIFFERENCES IN SPEECH AND SPEAKER RECOGNITION
M. J. HUNT *In* AGARD Speech Process. 8 p (SEE N83-34179 22-32) May 1983 refs
Avail: NTIS HC A06/MF A01

The range of ways in which speakers differ is surveyed, with distinctions being drawn on the one hand between physiological and usage differences and on the other hand between those differences stemming from the larynx and those stemming from the vocal tract. Methods of dealing with speaker differences in speaker-independent and speaker-adaptive speech recognition systems are discussed. This is followed by a discussion of the exploitation of speaker differences in speaker recognition systems. The latter discussion is divided into a consideration of speaker verification, in which a speaker is trying to prove his identity, and speaker identification, in which the identity of an unknown speaker has to be discovered and the speaker cannot be expected to cooperate in producing a predetermined phrase. A summary of the present state of the art in dealing with speaker differences together with some guesses about the prospects for practical systems in the near future. Author

N83-34185# Joint Speech Research Unit, Ruislip (England).
A SURVEY OF EQUIPMENT AND RESEARCH
J. S. BRIDLE *In* AGARD Speech Process. 7 p (SEE N83-34179 22-32) May 1983 refs
Avail: NTIS HC A06/MF A01

Terms for description of speech recognition systems are defined. A selection of real time, commercially available speech recognition equipment is described, concentrating on the high performance end of the market. Likely developments are indicated. A single approach to automatic speech recognition - that using whole-word templates was discussed. Current attempts to extend the capabilities of this approach, and also look at alternative approaches which are the subject of research in laboratories around the world are explained. Author

N83-34186# Crouzet Aerospace and Systems, Valence (France)
AUTOMATIC RECOGNITION OF SPEECH IN MILITARY AIRCRAFT [RECONNAISSANCE AUTOMATIQUE DE LA PAROLE DANS LES AVIONS D'ARMES]
J. R. COSTET *In* AGARD Speech Process. 11 p (SEE N83-34179 22-32) May 1983 In FRENCH
Avail: NTIS HC A06/MF A01

The application of word recognition techniques to vocal command control in military aircraft is discussed. The problems associated with cabin/oxygen mask noise and pilot respiration, and the effects of acceleration on word recognition are addressed. M.G.

N83-34187# Joint Speech Research Unit, Ruislip (England).
INSIDE A SPEECH RECOGNITION MACHINE
J. S. BRIDLE *In* AGARD Speech Process. 9 p (SEE N83-34179 22-32) May 1983 refs
Avail: NTIS HC A06/MF A01

Illustration of speech recognition techniques by concentrating on a particular speech recognition system was presented. The system, know as Logos is designed as a flexible, high performance, experimental machine for research on recognition methods and applications aspects. Algorithms for connected word recognition on which the system is based, are presented. Implementing such algorithms in computer programs and special purpose equipment is considered. An overview of the hardware system architecture, pointing out ways that the properties of the algorithms have influenced the design is given. Author

N83-34188# Naval Training Equipment Center, Orlando, Fla.
VOICE TECHNOLOGY IN NAVY TRAINING SYSTEMS
R. BREAUX, M. BLIND (Eagle Technology, Inc.), and R. R. LYNCHARD (Eagle Technology, Inc.) *In* AGARD Speech Process. 19 p (SEE N83-34179 22-32) May 1983 refs
(Contract N61339-80-G-0003)
Avail: NTIS HC A06/MF A01

The nature, constraints and applications of computer voice technology (CVT) are presented. It also shows you how to evaluate voice technology for meeting training requirements, and how to incorporate CVT into your training design. Let's look at the technology - the how does it work of computer speech generation and voice recognition. This is not a highly technical discussion for two reasons. First, a technical discussion would require a highly technical background and would not further your use of the technology. Second, the technology is continually diversifying. It is becoming increasingly difficult to keep track of the various agencies and vendors involved in CVT, no less their individual approaches, techniques, and special interests and applications. Rapid advances in language analysis and other related technologies add to the rapid technical growth of this field. Author

N84-12367# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THE PERFORMANCE OF ANTENNAS IN THEIR OPERATIONAL ENVIRONMENT
Loughton, England Sep. 1983 243 p refs Lecture ser. held in Ankara, Turkey, 19-20 Oct. 1983, in Athens, 24-25 Oct. 1983, and in Brussels, 27-28 Oct. 1983
(AGARD-LS-131; ISBN-92-835-1461-0; AD-A135087) Avail: NTIS HC A11/MF A01

Antennas provide gain in any direction, and the effect of the operational environment on this parameter is fundamentally important for the performance of radio systems. Yet the effect of the environment on antennas is often overlooked. The design of the antenna is often specified in terms of its operation over a perfectly conducting flat ground plane, which if the antenna is to be used on three dimensional bodies or in a complex environment, has little to recommend it except cost. The Lecture Series will cover: techniques for measurement/prediction of antenna performance (experimental modeling and in situ measurements); performance of fixed and transportable antennas (terrain effects, masts, building effects, re-radiation by supporting towers); performance of mobile antennas (effects of supporting platforms such as automobiles, ships, aircraft); non-linear scatterers; and performance of antennas in plasmas. For individual titles, see N84-12368 through N84-12377.

N84-12368# Communications Research Centre, Ottawa (Ontario).
SCALE MODELLING AND FULL SCALE MEASUREMENT TECHNIQUES WITH PARTICULAR REFERENCE TO ANTENNAS IN THEIR OPERATIONAL ENVIRONMENTS
J. S. BELROSE *In* AGARD The Performance of Antennas in their Operational Environ. 25 p (SEE N84-12367 03-32) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

Recent advances in antenna design and the need for more accurate prediction of performance of antennas in their operational environment has increased the need for improved electrical measurements, and there was a significant accompanying development in antenna metrology. Some of these developments, those relevant to the theme of these lectures, are reviewed here Author

N84-12369# Communications Satellite Corp., Clarksburg, Md.
CALCULATION OF GROUND WAVE ATTENUATION OVER IRREGULAR, INHOMOGENEOUS, LAYERED MEDIA USING PROGRAM WAGNER
R. H. OTT *In* AGARD The Performance of Antennas in their Operational Environ. 17 p (SEE N84-12367 03-32) Sep 1983 refs
Avail: NTIS HC A11/MF A01

A method for calculating the ground wave field over irregular, inhomogeneous terrain was developed, and comparisons with

alternative analytical methods were made for idealized terrain profiles such as concave parabolas, sea-land-sea paths, and single Gaussian ridges. This method employs a numerically efficient algorithm, PROGRAM WAGNER, based on an integral equation. PROGRAM WAGNER appears the only method general enough for calculating ground wave attenuation along detailed paths. The fundamentals of PROGRAM WAGNER to the user seeking to make path loss calculations are explained. A users guide, the complete FORTRAN IV program listing, and sample input and output are included. Comparisons of computed field strengths are presented, with measured values over a path in the Netherlands at 10 frequencies from 2 to 30 MHz. Also, PROGRAM WAGNER at 5 and 30 MHz is compared with a method based on scattering from multiple knife edges. Finally, reciprocity is shown to provide necessary and useful criteria for spacing the observation points along the terrain profile. Author

N84-12370# Lawrence Livermore National Lab., Calif.
PHYSICAL MODELING OF EM PROPAGATION OVER NONHOMOGENEOUS TERRAIN
R. J. KING *In* AGARD The Performance of Antennas in their Operational Environ. 19 p (SEE N84-12367 03-32) Sep. 1983 refs
(Contract W-7405-ENG-48)
Avail: NTIS HC A11/MF A01

To obtain experimental data for comparison with the theoretical results obtained from mathematical groundwave propagation models, it is often expedient to conduct experiments on laboratory models using microwaves. Besides the obvious convenience and reduced cost, practical difficulties encountered in full scale experiments are avoided (e.g., weather and other uncontrolled parameters such as path nonhomogeneities, earth curvature, buildings, right-of-ways, etc.). There is no need to use exact similitude scaling; the media and geometries are generally chosen to test the limits of the theory's validity. The design of several much models in the frequency range of 405 GHz is discussed, and the experimental results are compared with the corresponding theory. Specific examples are propagation over planar and curved surfaces (including stratified media, e.g., layered earth, sea ice, etc.), mixed paths (including media having abrupt discontinuities such as land-sea boundaries, gradual nonuniformities such as sloping beaches, off-path such as land-sea boundaries, gradual nonuniformities such as sloping beaches, off-path discontinuities such as islands, lakes and peninsulas), uniaxially anisotropic media, and media having an index of refraction near unity such as heavy vegetation. Author

N84-12371# Hochschule der Bundeswehr, Munich (West Germany).
INTERACTION OF ANTENNAS WITH MASTS UNDER SPECIAL CONSIDERATION OF THE SENSITIVITY AND NONLINEAR EFFECTS IN SHIP BORNE RECEIVING SYSTEMS
H. K. LINDENMEIER *In* AGARD The Performance of Antennas in their Operational Environ. 17 p (SEE N84-12367 03-32) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

The minimum height of active and passive rod antennas is presented as a function of the environmental noise. A high linearity of the system is necessary to suppress intermodulation and crossmodulation effects generated by high level signals radiation from the transmitters on the ship. In many cases this problem only is solved by selective means at the front end of a receiving system. An appropriate solution is found in a fast tunable active receiving antenna. The effective height, the antenna impedance and the vertical pattern of an antenna mounted on top of a mast are influenced in an undesired way. The available dynamic of the receiving system is reduced considerably by the interaction of the mast and the antenna. Due to the resonant effects of the mast-antenna structure this reduction factor is frequency dependent and increases with increasing height of the mast. In addition there is a severe disturbing influence of the mast on the vertical diagrams of the rod antenna on this mast. Passive broadband rod antennas should not be mounted on a mast at all. With an active antenna however the effect of the mast on the antenna properties are reduced. In contrary to rod antennas loop antennas are advantageously decoupled from the mast by symmetrical mounting on top of a rotationally symmetrical mast. Author

N84-12372# Royal Aircraft Establishment, Farnborough (England). Radio and Navigation Dept.
INFLUENCE OF THE AIRFRAME ON THE PERFORMANCE OF ANTENNAS FOR AVIONICS
M. J. SIDFORD *In* AGARD The Performance of Antennas in their Operational Environ. 15 p (SEE N84-12367 03-32) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

The performance of antennas mounted on airframes is an important factor in the design of airborne radio systems, and is considered at an early stage in the study and definition of the system requirements for any particular aircraft and associated operational scenario. This is becoming critical as the number of systems and their complexity increases, and as the number of associated antennas required is further multiplied in the application of such techniques as adaptive array signal processing. The infuences of the airframe environment on antenna properties such as radiation pattern, gain, impedance polarization and coupling, and means of quantifying such influences are discussed. Related electromagnetic structure-dependent effects due to non-linear junctions, and the use of carbon fiber composite materials are also considered. The limitations of system performance resulting from airframe-antenna interaction are difficult to quantify, since detailed knowledge of particular system parameters, associated hardware, and operational scenarios is required. Author

N84-12373# Lawrence Livermore National Lab., Calif. Electronics Engineering Dept.
NUMERICAL MODELING TECHNIQUES FOR ANTENNAS
E. K. MILLER *In* AGARD The Performance of Antennas in their Operational Environ. 29 p (SEE N84-12367 03-32) Sep. 1983 refs
(Contract W-7405-ENG-48)
Avail: NTIS HC A11/MF A01

An overview of wire-antenna computer modeling is given for infinite media and half-space type problems. The formulation and numerical solution methods are summarized, and applications are demonstrated with numerous examples. Author

N84-12374# Lawrence Livermore National Lab., Calif.
NUMERICAL MODELING TECHNIQUES FOR HALF-SPACE (GROUND) PROBLEMS
E. K. MILLER, G. J. BURKE, R. J. KING, and N. C. MATHUR (Illinois Univ., Chicago) *In* AGARD The Performance of Antennas in their Operational Environ. 33 p (SEE N84-12367 03-32) Sep. 1983 refs
(Contract W-7405-ENG-48)
Avail: NTIS HC A11/MF A01

In the frequency range below a few hundred MHz, the earth-air interface significantly affected are: the object's current distribution and input impedance (if an antenna); and the near and far fields that it produces. The problem of modeling both the object-ground near-field interaction and the ground screens used to reduce or control this interaction is discussed here. The basic model (Part 1) employed for the object-ground interaction uses a thin wire approximation to the electric-field integral equation in which the kernel includes the interface effect via the usual Sommerfeld integrals. Both the reflected and transmitted fields are accounted for so that objects on both sides of the interface, or even penetrating the interface, are modeled. Another approach (Part 2) to modeling a ground system uses the surface impedance Z (subs) to represent the boundary conditions at the interface. To permit applications to generic set of problems, Z (subs)(rho) is permitted to vary arbitrarily in the radial direction. A one dimensional integral equation is first used to solve for the tangential magnetic field on the interface. This field is then used in a two dimensional integral to find the radiation patterns for arrays of vertical dipoles over ground screens. Author

N84-12375# Concordia Univ., Loyola Campus, Montreal (Quebec). Dept. of Electrical Engineering.
NUMERICAL MODELLING METHODS FOR PREDICTING ANTENNA PERFORMANCE ON AIRCRAFT
S. J. KUBINA *In* AGARD The Performance of Antennas in their Operational Environ. 38 p (SEE N84-12367 03-32) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

Typical case studies that involve the application of Moment Methods to the prediction of the radiation characteristics of antennas in the HF frequency band are examined. The examples consist of the analysis of a shorted transmission line HF antenna on a CHSS-2/Sea King helicopter, wire antennas on the CP-140/Aurora patrol aircraft and a long dipole antenna on the Space Shuttle Orbiter spacecraft. In each of these cases the guidelines for antenna modeling by the use of the program called the Numerical Electromagnetic Code are progressively applied and results are compared to measurements made by the use of scale-model techniques. In complex examples of this type comparisons based on individual radiation patterns are insufficient for the validation of computer models. A volumetric method of radiation pattern comparison is used based on criteria that result from pattern integration and that are related to communication system performance. This is supplemented by hidden-surface displays of an entire set of conical radiation patterns resulting from measurements and computations. Antenna coupling considerations are discussed for the case of the dual HF installation on the CP-140/Aurora aircraft. Author

N84-12376# Los Alamos Scientific Lab., N. Mex.
EFFECTS OF NONLINEAR LOADS ON ANTENNAS AND SCATTERERS
J. A. LANDT *In* AGARD The Performance of Antennas in their Operational Environ. 22 p (SEE N84-12367 03-32) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

Nonlinear loads on antennas are used to advantage or degrade the performance of a communications system. Nonlinear elements are routinely used to protect sensitive receivers from high-power signals including high-power microwaves and EMP (electromagnetic pulse). Time-varying loading of antennas are used to modulate the radar backscatter cross section to produce sidebands at the modulation frequency. Nonlinear elements are used to detect the electromagnetic energy incident on an antenna, and thus used as a measurement technique. Nonlinear loads are also used for pulse shaping of the fields radiated by pulse-excited antennas. Active loads are used to increase the performance of electrically small antennas and closely coupled arrays. Alternatively, undesired semiconducting junctions on structures near antennas produce intermodulation products that seriously degrade performance (this is often called the "rusty-bolt" effect). The techniques available for analyzing these effects are reviewed and representative examples given. A time-stepping procedure is treated in detail.
Author

N84-12377# Toronto Univ. (Ontario). Dept. of Electrical Engineering.
PERFORMANCE OF ANTENNAS IN PLASMA
K. G. BALMAIN *In* AGARD The Performance of Antennas in their Operational Environ. 19 p (SEE N84-12367 03-32) Sep. 1983 refs
Avail: NTIS HC A11/MF A01

The Waves ı Space Plasmas (WISP) facility is expected to be flown on the Space Shuttle in 1987. The payload will include Spacelab, a 300 m tip-to-tip dipole antenna for wave launching and reception, and a small subsatellite for remote signal reception and plasma diagnostics. The objectives are to study wave injection and propagation in the ionospheric plasma, and to use these phenomena to probe the structure and morphology of the ionosphere. To achieve these objectives, it is essential to understand how much the properties of a long dipole antenna are affected by the surrounding anisotrop · plasma medium. The WISP project with emphasis on antenna-related aspected is summarized, and the state of the art on the subject of antennas in plasmas is reviewed. Author

N84-24943# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
CHARACTERISTICS OF THE LOWER ATMOSPHERE INFLUENCING RADIO WAVE PROPAGATION
A. W. BIGGS, ed. Loughton, England Feb. 1984 313 p refs In ENGLISH and FRENCH Symp. held in Spatind, Norway, 4-7 Oct. 1983
(AGARD-CP-346; ISBN-92-835-0347-3; AD-A145046) Avail: NTIS HC A14/MF A01

The lower atmosphere and its characteristics which influence radio wave propagation were studied. The influence of rain and other particles, refraction effects, long range propagation were examined. The following topics were discussed: (1) meteorological and radiometeorlogical parameters which may influence terrestrial on earth-space radio links; (2) various models and methods to predict the effects of these parameters on radio waves; (3) the effect of turbulence and particle scattering on optical propagation; investigation of methods to overcome perturbations due to the propagation effects. For individual titles, see N84-24944 through N84-24970.

N84-24944# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).
D-1 STATISTICAL MODEL OF TROPOSPHERIC MULTIPATH PROPAGATION [MODELE STATISTIQUE DE LA PROPAGATION PAR TRAJETS MULTIPLES TRAPOSPHERIQUES]
L. BOITHIAS *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 2 p (SEE N84-24943 15-32) Feb. 1984 refs In FRENCH
Avail: NTIS HC A14/MF A01

The distribution of levels received on a visibility link which does not involve stable reflections on the ground can, in general, be represented by the Rice-Nakagami law because this law gives the statistical distribution of the sum of a deterministic vector and of an uncertain vector. When the deterministic vector has a null or negligible amplitude, a Rayleigh law is obtained. The essential problem is to find the relations between the parameters of the distribution and those of the link (distance, frequency, climate, etc.). Current models of these relations flow from two propositions. The sum of the power transported by the deterministic vector and of that transported by the uncertain vector is an uncertain variable whose average is equal to the power received in free space and the variation type is proportional to the distance. For inferior distances around 50 km, the variation type can be considered as null (the sum of the powers is a certain quantity) The power transported by the deterministic vector decreases exponentially.
Transl. by A.R.H.

N84-24945# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).
TWO TYPES OF ERRORS MADE IN PREDICTION WAVE ATTENUATION BY RAIN [DEUX TYPES DERREURS FAITES DANS LA PREVISION DE ATTENUATION DES ONDES PAR LA PLUIE]
L. BOITHIAS *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 10 p (SEE N84-24943 15-32) Feb. 1984 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A14/MF A01

Most methods proposed for predicting wave attenuation due to rain aim to derive the statistical distribution of attenuation on a path from the statistical distribution of rain rate at a point of the path. For that, these methods require the choice of a space model of rainy area or rainy volume. It appears that two erroneous assumptions are often made in these models. In the horizontal rain model there is confusion in the general concept of rain cells. between the rainy area of 15 to 20 kilometers in diameter which has to be considered for rain attenuation and the core of a few kilometers in diameter which has to be considered for rain scatter In the vertical rain model, there is confusion between the vertical extent of rain fall and the height of 0 deg isotherm. In fact these quantities may be significantly different especially for low latitudes These two erroneous assumptions are partly responsible for delaying the elaboration of a simple and reliable rain model for the prediction of rain attenuation. A.R.H.

N84-24946*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Satellite Communications Group.
ICE DEPOLARIZATION ON LOW-ANGLE 2 GHZ SATELLITE DOWNLINKS
W. L. STUTZMAN, C. W. BOSTIAN, A. TSOLAKIS, and T. PRATT *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 11 p (SEE N84-24943 15-32) Feb. 1984 refs Sponsored in part by NASA and International Telecommunications Satellite Organization Prepared in cooperation with International Telecommunications Satellite Organization, Washington, D.C., and JPL, California Inst. of Tech., Pasadena
Avail: NTIS HC A14/MF A01

The impact of ice depolarization on the statistical performance of satellite downlinks were investigated. Propagation data recorded during 1979 and 1980 to see what impact of ice depolarization on link performance were analyzed. The effects on the cross polarization discrimination (XPD) statistics amounted to at most a 2 to 4 dB reduction in the XPD values which rain would have produced for a given percentage of time. Ice depolarization had no effect on the statistics of XPD values below the 0.01% level. Most of the severe ice depolarization events were associated with drops in barometric pressure and the passage of intense cold fronts through our area. Ice contents as the product of three individually undetermined quantities were defined: ice particle density, ice cloud thickness, and the average volume of the ice crystals. It is indicated that populations of ice particle with ice contents on the order of 0.002 m4/m3 are probably responsible for the lower values of measured XPD. E.A.K.

N84-24947# Rome Air Development Center, Hanscom AFB, Mass. Electromagnetic Sciences Div.
THE EFFECT OF A LOW-ALTITUDE NUCLEAR BURST ON MILLIMETER WAVE PROPAGATION
E. E. ALTSHULER *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 18 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

The limitations imposed on millimeter wave propagation by the dust produced by a low altitude nuclear burst were examined. The closer the burst is to the surface, the larger will be the dust loaded into the nuclear fireball, an extremely hot and highly ionized spherical mass of air and gaseous weapon residues. The fireball absorbs, scatters and refracts the propagated wave and may also produce scintillations. Only the losses due to absorption and scattering are calculated. A sensitivity analysis of attenuation dependence on the pertinent dust parameters was conducted. It was found that the dust attenuation is very heavily dependent on the maximum particle radius, the number of large particles in the distribution and the real and imaginary components of the index of refraction over the range from dry sand to clay. The attenuation is also proportional to the fraction of the atmosphere filled with dust. The attenuation includes losses due to fireball ionization, dust and atmospheric oxygen and water vapor. Results are obtained as a function of time after burst, distance from burst, elevation angle and frequency up to 95 GHz. It is found that very high attenuations occur within about 20 seconds after the burst if the path intersects the fireball. At later times attenuations of the order of tens of dB are possible due to dust alone. After several minutes the larger dust particles have settled and attenuations of several dB are present. E.A.K.

N84-24948# Norwegian Telecommunications Administration Research Establishment, Kjeller.
MEASUREMENTS OF ATMOSPHERIC EFFECTS ON SATELLITE LINKS AT VERY LOW ELEVATION ANGLE
O. GUTTEBERG *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 12 p (SEE N84-24943 15-32) Feb. 1984 refs Sponsored in part by ESA
Avail: NTIS HC A14/MF A01

Propagation measurements with the Orbital Test Satellite (OTS) at the Arctic islands of Spitzbergen (78 deg) are reported. The elevation angle to the satellite was 3.2 deg and the frequency 11.8 GHz. The experiments included: measurements of atmospheric scintillations, cross polarization discrimination and space diversity improvements. It is shown that the distributions of the received satellite beacon amplitude can be approximated by Rice distributions. Large diversity gain was obtained by using horizontal spacing of 1 km. A wideband (TV) transmission experiment was also performed. E.A.K.

N84-24949# Naval Ocean Systems Center, San Diego, Calif.
BLUE-GREEN PROPAGATION THROUGH CLOUDS Abstract Only
G. C. MOORADIAN *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 1 p (SEE N84-24943 15-32) Feb. 1984
Avail: NTIS HC A14/MF A01

Optical communications in the atmosphere, space and underwater was investigated. The performance of a space to Earth/underwater link through the adverse atmospheric propagation channel is of paramount importance. The presence of clouds along the propagation path scatter the blue-green radiation and cause spatial, angular, and temporal spreadings of the beam. This condition decreases the peak power at the receiver by both multipath time delays, and spatial spreading and also increases the apparent source size. Performance may be seriously degraded. This effect are somewhat compensated for by adapting the receiver; increasing the field of view of the receiver to accept the scattered radiation. The temporal, spatial, and angular spreading of a blue-green pulse through clouds and fogs are measured as a function of optical thickness and receiver field of view. E.A.K.

N84-24950# Naval Research Lab., Washington, D. C.
THE EFFECTS OF METEOROLOGY ON MARINE AEROSOL AND OPTICAL AND IN PROPAGATION
S. G. GATHMAN *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 16 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Optical and IR propagation which can be strongly influenced by aerosol in the marine boundary layer is discussed. The effects are wavelength dependent to use in all cases. Sources and sinks of this aerosol in operation over the ocean can be predicted from a full knowledge of the meteorological situation. Once airborne the spatial distribution of the aerosol is a function of the mixing processes, the micrometeorology of the marine boundary layer and the history of these processes to which the aerosol is exposed. The marine aerosol size distribution, which describes the concentration of droplets for each size class, is modeled from standard meteorological parameters and the resultant extinction and absorption is calculated from the size distribution for wavelengths of from 0.2 to 40.0 micrometers using Mie theory. The model uses the stored historical marine data bases to produce climatologies of the optical and IR properties over the oceans. The art of meteorological forecasting can be employed to forecast the necessary model inputs from which desired future optical, and IR properties can be determined. E.A.K.

N84-24951# Portsmouth Polytechnic (England). Dept. of Electrical and Electronic Engineering.
A SYSTEM TO MEASURE LOS ATMOSPHERIC TRANSMITTANCE AT 19 GHZ
E. VILAR, T. J. MOULSLEY, J. AUSTIN, A. HEWITT, J. R. NORBURY (Science Research Council, Chilton, England), and S. K. BARTON (Science Research Council, Chilton, England) *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 16 p (SEE N84-24943 15-32) Feb. 1984 refs Sponsored in part by UK Departmental Users Committee
Avail: NTIS HC A14/MF A01

The principles of a wideband test system for measuring the complex transmittance of a line-of-sight (LOS) microwave radio link subject to fading and multipath are discussed. The technique which uses cross-correlation between pseudo-binary random sequences falls into the realm of spread spectrum techniques. The system described is designed cover 1 GHz bandwidth at 19 GHz and has the objective of measuring both co-polar and cross-polar transmittance thus generating the complex transmittance matrix. Computer simulations and preliminary experimental results are presented together with a brief initial comparison with other systems. M.G.

N84-24952# Science Research Council, Chilton (England).
A GAAS REFRACTOMETER FOR TROPOSPHERIC STUDIES
U. M. YILMAZ, G. R. KENNEDY, and M. P. M. HALL *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 6 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

A microwave refractometer designed to be used in studies of multipath propagation on line-of-sight microwave links, and studies of transhorizon ducting is described. The application of a GaAs FET amplifier in a feedback loop containing the sampling cavity produced a lightweight and simple refractometer which was tested and used in a light aircraft with on-board data processing. These various aspects are discussed in some detail, together with the background requirements and specification. M.G.

N84-24953# National Telecommunications and Information Administration, Boulder, Colo.
PREDICTION OF MULTIPATH FADING ON TERRESTRIAL MICROWAVE LINKS AT FREQUENCIES OF 11 GHZ AND GREATER
D. D. CROMBIE *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 9 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Published data on the probability of multipath fading on different paths with lengths of to 45 km, at frequencies up to 37 GHz, measured in different countries, were analyzed. For the paths which have probabilities greater than 0.001% for 20 dB fades, it is found that the fading probability increases with antenna beam width. In addition, it is found that increasing the clearance of the path above surrounding terrain reduces the fading probability. Inclusion of these two variables, in addition to frequency and path length, reduces the uncertainty in prediction of fading probability by a factor of 80. Author

N84-24954# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).
EFFECT OF LEAP LENGTH ON THE QUALITY OF LARGE CAPACITY NUMERICAL LINKAGES [EFFET DE LA LONGUEUR *DU BOND SUR* LA QUALITE DES LIAISONS NUMERIQUES A GRANDE CAPACITE]
J. BATTESTI *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 4 p (SEE N84-24943 15-32) Feb. 1984 refs In FRENCH
Avail: NTIS HC A14/MF A01

With regards to the selectivity fadings due to multiple paths, these fadings produce signal degradation that is more important than that of a nonselective fading of the same profundity. This occurs as if the capacity of the equipment for fading were reduced in the presence of multipath propagation and leads to the introduction of the notion of sharply-defined capacity as opposed to the rough capacity measured in the case of nonselective fading. It is shown that, for a numeric signal of given characteristics (numeric debit, type of modulation) the finely defined capacity is independent of the length of the shift. Transl. by A.R.H.

N84-24955# Bell Telephone Labs., Inc., Holmdel, N. J.
MULTIPATH OUTAGE PERFORMANCE OF DIGITAL RADIO RECEIVERS USING FINITE-TAP ADAPTIVE EQUALIZERS
N. AMITAY and L. J. GREENSTEIN *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 10 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Recent analysis/simulation studies have quantified the multipath outage statistics of digital radio systems using ideal adaptive equalization. The use of finite-tap delay line equalizers is considered with the aim of determining how many taps are needed to approximate ideal performance. To this end, is considered an M-level QAM system using cosine rolloff spectral shaping and an adaptive equalizer with either fractionally-spaced or synchronously-spaced taps is assumed. A widely used statistical model for the fading channel is used. For each trial, we compute a [illegible] signal-to-distortion measure, suitably maximized with respect to the tap gains. One can thereby obtain probability distributions of this measure for specified combinations of system parameters. These distributions, in turn, can be interpreted as [illegible] capabilities (or outage seconds) vs. the number of [illegible]. A major finding is that, for the assumed multipath fading model, very few taps (the order of five) are needed to approximate the performance of an ideal infinite-tap equalizer. It is also found that a simple, suboptimal form of timing recovery is generally quite adequate; and that fractionally-spaced equalizers are more advantageous than synchronously-spaced equalizers with the same number of taps. This advantage is minor for rolloff factors of 0.5 and larger but increases dramatically as the rolloff factor approaches zero. M.G.

N84-24956# Technische Hogeschool, Delft (Netherlands). Dept. of Electrical Engineering.
SPHERICAL PROPAGATION MODELS FOR MULTIPATH-PROPAGATION PREDICTIONS
L. P. LIGTHART *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 8 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Multipath fading leads to a limitation in the availability and/or reliability of microwave links. To study the propagation mechanism under fading conditions propagation models, based on ray theory, above a spherical earth were developed and compared to the well-known planar propagation model above a flattened earth. The reasons for studying spherical propagation models are: (1) to avoid the limitation of small elevation angles in planar propagation models, (2) to investigate the computed and measured path delay on the microwave line of sight links, and (3) to set up an analytical approach for the spherical propagation model without numerical difficulties and computing-time intensive procedures. Computational results of the models are shown, including and accuracy analysis, and the use of spherical propagation models is illustrated for surface duct layers above water. M.G.

N84-24957# Netherlands Foundation for Radio Astronomy, Dwingelo.
CORRECTING RADIO ASTRONOMY INTERFEROMETRY OBSERVATIONS FOR IONOSPHERIC REFRACTION
T. A. T. SPOELSTRA *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 8 p (SEE N84-24943 15-32) Feb. 1984 refs Sponsored in part by The Netherlands Organization for the Advancement of Pure Research (Z.W.O.)
Avail: NTIS HC A14/MF A01

Radio astronomical observations with local interferometers and very long baseline interferometers (VLBI) are affected by atmospheric (i.e., tropospheric and ionospheric) refraction. A correction procedure for ionospheric refraction for radio astronomy interferometry is reviewed. This correction is applied to observations made with the Westerbork Synthesis Radio Telescope (WSRT). The method used for WSRT observations can also be used to correct VLBI observations for ionospheric refraction. If networks of ionosonde and satellite observing stations operate during the astronomical VLBI observations, pathlength corrections ranging from several wavelengths to a fraction of a wavelength are possible, provided the geographical distribution of these stations is similar to the VLBI network. The possibilities of this procedure are compared with the results derived by e.g., dual frequency VLBI observations. R.J.F.

N84-24958# Plessey Radar Ltd., Chessington (England). Operational Research.
THE ESTIMATION AND CORRECTION OF REFRACTIVE BENDING IN THE AR3-D TACTICAL RADAR SYSTEMS
F. BARKER *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 15 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

The development of techniques for the estimation and correction of refractive bending, in the vertical plane, in the evolution of a family of radar systems is discussed. The systems are based on the AR3-D radar and are in service in several countries and climates. After a brief description of the AR3-D radar systems, the Operational requirements, the Engineering solutions, some of the Human Factors which affect the design and implementation, and future possibilities are discussed. A simple and exact approach to sensitivity analysis is given. A fast algorithm for the online correction of radar plot elevation data is given. The need for education on refractive effects and for understanding the

possibilities which exist for estimation and correction in 3-D radar systems is emphasized. R.J.F.

N84-24959# Florence Univ. (Italy).
EFFECT OF MULTIPLE SCATTERING ON THE PROPAGATION OF LIGHT BEAMS IN DENSE NONHOMOGENEOUS MEDIA
P. BRUSCAGLIONI, A. ISMAELLI, L. LOPORTO, and G. ZACCANTI *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 13 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Calculations performed by means of a Monte Carlo method show that the contribution of forward single and multiple scattering to the received power in an optical transmission link through a turbid atmosphere increases when the scattering medium is more concentrated near the receiver. An experimental check of this result is also presented. Author

N84-24960# Massachusetts Inst. of Tech., Cambridge.
ADAPTIVE COMPENSATION FOR ATMOSPHERIC TURBULENCE EFFECTS ON OPTICAL PROPAGATION
D. P. GREENWOOD *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 10 p (SEE N84-24943 15-32) Feb. 1984 refs Sponsored in part by DARPA
Avail: NTIS HC A14/MF A01

Optical wavefronts propagated in atmospheric turbulence suffer significant degradation manifested as beam spread, beam wander, and scintillation. The state of progress of this field of research is reviewed as well as recent efforts to overcome the limiting effects of refractive turbulence. Adaptive optical systems are being developed to sense the phase distortion present on propagated beams and to compensate for these aberrations in real time. Equations describing the magnitude of the turbulence effect and also describing the degree to which compensation may be achieved are given. Supporting data are presented as well. R.J.F.

N84-24961# D-Peek, Inc., Boulder, Colo.
EFFECTS OF ATMOSPHERIC TURBULENCE ON OPTICAL PROPAGATION
R. S. LAWRENCE *In* AGARD Characteristics of the Lower Atmospher Influencing Radio Wave Propagation 8 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

The optical refractive index of the atmosphere depends on temperature, pressure, and humidity. Naturally occurring variations of these quantities, with scales of a few centimeters and associated with atmospheric turbulence, cause optical scintillation, image distortion, and laser beam broadening. The meteorological conditions that influence the occurrence of this optical turbulence are reviewed. The optical significance of turbulence at various heights in the atmosphere is discussed. The differences between these optical effects and the corresponding phenomena at radio wavelengths are pointed out. While beam broadening increases indefinitely with the strength of optical turbulence, scintillation saturates and eventually decreases with increasing turbulence. This important effect is discussed and a phenomenological theory that explains it is given. Estimates are given of the limitations imposed by atmospheric turbulence on various types of optical systems. The techniques that can be used to measure optical turbulence are discussed. R.J.F.

N84-24962# Service Meteorologique Metropolitan, Paris (France).
D-19 EVALUATING THE HEIGHT OF TROPOSPHERIC CONDUCTION OF EVAPORATION [EVALUATION DE LA HAUTEUR DU CONDUIT TROPOSPHERQUE DEVAPORATION]
B. STRAUSS *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 8 p (SEE N84-24943 15-32) Feb. 1984 refs In FRENCH
Avail: NTIS HC A14/MF A01

The first attempts to estimate the height of the conduction of evaporation from outputs of a numerical prediction model used in meteorology are presented. The model of the European Center of midterm weather forecasting is used. Outputs in grid points of wind at 10 meters, temperature and Td at 2 meters, and ocean surface temperature are used in the calculations. The method is tested on a section of the North Atlantic and on a zone of the Indian Ocean by comparing estimates from the model with marine meteorological observations. A.R.H.

N84-24963# Marconi Co. Ltd., Great Baddow (England)
A RADIO INTERFERENCE MODEL FOR WESTERN EUROPE
S. ROTHERAM *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 15 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Field strength distributions for 106 land, sea and mixed paths of three terrain types are analyzed for their dependence on scattering angle, probability, terrain type, frequency and terminal height. Good models are derived for the sea and low terrain land paths. The medium and high terrain land paths show greater variability. The frequency dependence is shown to be weak. The dependence on terminal heights is shown to be nonexistent except for the effect on the scattering angle. Mixed paths are shown to be like land paths and are quite unlike sea paths. Author

N84-24964# Consiglio Nazionale delle Ricerche, Bologna (Italy). Inst. di Radioastronomy.
TRANSHORIZON MICROWAVE PROPAGATION MEASUREMENTS RELATED TO SURFACE METEOROLOGICAL PARAMETERS
R. AMBROSINI, M. CAPORALONI (Bologna Univ., Italy), and G. TOMASSETTI *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 6 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Experimental results of three months of continuous measurements at 3cm. wavelengths are given for the following aligned paths; the first, 100 Km. long, over flat land (Po Valley); the second, 140 Km. long, across the Adriatic Sea; the third consisting of the sum of the previous ones. The stations are linked to radiowaves only during super standard atmospheric conditions. The period considered was in the autumn-winter season, from October to December, for 92 days of observations. Hourly efficiency istograms are drawn. They present a peculiar trend for the different paths; variable over land, with a strong maximum in the nocturnal hours; almost constant over sea, with a characteristic peak around noon for the combined path. Efficiencies up to 43% have been measured on flat land during the night, while lower values were found on the sea. An attempt to find a direct connection between radio signal reception in super standard conditions and surface meteorological parameters has shown a strong correlation with water vapor pressure for the sea path; radio ducting sets up for a monotonic decoying of the water content of the air. Measurements over flat land show radio ducting to be almost nocturnal phenomenon. Radio propagation beyond the horizon detects temperature inversions caused by nocturnal cooling and therefore, there is not very clear evidence of correlation with ground meteorological data. Author

N84-24965# Naval Ocean Systems Center, San Diego, Calif. Ocean and Atmospheric Sciences Div.
TROPOSPHERIC PROPAGATION ASSESSMENT
K. D. ANDERSON, J. H. RICHTER, and H. V. HITNEY *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 6 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

It is well known that microwave propagation in a marine environment frequently exhibits unexpected behavior. The deviation from 4/3 earth propagation calculations is due to the fact that the vertical refractivity distribution of the troposphere rarely follows the standard lapse rate of -39 N/km. Instead, the troposphere is generally composed of horizontally stratified layers of differing refractivity gradients. The most striking propagation anomalies result when a layer gradient is less than -157 N/km, forming a trapping layer. In the marine environment, there are two mechanisms which produce such layers. An elevated trapping layer is created by the advection of a warm, dry air mass over a cold, moist air mass producing either a surface-based or an elevated duct which may affect frequencies as low as 100 MHz. A very persistent surface trapping layer is due to water evaporation at the air-sea interface. This surface, or evaporation duct is generally thin, on the order of 10 m in vertical extent, and is an effective trapping mechanism for frequencies greater than 3 GHz. With the introduction of the Integrated Refraction Effects Prediction System

(IREPS) into the US Navy, fleet units now have the capability to evaluate accurately the performance of their EM systems when the refractive environment is known. However, these units may have to plan for operations thousands of miles away under different refractivity conditions. To assist in planning, a worldwide upper air and surface climatology has been developed for use through the IREPS programs. The IREPS concept is reviewed and a description of the tropospheric ducting data base is presented. Author

N84-24966# Brunel Technical Coll., Bristol (England). Dept. of Radiocommunications and Radar.
DISTORTION OF A NARROW RADIO BEAM IN A CONVECTIVE MEDIUM
W. G. BURROWS *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 21 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

In considering the basic mechanism of heat exchange by convective circulation in the atmosphere it is apparent that the resultant thermal cell structures, as proposed by Benard, may possess refractive index properties which will influence the cross-sectional shape of a narrow conical radio beam. A simplified classical toroidal cell is considered for the purpose of analysis to show that the core of such a cell in the atmosphere may act as a cylindrical concave lens. The resultant distortion of a narrow beam is then discussed. The concept if then developed further to show that trans-horizon propagation may result from an in-line array of thermal cells. Author

N84-24967# Johns Hopkins Univ., Silver Spring, Md.
ANOMALOUS PROPAGATION AND RADAR COVERAGE THROUGH INHOMOGENEOUS ATMOSPHERES
H. W. KO, J. W. SARI, M. E. THOMAS, P. J. HERCHENROEDER (ESD, Hanscom AFB, Mass.), and P. J. MARTONE *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 14 p (SEE N84-24943 15-32) Feb. 1984 refs
(Contract N00024-83-C-5301)
Avail: NTIS HC A14/MF A01

A method is outlined which enables radar coverage predictions to be made under anomalous propagation conditions. Spatial and temporal changes in the height and strength of refractive layers in the troposphere are known to compromise radar coverage. Refractive layers may create coverage voids by diverting rays and may introduce anomalous clutter and range height errors in radar systems. In this paper, elements of meteorology, atmospheric boundary layer physics, and electromagnetic wave propagation are combined to investigate the effect of inhomogeneous refractive layers on radar coverage. A computer program called EMPE (Electromagnetic Parabolic Equation) has been developed to aid in these investigations. A special feature of EMPE is its ability to deal with inhomogeneous atmospheric changes in both the horizontal and vertical directions. Predictions for anomalous wave behavior have been made for frequencies from 100 MHz to 10 GHz. The results are relevant to a variety of microwave electromagnetic systems such as those used for communications, radar, and aircraft instrument landing. Author

N84-24968# British Broadcasting Corp., Kingswood (England)
THE PREDICTION OF FIELD STRENGTH IN THE FREQUENCY RANGE 30 - 1000 MHZ
R. S. SANDELL and D. W. TAPLIN *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 10 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

The background of the BBC's involvement in propagation measurement at VHF and UHF is outlined. Weaknesses in the original data are discussed. The accuracy of prediction is related to the accuracy of measurement as illustrated by an experiment dating to the development period of an interim BBC prediction method for UHF, and the accuracy of the current path loss prediction method is discussed. Possible directions of future development in prediction methods are indicated and the objectives of the BBC's research in this area are outlined. E.A.K.

N84-24969# Communications Research Centre, Ottawa (Ontario).
VHF AND UHF PROPAGATION IN THE CANADIAN HIGH ARCTIC
R. S. BUTLER, J. I. STRICKLAND, and C. BILODEAU *In* AGARD Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 8 p (SEE N84-24943 15-32) Feb. 1984
Avail: NTIS HC A14/MF A01

Radio propagation in the Arctic maritime environment was studied. Five UHF radio paths between pairs of elevated points were selected along a 300 km east-west line which parallels a potentially important navigation route through the Arctic islands. Two VHF paths, each between an elevated site and a point near sea level were also chosen to simulate communications with a ship. Partial results from the summer to winter transition season show that propagation between the elevated points is highly reliable, but that propagation along the slanted paths appears to be strongly affected by radio wave ducting. E.A.K.

N84-24970# Royal Signals and Radar Establishment, Malvern (England).
CONSIDERATIONS PERTINENT TO PROPAGATION PREDICTION METHODS APPLIED TO AIRBORNE MICROWAVE EQUIPMENT
T. ALMOND *In* Agard Characteristics of the Lower Atmosphere Influencing Radio Wave Propagation 11 p (SEE N84-24943 15-32) Feb. 1984 refs
Avail: NTIS HC A14/MF A01

Current coverage diagrams for certain airborne microwave equipments which include radars, navigation aids, communications, countermeasures sets and command links are outlined. Coverage diagrams are affected by large-scale atmospheric refraction and superrefraction. Techniques of operational use for sounding the meteorological and radioelectrical characteristics of the troposphere and coverage prediction methods are reviewed. It is concluded that there is an unreasonable reliance on horizontal homogeneity in the current prediction techniques coupled with inadequate lateral spatial sampling of the tropospheric structure. E.A.K.

N85-19269# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PROPAGATION INFLUENCES ON DIGITAL TRANSMISSION SYSTEMS: PROBLEMS AND SOLUTIONS
J. BLYTHE, ed. Loughton, England Oct. 1984 510 p refs In ENGLISH and FRENCH Symp. held in Athens, 4-8 Jun. 1984 (AGARD-CP-363; ISBN-92-835-0367-8) Avail: NTIS HC A22/MF A01

Papers and session summaries are presented which examine propagation effects having an influence on the performance of digital systems, including: noise levels, and system sensitivities to noise; man-made interference types and system sensitivities to man-made interference, and multipath effects, dispersion, fading rates, medium coherent bandwidth, channel models, and system sensitivities to these. Systems designed to counter these effects, including the various kinds of adaptive systems are also reviewed. For individual titles see N85-19270 through N85-19308.

N85-19270# Siemens A.G., Munich (West Germany)
LIMITS OF THE PROPAGATION MEDIUM WITH RESPECT TO DIGITAL SIGNAL TRANSMISSION
E. W. LAMPERT *In* AGARD Propagation Influences on Digital Transmission Systems 15 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01 CSCL 20N

The effects of the propagation medium are more pronounced in digital communication systems than in analogue ones, in particular when considering single channel systems. The quality parameters: bit-error-rate and link availability are affected not only by the received signal level but also by multipath propagation which may result in frequency selective fading or just in a too low signal level when changing the location in a mobile system or signal fading when the medium is time variable. While fading decreases the signal to noise ratio of links causing short or long terms outages, frequency selective fading causes intersymbol interference and distortion which results in classical systems in an irreducible error rate. Propagation effects for each frequency region from HF to EHF are discussed individually. For LOS-links

the typical multipath geometry is presented and data for coherence bandwidth and fading duration are given. Meteor burst scatter can only be used in digital ARQ-systems. It is shown that present systems are rather power limited than distortion limited. In digital troposcatter systems selective fading due to the mutual differential delay of the signal components is a limiting factor especially in digital systems. Delay power spectra are discussed with respect to geometry and layer structure. M.G.

N85-19271# Hellenic Navy Technology Development Office, Athens (Greece).
PROPAGATION OF WIDE BANDWIDTH SIGNALS IN A TROPOSPHERIC DUCTING SYSTEM
N. K. UZUNOGLU *In* AGARD Propagation Influences on Digital Transmission Systems 12 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The propagation properties of wide bandwidth signals transmitted through a tropospheric ducting medium are examined analytically. A flat earth model with a perfect surface conductivity (sea surface) is taken. The refractive index profile n(h) is assumed a stepwise function of the height h. Horizontal and vertical polarized waves are treated in parallel by employing similar procedures. The corresponding boundary value problems are solved by using spectral representations for the primary antenna and induced fields. Guided and radiated mode contributions are then computed by applying approximate asymptotic integration techniques under a continuous wave (CW) excitation. The behavior of wide bandwidth signals propagating in a tropospheric duct is examined in terms of the inverse Fourier transformation of the CW field expressions. Several geometries are considered such as both transmitting and receiving antennas being inside the tropospheric waveguide or the opposite. Particular attention is given to the case when the communication path crosses the waveguide ceiling. In order to determine the influence of the multipath propagation, occurring inside the ducting medium, into a real communication link a phase shift keying modulation is considered. Numerical results are given for several tropospheric ducting media in terms of the bit error rate. M.G.

N85-19272# Bell Telephone Labs., Inc., Holmdel, N. J.
DIGITAL DATA *COMMUNICATIONS OVER MICROWAVE* RADIO CHANNELS
J. SALZ *In* AGARD Propagation Influences on Digital Transmission Systems 7 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

A major contribution to system outage in a terrestrial digital radio channel is deep fading of the frequency transfer characteristic, which in addition to causing a precipitous drop in received signal-to-noise ratio also causes signal dispersion that can result in severe intersymbol interference. Because the temporal variation of the channel is slow compared to the signaling rate, the information theoretic channel capacity and the efficiency index in bits/cycle can be viewed as random processes. Based on an established mathematical model for fading channels, the probability distribution of channel capacity and the distribution of efficiency indices for different communications techniques are estimated. A crucial obstacle to achieving these rates is the nonlinear distortion introduced by power amplifiers. A method for coping with this nonlinear distortion is also described. M.G.

N85-19273# Rome Air Development Center, Griffiss AFB, N.Y.
EHF AIR-TO-AIR COMMUNICATIONS
P. N. EDRAOS *In* AGARD Propagation Influences on Digital Transmission Systems 16 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The use of the extremely high frequency (EHF) oxygen-absorption frequency band for low-detectability air-to-air communications has been proposed at various times; the development of such an EHF short-range air-to-air communications system is considered. The protection to the communications system is provided by the cumulative oxygen absorption characteristics of the atmospehre. System considerations are dealt with parametrically; the effects of aircraft velocity, altitude, antenna coverage, transmitter power, and so forth, are discussed with regard to impact on range, frequency, acquisition time, data rate, etc. A baseline system is submitted; link power budget calculations are made for the baseline, resulting in estimates for maximum allowable attenuation; system performance is assessed for a number of situations. Emphasis is on communications and the problems involved in the design and implementation of an EHF air-to-air digital voice system, concentrating on the propagation influences and constraints. M.G.

N85-19274# British Telecom Research Labs., Ipswich (England).
PROPAGATION INFLUENCES ON THE PERFORMANCE OF A REDUCED BANDWIDTH QUADRATURE PHASE SHIFT KEYED DIGITAL RADIO SYSTEM
J. E. DOBLE *In* AGARD Propagation Influences on Digital Transmission Systems 7 p (SEE N85-19269 10-32) Oct. 1984
Avail: NTIS HC A22/MF A01

British Telecom is running a field trial of a spectrally efficient (4.2 bits/Hz) reduced bandwidth quadrature phase shift keyed digital radio system for the lower 6 GHz and 4 GHz bands in a part of the UK that is subject to above average multipath activity. Some of the observations made during a two-year period are described together with the improvements made to the antennas and the methods likely to be used in predicting system performance in other locations. The current method of predicting multipath fading is examined and found wanting in its application to digital system planning. An alternative is put forward and an example of its use is given. R.S.F.

N85-19275# Boston Univ., Mass. Dept. of Astronomy.
EQUATORIAL TRANSIONOSPHERIC PROPAGATION CONDITIONS AFFECTING DIGITAL COMMUNICATIONS
J. AARONS *In* AGARD Propagation Influences on Digital Transmission Systems 13 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The strength, morphology, and spectral characteristics of *trans-ionospheric* transmissions were assessed in order to mitigate fading in trans-ionospheric digital systems. The morphology and power spectra of equatorial scintillations are discussed along with fading characteristics relevant to digital communications. Solar flux levels are related to irregularities in the F layer of the ionosphere. R.S.F.

N85-19276# General Electric Co., Syracuse, N.Y.
PROPAGATION EFFECTS ON THE DOPPLER FREQUENCY SHIFT OF SATELLITE TRANSMISSIONS
G. H. MILLMAN and M. C. ARABADJIS *In* AGARD Propagation Influences on Digital Transmission Systems 15 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The refraction phenomenon in the troposphere and the ionosphere causes an error in the Doppler frequency shift of radio transmissions emitted from a nonstationary satellite and received on the ground. Estimates are made of the Doppler error for various atmospheric and solar-geophysical conditions and are applicable for frequencies in the VHF to UHF range and above. The Doppler error imposed by the troposphere is directly proportional to frequency while, in the case of the ionosphere, the error is approximately inversely proportional to the frequency and approximately directly proportional to the vertical electron content. Under average tropospheric conditions, the tropospheric contribution to the Doppler error is predominant for frequencies on the order of 400 MHz and above. Below about 400 MHz, the ionospheric refraction effects are prevalent. The Doppler effects can be compensated for, to some extent, when the angular bending and the space vehicle velocity are known. Estimates of the angular bending due to the troposphere can be made to a fair degree of accuracy, from measurements of the surface refractivity. For the ionosphere, the vertical electron content data can be used for the estimation of the refraction angle error. R.S.F.

N85-19277# Thomson-CSF, Levallois-Perret (France).
INFLUENCE OF PROPAGATION IN DIGITAL WIRELESS BEAM, MICROWAVE LINKS [INFLUENCE DE LA PROPAGATION DANS LES FAISCEAUX HERTZIENS NUMERIQUES]
J. BURSZTEJN *In* AGARD Propagation Influences on Digital Transmission Systems 17 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH
Avail: NTIS HC A22/MF A01

Methods are presented for determining the parameters which permit the prediction of the quality of tropospheric scattering and line of sight microwave links. Wireless beam, microwave links with tropospheric scattering are considered based on experiments for determining the coherence band which is the essential parameter for digital transmission by tropospheric scattering. The effects of propagation difficulties in line of sight links are discussed with focus on depolarization and selective fading. Experimental results are given which permit calculating the sensitivity of equipment and predicting the quality of the links. Transl. by A.R.H.

N85-19278# Dutch Post Office, Dr. Neher Lab., Leidschendam.
THE IMPACT OF PROPAGATION EFFECTS ON THE DESIGN OF HIGH CAPACITY DIGITAL MICROWAVE LINKS IN THE 18 GHZ FREQUENCY BAND
L. VANDERHOEK, A. MAWIRA, and J. NEESEN *In* AGARD Propagation Influences on Digital Transmission Systems 18 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

Propagation effects cause performance impairments in high capacity radio relay links. A transmission model is presented which allows the prediction of system performance during fading conditions. This model includes propagation and equipment parameters, the values of which depend on the local radio-meteorological environment and the actual equipment characteristics. Propagation and communication experiments were carried out, allowing the prediction of system performance in its operational environment at frequencies around 18 GHz. In particular, the effects on the bit-error-ratio as caused by attenuation and cross-polarization due to rain and multipath are discussed.
R.S.F.

N85-19279# Institute for Telecommunication Sciences, Boulder, Colo.
A REVIEW OF ATMOSPHERIC MULTIPATH MEASUREMENTS AND DIGITAL SYSTEM PERFORMANCE
R. W. HUBBARD *In* AGARD Propagation Influences on Digital Transmission Systems 18 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The effects of multipath propagation on digital communication systems are discussed. Recent literature and experiments are reviewed for information that either describes or defines the phenomenon in terms of the propagation media itself. A morphology is presented which is intended to produce better understanding and improved performance of digital radio systems. The technical posture for the digital troposcatter channel up to the 1980s is summarized. R.S.F.

N85-19280# CyberCom Corp., Arlington, Va.
UHF COMMUNICATIONS THROUGH FORESTED PROPAGATION CHANNELS
A. SCHNEIDER *In* AGARD Propagation Influences on Digital Transmission Systems 19 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

A stochastic radio wave propagation model useful for assessing the effects of forests and other vegetation upon communications signals in the UHF band is described. Considering the forest as a time-invariant ensemble of randomly positioned and oriented discrete canonical scatterers, the behavior of the mean scattered radio wave in the forest is reviewed. Actual statistical data describing trunk and leaf characteristics are discussed and are used in several numerical examples. The model is then used to derive the specific attenuation attributable to the mean field in tree trunks and leaves. A more realistic series of models is also introduced which treat the forest as a stratified continuous medium. The models are used to develop the resultant field occurring as a consequence of combined direct, reflected, and lateral wave components and ground reflections. The analysis is extended through Fourier transform techniques to derive the effects important to communications systems, including pulse response and two-frequency correlation functions. R.S.F.

N85-19281# Lowell Univ., Mass. Center for Atmospheric Research.
MULTIPATH AND DOPPLER OBSERVATIONS DURING TRANSATLANTIC DIGITAL HF PROPAGATION EXPERIMENTS
B. W. REINISCH, K. BIBL, M. AHMED (GTE Sylvania, Inc., Needham Heights, Mass.), H. SOICHER (Army Communications Electronics Command, Fort Monmouth, N.J.), F. GORMAN (Army Communications Electronics Command, Fort Monmouth, N.J.), and J. C. JODOGNE (Inst. Royal Meteorologique de Belgique, Brussels) *In* AGARD Propagation Influences on Digital Transmission Systems 11 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

Digital HF transatlantic propagation experiments between two nodes at Dourbes, Belgium, and Needham, MA, using identical digisonde 256 systems became operational in October 1983. Adaptive two way sounding and real time channel evaluation studies are to be conducted among the network's nodes. Presently, the Dourbes station is transmitting 10 kW pulses using a horizontal rhombic antenna while the Needham station uses a long-periodic antenna for both transmission and reception. Amplitude and Doppler shifts of different multipath modes were measured during magnetically quiescent and disturbed periods for the first month of operation. The pulse modulation enables clear separation and identification of the multihop paths. Real time discrete Fourier transforms determine the Doppler shifts imposed by height changes of the reflecting ionospheric layers. A comparison of the observed MUF's of the dominant 2F mode with the MUF's predicted by the IONCAP model show the latter to be about 20 to 30% higher.
R.S.F.

N85-19282# Leicester Univ. (England). Dept. of Physics.
AN IONOSPHERIC MODE DETECTION SYSTEM FOR HF COMMUNICATIONS APPLICATION
T. B. JONES and P. L. HAYHURST *In* AGARD Propagation Influences on Digital Transmission Systems 12 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The injection of sounding pulses into a communications channel was used as a technique for mode detection. This pulse sounding procedure was shown to reliability recognize propagation modes within the following limits. The maximum time resolution of the system is approximately 0.5ms between arriving pulses. Thus modes with nearly equal times of flight are not easily resolved. The majority of errors recorded were due to random noise. The pulse sounding system is a low cost aid to HF communications which enables the structure of signals received via multiple propagation paths to be evaluated. From this information an estimate of the expected fading induced error rate is obtained by comparing the relative amplitudes of the active modes. The measured relative time delays between modes provide an indication of the maximum data transmission rate possible before bit errors occur due to multipath propagation. Moreover, the pulse sounding signal can provide the (S/N) ratio for a given channel from which error rate estimates can be based. R.S.F.

N85-19283# Deutsche Bundespost, Darmstadt (West Germany).
WIDEBAND LINE-OF-SIGHT CHANNEL MEASUREMENTS AND SIMULATION: APPLICATION TO DIGITAL RADIO LINKS
R. VALENTIN and K. METZGER *In* AGARD Propagation Influences on Digital Transmission Systems 11 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The performance of high-capacity digital radio links which is impaired by frequency-selective fading during multipath propagation, even if the signal-to-noise ratio is adequate was examined. The amplitude and group delay distortions were measured in a 40-MHz bandwidth at 4 GHz on a line-of-sight path. It is shown that the complex transfer function H(Omega) of the propagation channel can be well approximated by a two-ray model. The influence of two-path fading can be estimated if the dependence of the notch depth versus the deviation between the notch frequency and the carrier frequency f sub c for a fixed bit-error rate is known. Perfect Nyquist pulse shaping was assumed

and the effects of timing and carrier recovery circuits during two-path propagation were considered. The comparison with the measured signature showed a small degradation which is attributed to modem imperfections. A two-channel simulator for two-path fading was developed, where the indirect wave which was delayed by tau = 6.3 ns relative to the direct wave was Rayleigh-distributed. By variation of the parameter-K which describes the power ratio between the indirect and the direct wave, it is possible to simulate different fading processes. The improvement by the use of an inphase diversity combiner is investigated for different values of the correlation coefficient between the two channels. E.A.K.

N85-19284# Technische Hogeschool, Delft (Netherlands). Microwave Lab.

DESIGN CRITERIA FOR LIMITED SCAN ANTENNAS AT DIGITAL MICROWAVE LINE OF SIGHT LINKS

L. P. LIGHTHART *In* AGARD Propagation Influences on Digital Transmission Systems 7 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

The angle diversity technique for multipath fading reduction which uses limited scan antennas is examined. Antenna design criteria for this purpose are investigated under the assumption that only group delay requirements instead of fading depth are the determining factors to fulfill bit error ratio (BER) specifications. In a two-way fading model the maximum group delay time difference is in first approximation equal to the ratio between the minimum received signal strength and the path delay time difference. It is known that group delay time differences are dependent on the worst BER and the modulation system. The path delay time difference and the angles of arrival are calculated in a spherical propagation model. To come to a design procedure independent of refractive index profiles it is assumed that each ray is influenced along its path by a constant refractive index gradient. Combining the results from the spherical propagation model and the group delay requirements allows the computation of the maximum fading depth for given angles of arrival. The pattern envelope of limited scan antennas around the angles of interest are derived under the assumption that infinite deep fading occurs if no diversity technique is used. E.A.K.

N85-19285# *Norwegian Defence Research Establishment*, Kjeller.

A COMPARISON BETWEEN PREDICTED AND MEASURED PROPAGATION LOSS IN THE VHF/UHF RANGE IN RUGGED TERRAIN

K. BESSERUDHAGEN, N. KLIPPENBERG, and M. NORLAND *In* AGARD Propagation Influences on Digital Transmission Systems 9 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

Data from field measurements were compared with predictions based on the Longley-Rice model applied to individual path profiles. The field experiments were designed to reflect the communications deployment situation experienced by group forces. It is indicated that the value of accurate transmission loss calculations is doubtful, particularly in rugged terrain. Strong local variations introduce significant spread in the observed field strength at a given location. The median prediction error was 13 dB at 390 MHz and 20 dB at 34.5 MHz in a moderately rugged area. It is believed that reflections from objects in the horizontal plane are an important contributing factor in reducing prediction reliability at VHF and UHF. The possibility of modelling such phenomena is discussed in a context of tactical applications. E.A.K.

N85-19286# Telettra Telefonia Elettronica e Radio S.p.A., Vimercate (Italy).

SOME PROPAGATION EXPERIMENTAL RESULTS ON PROTECTION TECHNIQUES FOR LINE-OF-SIGHT DIGITAL SYSTEMS

F. FABBRI *In* AGARD Propagation Influences on Digital Transmission Systems 17 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

The main causes of distortion produced by propagation on digital signals, the protection systems generally adopted to contrast such a distortion and some methods used for the calculation of the digital performance are examined. The most significant results obtained from field measurements, especially concerning the efficiency of the protection systems are described. An overall layout of the current possibilities of high capacity digital transmission over radio links is given on the basis of theoretical and experimental results. E.A.K.

N85-19287# Centre National d'Etudes des Telecommunications, Lannion (France).

A SYSTEM FOR MEASURING THE CHARACTERISTICS OF THE IONOSPHERIC CHANNEL BY DIGITAL TRANSMISSIONS [SYSTEME DE MESURE DES CARACTERISTIQUES DU CANAL IONOSPHERIQUE]

Y. M. LEROUX, L. BERTEL, J. P. JOLIVET, P. LASSUDRIE-DUCHESNE, and H. ROUAULT *In* AGARD Propagation Influences on Digital Transmission Systems 17 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH; ENGLISH summary

Avail: NTIS HC A22/MF A01

The increase of digital transmission rates in the decametric range, by adaptative modems was examined. The ionospheric channel is defined for its rapid fluctuations, and its slower time evolutions. The measuring system is designed to provide for two types of ionospheric medium studies. The first study estimates the main parameters of the channel transfer function, with an update process in the order of 10 milliseconds. With such a cyclic-rate analysis, constraints of data recording restrict the length of the observations. The system gives information about the channel time-variation characteristics over intervals of a few tens of seconds, and thus allows a survey of the average behavior of the channel in a quasi-continuous manner. The first results obtained during an experiment at vertical incidence to validate equipment and measurement technique are presented. E.A.K.

N85-19288# Centre National d'Etudes des Telecommunications, Issy-les-Moulineaux (France).

MEASUREMENTS OF PROPAGATION AT 900 MHZ IN AN URBAN ZONE FOR ESTABLISHING A DIGITAL RADIOMOBILE SYSTEM [MESURES DE PROPAGATION EN ZONE URBAINE A 900 MHZ POUR L'ETABLISSEMENT D'UN SYSTEME RADIOMOBILE NUMERIQUE]

C. HAVEL and A. MALOBERTI *In* AGARD Propagation Influences on Digital Transmission Systems 8 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH

Avail: NTIS HC A22/MF A01

An experiment was conducted to study UHF (900 MHz) propagation in Paris and its outskirts. Measurements of the pure carrier field can be used to engineer a cellular communication system with digital mobile units. Radio propagation with mobile units is analyzed; requirements and measurements are defined. Results are compared with those obtained using a model proposed in the literature. The decrease of the field follows a D sup - alpha laws, with alpha 3.5. Good correlation can be established with an 8 dB normal log variation law for the effects of masks and a Rice law for rapid fading. Two applications of these measurements are examined. Transl by A.R.H.

N85-19289# GEC-Marconi Electronics Ltd., Chelmsford (England) Communications Research Lab.

MEASUREMENTS AND PREDICTIONS OF MULTIPATH DISPERSION FOR TROPOSCATTER LINKS

R. LARSEN *In* AGARD Propagation Influences on Digital Transmission Systems 9 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

Multipath dispersion measurements made on several 4.5 GHz paths in the United Kingdom are presented. Beamwidth and scatter angle dependence and several features of dispersion in angle and space diversity are discussed. These measurements and other from the literature are compared with predictions of dispersion. The predictions considerably underestimated the measured dispersion, but the inclusion of a beam broadening factor in the calculations gave a significant improvement in accuracy. Author

N85-19290# Kansas Univ. Center for Research, Inc., Lawrence. Telecommunications and Information Systems Lab.

DIGITAL SIMULATION OF COMMUNICATIONS CHANNELS: AN OVERVIEW

J. C. HOLTZMAN and K. S. SHANMUGAN *In* AGARD Propagation Influences on Digital Transmission Systems 8 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

Improved characterization of the propagation channel is required in the simulation of wideband communication systems. Some of the popular channel models that are currently in use are discussed, as well as their capabilities and limitations. One major shortcoming of these models is the way in which they are most often used to calculate transmission losses at a single frequency, neglecting the frequency and time dependency of the various propagation phenomena. A tapped delay line model with time varying tap gains is proposed as the generic simulation model for propagation channels. It is shown how this model can be used to analyze the effects of gaseous absorption and dispersive refraction of moist air at microwave frequencies. R.J.F.

N85-19291# Institute for Telecommunication Sciences, Boulder, Colo.

LOS MICROWAVE CHANNEL SIMULATION: A SURVEY OF MODELS, REALIZATIONS AND NEW CONCEPTS

J. A. HOFFMEYER and W. J. HARTMAN *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 17 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01 CSCL 20N

Channel simulation concepts and recent work in line of sight channel modeling and the hardware realization of these models in a channel simulator are reviewed. A new approach in which the channel simulator is realized at RF rather than at IF is discussed. The need for a standard performance measure for digital radios is discussed. Although bit-error rate (BER) is frequently used, this measure does not facilitate comparisons between tests conducted by different researchers because of differences in the ways that BER statistics are accumulated. The use of the synchronous error second and other performance measures are addressed. R.J.F.

N85-19292# National Aerospace Lab., Amsterdam (Netherlands).

SIMULATION OF THE PERFORMANCE OF ADAPTIVELY CONTROLLED NAVSTAR ANTENNAS IN BATTLEFIELD SCENARIOS

F. KLINKER and O. B. M. PIETERSEN *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 11 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

As the tool for the determination of the requirements for threat suppression and the performance of adaptively controlled antennas in electronic warfare conditions, the ANABASIS computer program was developed. The signal propagation model and the weight vector calculation are discussed. Some examples of simulation results are presented. The Navstar Global Positioning System (GPS) is a navigation system developed by the US Department of Defense. Its main purpose is to provide highly accurate positioning and timing data to military users. Although the use of the spread spectrum technique in GPS provides for a reasonable protection against jamming or other interference signals, one can increase the immunity to a great extent by using adaptive antennas. It depends on the expected scenarios, including jammers, if any suppression by antennas is necessary. R.J.F

N85-19293# York Univ. (England).

AN H.F. SIMULATOR FOR USE WITH REAL TIME CHANNEL EVALUATION SYSTEMS

J. DAWSON *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 15 p (SEE N85-19269 10-32) Oct. 1984

Avail: NTIS HC A22/MF A01

A high frequency (HF) simulator constructed at York University as an off-air test bed for an HF radio link using real time channel evaluation aided frequency selection is discussed. The simulator implements the basic channel model proposed by Watterson et al Watterson 69a with the addition of several novel features applicable to real time channel evaluation systems: rapid selection of channel parameters from stored sets; a realistic and repeatable interference simulation; and time variable channel statistics. A brief resume of channel modelling and atmospheric noise is given. R.J.F.

N85-19294# Centre National d'Etudes des Telecommunications, Lannion (France). Dept. MER/TSF

THEORETICAL STUDY OF A DYNAMIC SIMULATOR OF SELECTIVE FADING FOR DIGITAL, WIRELESS BEAM MICROWAVE LINKS [ETUDE THEORIQUE D'UN SIMULATEUR DYNAMIQUE D'EVANOUISSEMENTS SELECTIFS POUR FAISCEAUX HERTZIENS NUMERIQUES]

A. BOUIDENE and P. VANDAMME *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 13 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH; ENGLISH summary

Avail: NTIS HC A22/MF A01

A channel simulator for line-of-sight digital radio systems is presented. The basic principle is to reproduce channel transfer functions measured in the field during multipath propagation activity, by driving a complex linear transversal filter with precomputed data. The criterion used for calculating the values of the filter taps for each transfer function is the minimum mean square error criterion. It is shown that a thirteen-taps complex transversal filter with a period of 70 MHz in the frequency domain leads to accurate simulations of selective fading transfer functions in a 50 MHz bandwidth. Technological features are investigated. Effects of the accuracy in the delays implementation and of the tap-weight quantification are particularly analyzed. Author

N85-19295# Signatron, Inc., Lexington, Mass.

ADAPTIVE SIGNAL PROCESSING FOR RADIO COMMUNICATIONS

P. MONSEN *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 16 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

A tutorial examination of adaptive processors for radio communication applications is presented. The general form of adaptive equalizers and Maximum Likelihood Sequence Estimators is discussed. The method of determining the performance of an adaptive equalizer in a fading channel environment is summarized. A simple example illustrates how implicit diversity is realized by channel adaptation. Methods of adaptation including Kalman filter techniques are presented along with performance results of practical fast adapting systems. The use of channel adaptation with error correction coding is also examined and practical results presented. These results show that most of the fading effect can be eliminated when there is no restriction on channel time delay. Multiple channel adaptive processors which eliminate correlated interference are also discussed. Performance results for a tropospheric scatter application are predicted and compared with laboratory measurements on a real system. Methods of fast adaptation of these multi-channel processors are discussed. Author

N85-19296# Norwegian Defence Research Establishment, Kjeller.

FAST SYNCHRONIZATION MODEL FOR UHF SPREAD-SPECTRUM COMMUNICATION SYSTEM

R. SKAUG and H. OLAISEN *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 8 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

Communication systems employing wideband digital techniques and special modulation methods are presently being developed to support the requirements for speed and volume as well as survivability and efficiency in tactical battlefield data distribution. The transport of information in a battlefield scenario presents considerable problems where both the laws of physics and enemy and own actions are limiting factors. Introduction of spread spectrum equipment able to withstand the electronic warfare threat has often been impracticable in tactical systems with push-to-talk signalling. One of the reasons has been synchronization difficulties. Rapid and effective synchronization of spread spectrum systems often requires matched filter processing in the receiver. The realization of such filters presents technological problems for high data speeds. Surface acoustic wave (SAW) technology has, however, been very promising in this connection. A spread

spectrum modem utilizing state of the art SAW technology to process the communication signals is discussed. The system operating at UHF is optimized for push-to-talk operation with a synchronization time of 20 microsec and offers data speeds up to 100 kbit/sec. With a processing gain of approximately 30 dB, the radio modem is also able to resolve and reject multipaths on the order of 10 nsec. It is thus expected to avoid certain selective effects due to multipath which are usually encountered in narrowband communication systems. B.W.

N85-19297# Selenia S.p.A., Rome (Italy).
A TECHNICAL SOLUTION TO FADINGS IN TACTICAL SATELLITE DIGITAL TRANSMISSIONS
G. LOSQUARDO and A. LORENZONI (Centro Consultivo Studi e Ricerche Dell'Aeronautica Militare) *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 8 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

Tactical satellite communication systems may provide service to high performance aircrafts employing antennas with relatively wide beamwidths. Unfortunately, the fading and multipath phenomena could strongly influence the capability of point to point data transmission. In order to overcome the problem of the design of a coding/mo-demodulation structure, and to determine the actual link margin, an analysis and a simulation of a multipath channel has been performed. The performance gains that are achieved with the use of a suitably wide bandwidth modulation and with three different theoretical fading models are shown. The problem of the bandwidth spreading has been related to the aircraft height and to the geometry of the multipath model. A solution to the problem of multiplexing of several wideband signals, over a repeater bandwidth, proposed and the performances of a receiver, based on a FFT spectra analyzer, are illustrated. The simulation to the problem of multiplexing of several wideband signals, over a repeater bandwidth, was proposed and the performance of a receiver, based on a FFT spectra analyzer, are illustrated. The simulation results confirm that, the FFT based receiver allows the soft decision demodulation of one or several simultaneous channels, with performances that are very close to the ones given by the optimal receiver for orthogonal codewords; moreover, the FFT solves, elegantly, the problem of Doppler shifts even in presence of fadings and with the capability to track the satellite signal even for maneuvering aircraft. B.W.

N85-19298# Rome Air Development Center, Griffiss AFB, N.Y.
TIME AND SPACE DOMAIN FILTERING FOR IMPROVED HF COMMUNICATION
R. N. SMITH and R. L. MOSES (Virginia Polytechnic Inst. and State Univ.) *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 15 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

High speed data transfer has until recently been generally unattainable over HF channels because of the highly disturbed nature of the channel. The development of real-time signal processors has done much to mitigate effects of channel disturbances, making it possible to substantially increase throughput. Data rates as high as 9600 bits per second can be achieved by implementing signal processors as adaptive channel equalizers. This recent increase in data rates has rendered feasible HF spread spectrum communication systems. Spread spectrum systems are attractive in many applications because they are resistant to narrowband interference. However, channel equalizers necessary for high data rates are susceptible to narrowband interference. Spatial or temporal prefiltering has commonly been employed to prewhiten the received data, providing improved equalizer performance. The more popular one-dimensional techniques for temporal and spatial prewhitening of HF communication signals are reviewed. Also, combined space-time prewhitening techniques are proposed. Algorithms for designing and implementing these two-dimensional whitening filters are presented. Advantages and disadvantages of the two design strategies are discussed. Particular attention is focused on system performance, computational requirements, and cost. Computer simulated results for these signal processing algorithms are presented. B.W.

N85-19299# Rome Air Development Center, Griffiss AFB, N.Y.
OVERVIEW OF RADC ADAPTIVE ANTENNA DEVELOPMENTS FOR COMMUNICATIONS Abstract Only
J. A. GRANIERO, C. J. LUVERA, and J. R. PERIARD *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 2 p (SEE N85-19269 10-32) Oct. 1984
Avail: NTIS HC A22/MF A01

Adaptive Antennas are a key technology in providing reliable communications in an interference environment. Key developments at the Rome Air Development Center (RADC) in areas of adaptive algorithms, experimental processors and test and evaluation are described. The developments are aimed at improving adaptive antenna performance such as: null depths over bandwidth and in high multipath, convergence speeds and processor size, weight and cost. A new test bed at RADC called the Flexible Adaptive Spatial Signal Processor (FASSP) is also described. The FASSP provides the capability of comparative evaluation of various adaptive algorithms in either or both of two modes: full digital beamforming/nullsteering or a hybrid mode with analog weighting and digital weight computation. B.W.

N85-19300# LMT Radioprofessionelle, Boulogne-Billancourt (France).
ASYNCHRONOUS TRANSMISSION WITH STRONG SPECTRAL SPREAD [TRANSMISSION ASYNCHRONE A FORT ETALEMENT DE SPECTRE]
M. SCHILLIGER and C. LELOUP *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 14 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH
Avail: NTIS HC A22/MF A01

Resistance to signal detection and interception and resistance to interference and mixing are advantages of spread spectrum transmission in military communications. The construction of the emitter and receiver permitted testing an asynchronous radio link with a digitalization of speech by delta code, and also facilitated the obtaining of measurements. Spectrum spreading was achieved on a 80 MHz band by means of pseudo-random sequences coded in binary orthogonal keying using P.S.K. or M.S.K. modulation. Demodulation at reception was achieved in an asynchronous mode by a double piezoelectric surface acoustic wave convolutor operating at a frequency on the order of 400 MHz. Each convolutor was fed, partly by the signal received, and partly by a replica of the signal expected, at the same frequency, and with the same code inversed in time. Transl. by A.R.H.

N85-19301# York Univ. (England). Dept. of Electronics.
A REVIEW OF TRANSMISSION AND CHANNEL EVALUATION TECHNIQUES FOR DIGITAL COMMUNICATION SYSTEMS
M. DARNELL *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 18 p (SEE N85-19269 10-32) Oct. 1984 refs
Avail: NTIS HC A22/MF A01

The advantages and disadvantages of digital modes of transmission are reviewed. A brief survey of the main propagation characteristics of the different types of radio systems is presented, with attention being drawn to the factors which influence the choice and performance of digital transmission techniques. The most widely used digital transmission techniques are then discussed and their applicability to various radio frequency bands considered. Finally, channel evaluation techniques yielding models of the propagation and interference environments are described and the manner in which they can be employed to enhance the reliability of digital communication systems is indicated. Author

N85-19302# Paris-Sud Univ., Cachan (France). Lab. d'Etude des Transmissions Ionospheriques.
A MODEM WITH PSEUDO-ORTHOGANAL CODES: EXPERIMENTAL RESULTS [MODEM A CODES PSEUDO-ORTHOGANAUX: RESULTATS EXPERIMENTAUX]
F. CHAVAND, D. DESAGE (Telecommunications Radioelectriques et Telephoniques), C. GOUTELARD, and J. P. VANUFFELEN *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 14 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH
Avail: NTIS HC A22/MF A01

The decametric ionospheric channel is characterized by the existence of multiple paths which introduce selective fading and intersymbolic distortions. Modems with slow cadence can solve

the problem of intersymbolic interference, but are sensitive to selective fading. On the other hand, modems with rapid cadence are sensitive to intersymbolic interference, but have little sensitivity to selective fading. A modem using pseudo-orthogonal codes is presented which effects a series transmission while preserving good protection against intersymbolic distortions. The characteristics of these codes, which constitute optimal codes, are reviewed and techniques used in the modem are described. A simulator was used to measure the characteristics of the modem under propagation and perfectly defined mixing conditions. Tests on a real link permitted comparison of the performance of a modem with pseudo-orthogonal codes with that of a noncoded modem with the same output. The gain contributed by coding is demonstrated. Transl. by A.R.H.

N85-19303# Paris-Sud Univ., Cachan (France). Lab. d'Etude des Transmissions Ionospheriques.

ERROR CORRECTION CODING FOR A SELF-ADAPTIVE MODEM: THEORETICAL AND EXPERIMENTAL RESULTS [CODAGE CORRECTEUR D'ERREURS POUR MODEM AUTO DAPTATIF RESULTATS THEORIQUES ET EXPERIMENTAUX]

F. CHAVAND, C. GOUTELARD, and S. HARARI *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 16 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH; ENGLISH summary

Avail: NTIS HC A22/MF A01

An error correcting system designed for a 1200 bits/s self adaptive modem operating on the HF ionospheric channel is presented. Error statistics were analyzed by simulating a specific link whose characteristics had been measured previously by a HF backscatter probe. Some 30 millions of bits were processed which represent 27 different cases of propagation and scrambling. The coding system consists of a cascade of two codes: one corrects single error and small bursts (Reed Solomon codes); the other corrects long bursts of errors (Kasama code). The overall rate is 0.55. An error correcting simulation shows that least 10 -2 has been achieved. Limitations of these correction methods on such systems are discussed. The total error was reduced by a factor equal to or greater than 100 in all cases. Author

N85-19304# Siemens A.G., Munich (West Germany).

A MICROPROCESSOR CONTROLLED PARALLEL MODEL WITH FDPSK

H. E. BUDING *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu 13 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

Within the frequency band of a HF-channel (3 kHz) the phase distortion is time variable and of a considerable size. In this environment it is advantageous to use FDPSK (frequency differential phase shift keying) for transmission instead of TDPSK (time differential phase shift keying). In FDPSK the information is transmitted as the phase difference between two synchronized carriers of different frequency. When they only have a small frequency difference (60 Hz) both are exposed to the same phase distortion of the HF-channel. With an appropriate demodulation method this phase error therefore can be cancelled. Measurements were done over two different HF links (40 km and 1200 km). Wideband dipole antennas and a frame antenna were used. The power output of the HF radio equipment was switchable between 70 and 400 watts. The measured error rates were in the order of magnitude 10 to 100. With the inclusion of the forward error correction (FEC) these error rates could be improved to 100 to 10000. B.G.

N85-19305# Telecommunications Radioelectriques et Telephoniques, Le Plessis-Robinson (France).

SERIAL DATA TRANSMISSION WITH LARGE OUTPUT ON THE HF CHANNEL [TRANSMISSION DE DONNES SERIE A GRAND DEBIT SUR CANAL HF]

J. P. VANUFFELEN IN AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 8 p (SEE N85-19269 10-32) Oct. 1984 refs In FRENCH

Avail: NTIS HC A22/MF A01

A modem is described that uses series transmission and a self-adaptive equalizer for correcting propagation distortions. The modem permits data transmission to a maximum output of 2400 b/s as well as in a continued mode with brief messages of one-second normal duration. Characteristics of the modem and the signal processing applied are discussed. Laboratory measurements of modem performance are compared with results of tests during simulated multipath propagation or with frequency shifting. Still other tests carried out on a 500 km link are discussed. Results were analyzed on a computer and are presented in the form of long- and short-term statistics. A.R.H.

N85-19306# Standard Elektrik Lorenz A.G., Stuttgart (West Germany).

FAST DATA AND VOICE TRANSMISSION FOR MOBILE SERVICES WITH HIGH IMMUNITY AGAINST MULTIPATH AND CO-CHANNEL INTERFERENCE

U. LANGEWELLPOTT *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 6 p (SEE N85-19269 10-32) Oct. 1984 refs

Avail: NTIS HC A22/MF A01

A scheme for high rate data and voice transmission over multipath channels was developed and evaluated during the design of a wideband cellular mobile telephone and data system operating at 900 MHz. The transmission bandwidth in the order of 5 MHz is a consequence of the time division multiple access (TDMA) architecture was selected for cost savings and advantages in system organization. In TDMA time is divided into a contiguous stream of short time slots and individual channels consist of different subsets of time slots. All time slots use the same frequency, so no synthesizer is required. In addition, there is no need for a diplexer at the mobile because the transmit and receive time slots can be separated in time. For the same reason the base stations only need one transmitter and one receiver tuned to the transmit and receive frequency respectively. So the complexity is favorably reduced. The highest potential for cost savings stems from digital transmission which, in conjunction with a forecast number of more than one million subscribers, fulfills the prerequisite to low production cost. System organization is facilitated by the TDMA approach because the mobiles only need to be active during the short transmit and receive times slots and can easily monitor all surrounding base stations and decide to initiate hand-off to the one offering the best propagation conditions. Author

N85-19307# ANT Nachrichtentechnik, Backnang (West Germany).

NARROWBAND SPREAD SPECTRUM SYSTEMS

K. H. ANNECKE and M. OTTKA *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 11 p (SEE N85-19269 10-32) Oct. 1984 refs Sponsored in part by Bundesministerium fuer Verteidigung

Avail: NTIS HC A22/MF A01

The available military radio frequency bands are covered very densely by the already existing conventional systems and therefore the application of bandwidth widening procedures as antijam measures will be allowed only with small spreading factors within these RF-bands. The problems arising from the random code selection for spread spectrum systems with small spreading factors are discussed. The calculations show the dependence between certain statistical properties of classes of codewords and the number of codewords available in these classes. The bit error probabilities in case of jamming by white Gaussian noise, narrowband and CW-jammers are calculated in comparison with the error probability of the class of codewords with ideal correlation properties. Author

N85-19308# Standard Elektrik Lorenz A.G., Stuttgart (West Germany).

EFFECTIVE MILLIMETER WAVE TRANSMISSION UNDER SEVERE MULTIPATH CONDITIONS

U. SCHULZ and G. HOEFGEN *In* AGARD Propagation Influences on Digital Transmission Systems: Probl. and Solu. 7 p (SEE N85-19269 10-32) Oct. 1984

Avail: NTIS HC A22/MF A01

Radio transmission on millimeter waves substantially suffers from multipath propagation as long as obstacles cannot be avoided in the propagation path. A system concept to overcome the fading problem will be presented. A broadband RF-transmission by chirp modulation and a respective correlation technique in the receiver are used. The transmission principle and the basic equipment functions are described. In addition, the results of the theoretical

investigations on the receiver signal processing are presented.
Author

N85-27128# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THE IMPACT OF PROPOSED RADIO FREQUENCY RADIATION STANDARDS ON MILITARY OPERATIONS
Loughton, England Mar. 1985 171 p refs Lectures were held in Rome, 11-12 Apr. 1985, in Lisbon, 15-16 Apr. 1985, and in Paris, 18-19 Apr. 1985
(AGARD-LS-138; ISBN-92-835-1494-7; AD-A154473) Avail: NTIS HC A08/MF A01

The development and application of devices that emit radiofrequency radiation (RFR) have significantly increased the quality of life throughout the world. Yet in recent years the beneficial aspects of the radiofrequency/microwave technology have been somewhat overshadowed by a public fear of potential biological effects. This fear, in turn, has incresed RFR research, lead to a much better understanding of the interactions of RFR fields and biological systems, and resulted in the promulgation of new RFR safety guidelines. Subject areas covered are: (1) the physical interactions of RFR fields with biological systems, (2) the biological effects of RFR exposures, (3) the procedures for measuring RFR fields in military operations, and (4) the development and operational impact of new RFR safety guidelines. For individual titles see N85-27129 through N85-27138.

N85-27129# Utah Univ., Salt Lake City. Dept. of Electrical Engineering.
THE PHYSICAL INTERACTIONS OF RADIOFREQUENCY RADIATION FIELDS AND BIOLOGICAL SYSTEMS
C. H. DURNEY *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 19 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

A biological system irradiated by radiofrequency radiation (RFR) responds to the internal RFR fields produced by that irradiation. The measurement and calculation of the internal fields is called dosimetry. The internal fields are often described in terms of the specific absorption rate (SAR) in watts/kilogram. SARs are usually determined experimentally by measuring temperature rise in the absorber (either by discrete probes or thermographic cameras) or by directly measuring the internal electric field. A combination of techniques, each valid for a particular model and in a particular frequency range, are used to calculate average whole body SARs for models of human beings and other animals over a wide frequency range for plane wave irradiation. Calculating SARs for near field irradiation is much more difficult than for plane wave irradiation; thus fewer near field SAR data are available. To calculate the spatial distribution of SARs is still more difficult (especially at higher frequencies); this problem in dosimetry is yet to be solved satisfactorily, although significant progress has recently been made in this area.
Author

N85-27130# Washington Univ., Seattle. Bioelectromagnetics Research Lab.
THERMAL CONSEQUENCES OF LOCALIZED SAR FROM RFR EXPOSURES
A. W. GUY *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 18 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

Local SAR levels from 50 to 170 W/kg are used for theraputic heating in clinical medicine. These levels cause tissue temperatures to rapidly increase and stimulate a rapid increase in blood flow. Localized high levels of SAR destroy tumors with minimal damage to healthy surrounding tissue due to the difference in blood cooling rates and thermal sensitivity of neoplastic as compared to normal tissues. SARs of 140 W/kg or greater produce cataracts in the eyes of rabbits that are exposed locally to 150 mW/sq cm cm 2450 MHz microwave radiation but similiar levels of exposure does not produce cataractogenic levels of SAR in primates. Experiments show that SAR levels of 72 W/kg or greater applied for 1.5 to 6 min to the brain of cats will produce temperature rise of 4.4 to 6.5 C resulting in pulse rate increases, hyperventilation, bradycardia, and intense tachypnea for 15 to 20 minutes after exposure. No pathological changes are noted in the cat due to these localized exposure levels. Localized exposure of living cat brain at SAR levels of 2.5 to 5 W/kg produce measureable temperature rises and change sin latency of evoked potentials. A thermal response occurring at the lowest known level of applied energy is that of microwave pulse hearing.
Author

N85-27131# Rochester Univ., N. Y. Dept. of Medicine.
THE BIOLOGICAL EFFECTS OF RADIOFREQUENCY RADIATION
N. J. ROBERTS, JR. and S. M. MICHAELSON *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 26 p (SEE N85-27128 16-32) Mar. 1985 refs
(Contract F33615-84-C-0608; DE-AC02-76EV-03490; NIH-N01-AL-15547; NIH-N01-ES-03239)
Avail: NTIS HC A08/MF A01

Exposure of the general public and in particular certain occupational groups to radiofrequency radiation (RFR) is ubiquitous and of growing concern. No clear and widely accepted understanding of the biological effects and health implications of such RFR exposure has emerged. The data available, including reports of RFR effects on single cells or cell components, on genetic composition or development, on developed organs, tissues, or cell systems, and on integrative and regulatory biological systems are reviewed. Reports of RFR effects on the immunological system with consideration of the influence of neuroendocrine responses, are critically reviewed in greater detail to illustrate important points regarding data acquisition and assessment, and understanding and application of the RFR bioeffects literature in general. Factors affecting RFR bioeffects research are reviewed, and recommendations for future studies are provided.
Author

N85-27132# School of Aerospace Medicine, Brooks AFB, Tex.
THE CUMULATIVE EFFECTS OF LONG TERM EXPOSURE TO LOW LEVELS OF RADIOFREQUENCY RADIATION (RFR)
J. H. KRUPP *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 14 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

One of the concerns for the effects of nonionizing radiofrequency radiation (RFR) is the accumulation of subtle injury over a long period of time, resulting in a delayed expression of deleterious effect. Of the more than 6,000 articles in the literature today, the vast majority involve acute exposures at levels where significant thermal energy is deposited. The resulting effects, in most cases, could be explained on the basis of the specific energy absorption, expressed as watts per kilogram (W/kg), with a generally accepted threshold for effects of 4 W/kg. The advocacy of nonthermal mechanisms by means of mathematical modeling, theoretical predictions, and in vitro studies, raised the possibility of subtle injury or alteration in function which, over time, would be expressed as a harmful bioeffect. Over a 4-year period of planning, pilot study, and definitive experiment, a lifetime exposure is given to a population of tst animals (100) whose state of health, growth, and cause of death are closely monitored. An equal number of sham expected animals served as a comparison population. After 25 months of exposure, and at the point where there is 90% mortality in both groups, the remaining subjects are sacrificed and assayed. The overall conclusion is that no cumulative ill effects could be attributed to the life long exposure at absorption rates of 0.4 W/kg or less.
Author

N85-27133# Air Force Occupational and Environmental Health Lab., Brooks AFB, Tex.
THE MEDICAL RESULTS OF HUMAN EXPOSURES TO RADIO FREQUENCY RADIATION
R. B. GRAHAM *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 8 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

The United States Air Force conducted a clearly defined and effective radio frequency radiation (RFR) protection program since 1970. As an important part of the program, since 1972 the Air Force Medical Service investigated RFR exposure incidents involving more than 330 individuals; of which 58 are determined to have been actually overexposed with another 17 found to have been inconclusive. Medical evaluations of the exposes are extensive and the findings almost universally unremarkable. A short history of the program's evolution is presented and some examples of exposure incidents and some general impressions of the clinical

evaluations of the confirmed exposees are also presented.
Author

N85-27134# Rochester Univ., N. Y. Dept. of Medicine.
REVIEW OF EPIDEMIOLOGICAL STUDIES OF HUMAN EXPOSURES TO RADIOFREQUENCY RADIATION
N. J. ROBERTS, JR. and S. M. MICHAELSON *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 6 p (SEE N85-27128 16-32) Mar. 1985 refs
(Contract F33615-84-C-0608; DE-AC02-76EV-03490; NIH-N01-AL-15547; NIH-N01-ES-03239)
Avail: NTIS HC A08/MF A01

The health effects of exposure to radiofrequency radiation (RFR) remain underfined and controversial. Epidemiological studies of human exposures to RFR are confounded by difficulties in determining the type and true extent of exposures, in selecting an appropriate control group for comparisons, in determining the existence and influence of many concomitant environmental factors, and in establishing the presence or measuring the frequency or severity of subjective complaints as well as objective findings in the studied populations. Reported RFR effects on general health, growth and development, physiological systems such as the cardiovascular and nervous systems, and organs such as the eye are reviewed. Criteria for reliable epidemiological studies are presented to allow critical analysis of such reports. Author

N85-27135# Bundesgesundheitsamt, Neuherberg (West Germany). Inst. for Radiation Hygiene.
EVALUATION OF HUMAN EXPOSURES TO LOW FREQUENCY FIELDS
J. H. BERNHARDT *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 18 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

The biophysical model concept described might be suited as a basis of discussion to determine and define limits of exposure to electric or magnetic fields below 100 kHz, including 50/60 Hz. The electric field strength within the tissue in the environment of excitable neurons and muscle cells is considered decisive for the biological effect. Threshold values of field strength or current density, inducting biological effects are compiled from experimental and theoretical studies. On the basis of these data it is possible to establish safe, dangerous and hazardous current density curves as a function of frequency. The criterion for the definition of injury is the elicitation of ventricular fibrillation which must be avoided. To define exposure limits, the field strength or current density causing injury should be reduced by a factor exceeding 100. The arguments supporting this wide safety margin are discussed. The electric and magnetic field strength in the human environment is correlated with the corresponding electric current density induced in the human body. This enable safe, dangerous and hazardous levels of current density in the human body to be correlated with the external electric or magnetic field strength. Parts of the concept presented are adopted as the scientific basis for the lower frequency range of the standard DIN 57848/VDE 0848: Hazards by electromagnetic fields; Protection of persons in the frequency range from 10 kHz to 3.000 GHz. Author

N85-27136# Washington Univ., Seattle. Center for Bioengineering
HAZARDS OF VLF ELECTROMAGNETIC FIELDS
A. W. GUY *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 20 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

Biological hazards to humans exposed to Very Low Frequencies (VLF) electromagnetic fields may result from electric shock, spark discharge, elevation of tissue temperature and burns. A number of nonthermal nonshock effects, such as the neurasthenic syndrome are reported widely in the Soviet and East-European literature. Generally a subject exposed to even the highest electromagnetic fields in the environment will not experience an electric shock unless he comes in contact with the ground or objects such as vehicles, crane cables and guy wires. The steady state current from touching objects increases directly with the frequency. On the other hand, the physiological shock effects of the current are less pronounced with increasing frequency. However, at frequencies where the shock hazard is negligible, deleterious heating of the body occurs for whole body average Specific Absorption Rates (SAR) greater than 4 W/kg and localized values of SAR greater than 80 W/kg so VLF exposure levels should be limited to prevent SAR from reaching one tenth of these levels. Free space exposures to fields of less than 1 kV/m electric field strength should be safe if proper precautions are taken to limit direct body contact with conducting objects.
Author

N85-27137# School of Aerospace Medicine, Brooks AFB, Tex.
DEVELOPMENT AND APPLICATION OF NEW RADIOFREQUENCY RADIATION SAFETY STANDARDS
J. C. MITCHELL *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 13 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

Radiofrequency radiation (RFR) is defined to cover the frequency range from 10 kHz to 300 GHz and includes microwaves. Absorption and distribution of RFR are strongly dependent on the size of the irradiated object and the frequency of the incident energy. It is common practice to report biological effects of RFR as a function of specific absorption rate (SAR) expressed as W/kg. The most widely held view is that the threshold for adverse effects lies above 4 W/kg. This value underlies the rationale for most standards that have emerged since 1982. Using a safety factor of 10, the American National Standards Institute developed RFR protection guides that limit all human whole body exposures to incident energy that results in an SAR no greater than 0.4 W/kg. This allows incident average power densities from 1 to 100 mW/cm2, depending on the frequency of the radiation. New safety guidelines are compared with many other RFR standards used throughout the world today including NATO STANAG 2345.
Author

N85-27138# Air Force Occupational and Environmental Health Lab., Brooks AFB, Tex.
RADIO FREQUENCY RADIATION (RFR) MEASUREMENTS IN OPERATIONAL SETTINGS
R. B. GRAHAM *In* AGARD The Impact of Proposed Radio Frequency Radiation Standards on Mil. Operations 10 p (SEE N85-27128 16-32) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

A detailed discussion of the principles, procedures, and instrumentation required to carry out routine RFR measurements under field or operational conditions is presented. The information herein contained comes largely from several years of experience gathered by the USAF Occupational and Environmental Health Laboratory (USAF OEHL) and its predecessor the USAF Radiological Health Laboratory (USAF RHL). Over the last 12 years the USAF OEHL have evaluated and field tested a wide variety of RFR power density instrumentation designed, developed and manufactured by a number of firms and agencies. Each of these instruments has some outstanding characteristics and some equally poor features. Based on a number of years of experience only about 15% of the RFR emitters account for about 95% of the measurement problems. There are a number of classes of emitters that may be easily and promptly dismissed from consideration as a potential hazard to personnel. Author

N86-24903# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TECHNICAL EVALUATION REPORT ON THE ELECTROMAGNETICWAVE PROPAGATION PANEL SYMPOSIUM ON PROPAGATION EFFECTS ON MILITARY SYSTEMS IN THE HIGH LATITUDE REGION
R. D. HUNSUCKER Nov. 1985 15 p
(AGARD-AR-218; ISBN-92-835-1514-7; AD-A166595) Avail: NTIS HC A02/MF A01

Propagation effects on military systems in the high latitude region were examined. Topics discussed include: experimental studies of ionospheric irregularities and regular structure, results of ionospheric modification (HF heating) experiments,theoretical studies of ionospheric irregularity formation, global survey of ground conductivities,disturbance modeling studies, high latitude effects on HF radio communicaton, transionospheric communications, satellite synthetic aperture radar (SAR), MF radio broadcasting, spatially adaptive propagation, HF digital, Skywave HF sea state radar, and meteor burst communication. E.A.K.

N86-27531# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
PROPAGATION EFFECTS ON MILITARY SYSTEMS IN THE HIGH LATITUDE REGION
H. SOICHER, ed. (Army Communications-Electronics Command, Fort Monmouth, N.J.) Loughton, England Nov. 1985 577 p Proceedings of the 36th Symposium of the Electromagnetic Wave Propagation Panel, Fairbanks, Alaska, 3-7 Jun. 1985
(AGARD-CP-382; ISBN-92-835-0383-X; AD-A166585) Avail: NTIS HC A25/MF A01

Various topics relative to propagation effects on military systems at high latitudes are discussed. Ionospheric propagation, propagation aspects of high frequency communication, high altitude probes, scattering, measurement techniques, and meteor scatter radio communication are among the topics covered. For individual titles see N86-27532 through N86-27565.

N86-27532# Alaska Univ., Fairbanks. Geophysical Inst.
SOLAR-TERRESTRIAL RELATIONSHIPS IN THE HIGH LATITUDE REGION
S. I. AKASOFU *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 17 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

It is shown how the magnetosphere responds to the three components (B sux x, B sub y, B sub z) of the interplanetary magnetic field (IMF) and to the power sigma of the solar wind magnetosphere dynamo. In particular, it is shown that the geometry of the auroral oval and the polar cap depends greatly on the magnitude and signs of the IMF three components. Geomagnetic storms result when the dynamo power sigma exceeds approx. 1 million Mwatts. Once such knowledge is available, it is possible to predict the geometry of the auroral oval and the intensity of a geomagnetic storm as a function of time, if one can predict time variations of the solar wind speed and the IMF three components. We demonstrate such a possibility by a computer model study, namely by the first generation numerical forecasting scheme.
Author

N86-27533# Norwegian Defence Research Establishment, Kjeller.
MEDIA EFFECTS ON SYSTEMS IN THE HIGH LATITUDE REGION
E. V. THRANE *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 16 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

The effects of the transmission medium on radio systems in the high latitude regions are reviewed. First, some general properties of propagation media are discussed, followed by brief descriptions of the effects on radio waves of the Earth's surface, the troposphere and the ionosphere in high latitudes. General principles are illustrated by examples from observations and model calculations
Author

N86-27534# Physical Dynamics Northwest, Bellevue, Wash.
RECENT HILAT RESULTS
E. J. FREMOUW *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 14 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

The Defense Nuclear Agency (DNA) HiLat Satellite was launched on 27 June 1983 for the purpose of studying the development and dynamics of F-layer irregularities between the plasmapause and the pole. In a circular 800-km orbit at 82 inclination, it carries (1) a coherent radio beacon for measuring complex-signal scintillation and TEC, (2) a three-instrument thermal-plasma experiment consisting of a Langmuiare probe (debilitated on launch), a retarding-potential analyzer (RPA), and an ion drift meter; (3) an energetic-electron spectrometer operating between 20 ev and 20 kev, (4) a three-axis fluxgate magnetometer, and (5) an optical package consisting of a vacuum-ultraviolet (vuv) imaging spectrophometer (failed after collecting forty orbits of data) and two visible-wavelength telephotometers. All instruments other than the Langmuire probe and the vuv imager continue to operate reliably. To date, HiLat has returned the following three specific observations of note: first auroral image in full daylight, most intense field-aligned current flowing into the ionsophere, and energy-dispersed electron precipitation impulses with about a one-second periodicity. These observations and on-going analyses of HiLat's bulk data base are summarized.
Author

N86-27535# Air Force Geophysics Lab., Hanscom AFB, Mass. Ionosphereic Physics Div.
TOTAL ELECTRON CONTENT AND L-BAND AMPLITUDE AND PHASE SCINTILLATION MEASUREMENTS IN THE POLAR CAP IONOSPHERE
J. A. KLOBUCHAR, G. J. BISHOP, and P. H. DOHERTY (Emmanuel Coll., Boston, Mass.) *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 8 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

The first measurements of absolute Total Electron Content (TEC) and L-band amplitude and phase scintillation were made from Thule, Greenland, a polar cap station, in early 1984. These measurements were made using signals transmitted from the Global Positioning System (GPS) satellites. The variability of the TEC, especially during the afternoon to pre-midnight hours, is large, with increases in TEC above the background values of greater than 100 percent not uncommon. During one disturbed time quasi-periodic TEC enhancements having periods as short as ten minutes and amplitudes equal to the background TEC were observed for over two hours. The TEC during some of the disturbed periods in the dark Thule ionosphere exceeded mid-latitude daytime values. Amplitude scintillations were small, not exceeding 3 dB peak to peak during the entire observing period, but they were associated with the times of TEC enhancements, with some evidence for stronger scintillation occurring during the negative gradients of the TEC enhancements. Phase scintillations were highest during some of the times of enhanced TEC, and depend critically upon the phase detrend interval used.
Author

N86-27536# Army Communications-Electronics Command, Fort Monmouth, N.J. Center for Communications Systems.
VARIABILITY OF TRANSIONOSPHERIC SIGNAL TIME DELAY AT HIGH LATITUDES NEAR SOLAR MINIMUM
H. SOICHER *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 9 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Faraday observations were conducted at Anchorage, Alaska (61.04 degrees N, 149.75 degrees W) utilizing beacon transmissions from a geostationary satellite during the period just following the minimum phase of solar cycle 21. Average maximum monthly values of total electron content (TEC), which is proportional to transionospheric signal time delay, were below 15 x 10 to the 16th power el m-2, while individual daily maximum values never exceeded 20 x 10 to the 16th power m-2 Seasonal and day-to-day variabilities were observed. Unique representation of the data has permitted the study of day-to-day variability of TEC. For example, during all seasons the TEC structure appears uniform from day to day during the buildup and decay phase of the local ionosphere. During the maximum and minimum of the diurnal phase, the TEC structure variability is seasonally dependent. During periods of magnetic sudden commencements, which rarely occurred in the observations period, significant positive phase response of TEC did not materialize.
Author

N86-27537# Boston Univ., Mass. Dept. of Astronomy.
F LAYER IRREGULARITIES AT PLASMAPAUSE AND AURORAL LATITUDES
J. AARONS *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 16 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Distinctive effects of two irregularity regions, one at plasmapause latitudes and the second in the auroral region, were explored using primarily radio scintillation data. Using scintillation measurements at the times numbering seven to nine sensors within a relatively confined area, it is possible to document the morphology of development of irregularities in the plasmapause and in the auroral region over a period of time, a technique difficult with only low altitude satellite scintillation observations. Two cases of irregularity storms one in the plasmapause and the second in the auroral oval are reported. During the stable auroral red arc of

March 5 to 6, 1981, intense irregularities were centered at plasmapause latitudes but levels tapered off in the same longitude sector at auroral latitudes. Reported Synthetic Aperture Radar (SAR) measurements indicated no visible aurora until areas 4 L shells polewards. Low energy (approx. 8ev) electron precipitation has been reported within the region covered by the SAR arcs. Higher temperatures have also been reported within the SAR arc, perhaps indicating a need to invoke the temperature gradient drift instability as the source for the generation of irregularities. Scintillation of moderate level is not uncommon for the plasmapause region. In March 1981 approximately 60% of the nights had scintillation levels approx. 6 dB at 137 MHz lasting over one hour. Author

N86-27538# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio. Avionics Lab.

INFLUENCE OF IONOSPHERIC IRREGULARITY SHAPE AND VELOCITY ON THE DESIGN OF AIRBORNE SATELLITE COMMUNICATIONS SYSTEMS

A. L. JOHNSON *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 10 p (SEE N86-27531 18-32) Nov. 1985

Avail: NTIS HC A25/MF A01

Extensive ground and airborne UHF ionospheric scintillation measurements were conducted in the polar region during the peak of the current solar cycle. Using three spaced antennas the speed and direction of the irregularity drift was obtained from cross-correlation plots. Measurements taken during 1980 at Thule, Greenland; Sonderstrom, Greenland, and Goosebay, Labrador showed velocities of up to s1000 meters per second. A diurnal pattern of rapid direction changes provided information on the two cell polar circulation of the irregularities from the noon sector of the auroral oval over the polar cap to the midnight section and back around the oval to the noon section. Airborne ionospheric scintillation fading measurements conducted near Goosebay were compared with simultaneous ground measurements to investigate the ionospheric irregularity shape. Polar ionospheric scintillation fading measurement indicates that special care is required in the design of airborne satellite communications systems intended for polar operation. Applicable coding techniques, interleaving length, modulation schemes, and message length to provide an airborne satellite communication system protection against polar ionospheric scintillation fading are discussed. Author

N86-27539# SRI International Corp., Menlo Park, Calif.

PROPAGATION EFFECTS ON SATELLITE-BORNE SYNTHETIC APERTURE RADARS Abstract Only

C. L. RINO and J. OWEN *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 1 p (SEE N86-27531 18-32) Nov. 1985

Avail: NTIS HC A25/MF A01

A numerical Synthetic Aperture Radar (SAR) simulator is discussed. The simulator can generate and process image segments with full or partial corrections for range walk and quadratic phase-error correction. The simulations also include the effects of coherent target speckle, which is important in assessing SAR image quality. Results show that moderate auroral-zone scintillation will degrade an image to about the same level as any undisturbed image processed with only partial range-walk compensation. Thus, propagation effects are undoubtedly present in many of the SEASAT-A high-latitude images, but the degradation is comparable to other distortions introduced in the processing itself. Phase error compensation is effective, but amplitude scintillation is also important for larger disturbances. Ramifications of SAR imaging are discussed. Author

N86-27540# University Coll. of Wales, Aberystwyth.

HIGH-LATITUTDE SCINTILLATIONS USING NNSS SATELLITES

L. KERSLEY *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 7 p (SEE N86-27531 18-32) Nov. 1985

(Contract AF-AFOSR-0037-84)

Avail: NTIS HC A25/MF A01

An experiment is described which has been established in Northern Sweden since September 1984 to monitor scintillations using transmissions from NNSS satellites. Designed for long-term nearly-unattended operation, with control and data handling based around a PDP 11/23 minicomputer, the equipment records and processes data from more than 20 NNSS passes per day. Stored on magnetic tape for further study for each 20s segment of received signal after suitable detrending, are S4-indices for both frequencies, the r.m.s. differential phase fluctuations, the differential phase rotation (differential doppler), together with statistics of signal fading below selected thresholds and durations of individual fades. Determination of satellite position in nearly-real time from the transmitted ephemeris parameters enables estimates of effective ionospheric irregularity height to be made for high-elevation passes by means of the cross correlation of signals received on two separated antennas. A second mode of operation allows the raw data to be stored for subsequent analysis. This has been used successfully for coordinated special program experiments in conjunction with the EISCAT ionospheric radar facility in the study of the physical processes reponsible for the scintillation-producing irregularities. Author

N86-27541# Mitre Corp., Bedford, Mass.

SHF/EHF RAY BENDING

D. L. ZIMMERMAN, G. F. PROVIDAKES, D. L. POST, and S. H. TALBOT (Rome Air Development Center, Griffiss AFB, N.Y.) *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 6 p (SEE N86-27531 18-32) Nov. 1985 Sponsored in part by AF

Avail: NTIS HC A25/MF A01

Ray bending expected for narrow-beam satellite links in the atmosphere are discussed. Satellite communications terminals in the upper latitudes frequently operate at low elevation angles with high gain antennas. These antennas produce narrow beams that pass through the atmosphere at low terminal-to-satellite evaluation angles for communication with geostationary equatorial satellites. The propagation paths experience ray bending caused by earth curvature and a decrease in atmospheric refractivity with altitude. Unless these effects are properly accounted for, acquisition and tracking problems can occur. Ray bending was found to vary from about 0.1 degrees for 10 degrees elevation angles to about 0.75 degrees for 0 degrees elevation angles under standard atmospheric conditions. Bending was found to be nearly independent of frequency in the SHF/EHF (20 GHz to 50 GHz) region. Warm high-humidity areas tended to produce more bending. Potential problem areas, including tracking and spatial acquisition, are discussed for satellite systems. The authors propose using elliptic reflectors and analytic prediction of ray bending to minimize adverse effects of ray bending. Author

N86-27542# Communications Research Centre, Ottawa (Ontario).

E.H.F. PROPAGATION MEASUREMENTS ALONG SATELLITE-EARTH PATHS IN THE CANADIAN HIGH ARCTIC

I. LAM and J. I. STRICKLAND *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 8 p (SEE N86-27531 18-32) Nov. 1985

Avail: NTIS HC A25/MF A01

Observations of the signal received from an EHF satellite beacon were made during June, August and December 1984 from a location in the Canadian arctic north of 80 deg N. The satellite follows an inclined orbit and as a result is visible for about eleven hours per day. During this period the elevation angle to the satellite varies between zero and approximately 21 degrees. The pointing of the receive antenna towards the satellite was achieved through computer-controlled tracking with a resolution better than 5% of the antenna beamwidth. Throughout the experimental period the changes in atmospheric conditions were mainly due to movement of air masses rather than diurnal variations in ground heating. Also, even though fog from the nearly ocean occurred frequently, there were no significant amounts of precipitation during the experiment. The results of the experiment indicate that signal fading occurs almost entirely at elevation angles less than approximately 5 degrees. Variations in the median signal level are presented as a function of the elevation angle. Also included are cumulative distributions of received signal level computed for various elevation angles. In general, the experimental results correlate well with the atmospheric conditions. The fading was found to be less severe in the winter than either spring or summer. Author

N86-27543# GEC-Marconi Electronics Ltd., Chelmsford (England).
IONOSPHERIC MODELLING AND HF RADIO SYSTEMS AT HIGH LATITUDES
S. QUEGAN, J. D. MILSOM, and R. N. HERRING *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 8 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Successful planning of HF radio systems to operate at high latitudes requires some means of predicting ionospheric morphology, both as regards ambient electron density and ionospheric irregularities causing backscatter. Because of the presence of several physical processes, and the sparsity of data, reliable statistical models are not easily constructed. However, increasing knowledge of the processes operating, and the availability of powerful computers, makes the construction of physically-based numerical models of ionospheric structure a viable proposition. Such a model at a fairly advanced stage of development is described. Examples of calculated electron densities are given. The ingredients and shortcomings of the model are be described, together with the steps to be taken to account for ionospheric irregularities, and to allow us to predict HF system performance using ray-tracing. Author

N86-27544# Rome Air Development Center, Hanscom AFB, Mass. Electromagnetic Sciences Div.
HIGH LATITUDE SPATIALLY ADAPTIVE PROPAGATION EXPERIMENT
G. S. SALES, R. J. CORMIER, R. A. GREENWALD (Johns Hopkins Univ., Laurel, Md.), and K. B. BAKER *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 7 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

A special HF phased array was used to obtain high latitude HF propagation data. The antenna located at Goose Bay, Labrador, Canada, received HF transmission (8 to 20 MHz) from Thule, Greenland. The receiving antenna at Goose Bay consisted of two parallel linear arrays each with 16 horizontal log-periodic antennas. This system was used to measure both the azimuth and elevation angle of arrival of the propagated radio wave. Comparisons are made with model calculations and the received modes are analyzed to determine the presence of ionospheric tilts. Author

N86-27545# York Univ. (England). Dept. of Electronics.
TECHNIQUES FOR IMPROVING THE RELIABILITY OF MOBILE HF COMMUNICATIONS OVER HIGH-ABSORPTION PATHS
M. DARNELL *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 15 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

System design aspects of the mobile HF communications problem in high-latitude regions are discussed. An attempt is made to identify the various techniques available for enhanced reliability of reception under high-absorption conditions and to indicate how these can be coalesced into an improved HF system design. The basic problem associated with excess absorption is that received signal-to-noise ratios (SNR's) are lower than those which might be expected for say mid-latitude paths. Specific methods by which the value of the SNR required at the receiver can be reduced, either directly or effectively are discussed. Techniques discussed include: (1) the use of various forms of diversity processing, emphasising the value of path/geographical diversity combining; (2) relaying out of the disturbed region with a view to avoiding the perturbed ionosphere and operating the transmitting antenna system more efficiently at a high frequency; (3) the use of meteor-burst and ionospheric scatter communication to complement normal HF communication; (4) the use of modulation and coding schemes requiring a relatively low SNR at the receiver; and (5) system control procedures. Author

N86-27546# Alaska Univ., Fairbanks. Geophysical Inst.
PROPAGATION CHARACTERISTICS OF MEDIUM FREQUENCY SKYWAVE SIGNALS FROM THE CONTINENTAL US AND CANADA RECEIVED AT FAIRBANKS, ALASKA
R. D. HUNSUCKER, B. S. DELANA, and J. C. H. WANG *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 14 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Since September 1981, an F.C.C.-sponsored medium-frequency (MF) skywave monitoring program has been in continuous operation at the Geophysical Institute of the University of Alaska. The receiver frequency is automatically stepped through 16 channels every five minutes by the system programmer. Recordings are continuously made of ten or more standard broadcast stations on digital tape cassettes, which are then transferred on a weekly basis to form a data base on a VAX 11/780-785 computer. A noise source has also been provided for system calibration. Three antennas have been utilized during the program to date, a 32-meter top-loaded vertical with ground screen being the primary antenna. Measurements of the electrical characteristics and computer modeling of the antenna systems have been made, and selected results are presented, as well as daily, seasonal and sunspot variation effects on measured MF skywave signal strengths. The summer/winter and magnetic activity effects are profound on medium and long-distance paths to Fairbanks. Present plans are to continue this monitoring program until Fall 1987 at least half of a sunspot cycle. Author

N86-27547# Paris-Sud Univ., Cachan (France). Lab. d'Etude des Transmissions Ionospheriques.
OPTIMISATION DES SYSTEMS OF TRANSMISSION NUMERIQUE TRANSAURORAUX EN ONDES DECAMETRIQUES OPTIMIZATION OF H.F. DIGITAL RADIO SYSTEMS AT HIGH LATITUDES
C. GOUTELARD, J. CARATORI, and A. NEHME *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 18 p (SEE N86-27531 18-32) Nov. 1985 In FRENCH; ENGLISH summary
Avail: NTIS HC A25/MF A01

High latitudes are inevitably encountered in telecommunications, especially in long distance transmissions. At high latitudes the following phenomena appear: auroral and polar absorptions, spread F, perturbations aligned with the magnetic field, sporadic E... which make long distance transmission characteristics special. Researchers were able to establish a channel model from experimental observations of transmissions travelling through high latitudinal regions. The parameters of the model must include the perturbations found at high latitudes, the length of the transmission, and its position relative to the magnetic pole and the auroral zone. From these models, which point out the spectral modifications of the signal, the fading, the duration of coherence, researchers determined the classes of signals which can be needed for H.F. digital telecommunications with the aim of diverse techniques: serial or parallel transmissions, autoadaptative systems, coded transmission systems. Author

N86-27548# Forschungsinstitut der Deutschen Bundespost, Darmstadt (West Germany).
OBSERVATIONS WITH AN IONOSONDE IN NORTHERN GERMANY NEAR THE MID-LATITUDE TROUGH
T. DAMBOLDT *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 5 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

A new-vertical incidence ionosonde was installed more than two years ago near Hamburg, in order to improve HF propagation predictions and frequency management. HF propagation in the North-Sea and Baltic-Sea areas - close to the auroral zone, near the mid-latitude trough - is highly variable. This manifests itself also on the ionograms. Many of them show peculiarities normally not seen farther south. The day-to-day variation of measured ionospheric characteristics is compared with those obtained by the CCIR method (Report 340). In addition statistics of ionospherically disturbed days in the years 1983 and 1984 are given and compared with measurements of the variations of the geomagnetic field at the near-by observatory Wingst. Although the ionosonde is used mainly as a tool for up-to-date HF propagation predictions, the collected data can be of considerable

use also for the design of new HF radio systems in the area under consideration. Author

N86-27549# Rutherford High Energy Lab., Chilton (England).
IONOSPHERIC FACTORS AFFECTING THE PERFORMANCE OF HF SKY-WAVE SEA-STATE RADARS AT HIGH LATITUDES
P. A. BRADLEY, A. J. GIBSON, J. C. SCHLOBOHM (SRI International Corp., Menlo Park, Calif.), and D. E. WESTOVER *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 14 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Sky-wave radars provide a means of ocean surveillance beyond line of sight and beyond the ranges achievable with a ground-wave radar. However, the ionosphere introduces a number of important propagation limitations. Firstly, it is necessary to provide illumination of the areas of interest, which may place restrictions on radar sitting and periods of operation. Then, backscattered signals must have sufficient amplitude to provide adequate discrimination above the naturally occurring and interference backgrounds. A radar measures time-of-flight and such information needs transforming to equivalent ground range in terms of the prevailing ionospheric path. Finally, ionospheric motions create Doppler shifts and spreads of the returned signals which prevent spectral resolution of Bragg scattered components. The high-latitude ionosphere is characterised by features which exhibit marked spatial and temporal variability. Specific problems are discussed and possible ways of alleviating some of these considered. Author

N86-27550# Paris VI Univ. (France).
SPECTRAL CHARACTERISTICS OF HIGH FREQUENCY WAVES BACKSCATTERED BY SMALL SCALE F REGION IRREGULARITIES: EVIDENCE OF STRONG SUB-AURORAL ION FLOW
A. BOURDILLON *In* AGARD Propagation Effects on Military Systems in the High Latitude Regin 16 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

The spectra of H.F. waves backscattered at night by small scale (10 to 20 m) sub-auroral F region irregularities often exhibit large Doppler shifts and widths in the local time sector 2000 to 2400. After local midnight the Doppler shifts and the widths of the spectra decrease rapidly. Examples of experimental data obtained with the two coherent backscatter radars of the EDIA experiment, showing the spectral characteristics just mentioned are given. From the Doppler shift measured at the two sites researchers deduced the perpendicular velocity of the irregularities, which can reach values as high as 2000 m/s. These observations are interpreted using results of theoretical models which predict strong sub-auroral ion flow in the trough region. Author

N86-27551# *Toulon Univ. (France).* Lab. de Sondages Electromagnetiques de l'Environment.
SMALL-SCALE IRREGULARITIES IN THE HIGH-LATITUDE F REGION
C. HANUISE, J. P. VILLAIN, C. BEGHIN (Centre National de la Recherche Scientifique, Orleans, France), and G. CAUDAL (Centre National de la Recherche Scientifique, Saint-Maur-des-Fosses, France) *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 12 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Coordinated observations performed at high and very high latitudes in the European sector with the ISOPROBE experiment on board the AUREOL 3 satellite, the EISCAT incoherent scatter radar and the SAFARI HF coherent radar system are reported. The latitudinal profiles of electron density measured by the incoherent scatter radar are used to determine the influence of the propagation of the HF radio wave on the detectability of the density variations deduced from in-situ measurements. The physical processes leading to the formation of the fluctuations are studied at several wavelengths from in-situ and radar data. The phase velocity vector constructed from the radial velocities measured by two HF radars are compared to the plasma drift measured with the EISCAT facility under various geophysical conditions. The excellent agreement between the estimates confirms, as predicted theoretically, that the F-region small-scale irregularities are drifting with the bulk plasma. Their motion can therefore can therefore be used to derive the two-dimensional flow pattern of plasma convection in the auroral and polar ionosphere. Author

N86-27552# SRI International Corp., Menlo Park, Calif. Radio Physics Lab.
ON THE RELATIONSHIP OF F-REGION STRUCTURE IN THE DAYSIDE AURORAL OVAL TO HF BACKSCATTER SIGNATURES ATTRIBUTED TO THE POLAR CUSP
J. D. KELLY, R. T. TSUNODA, J. K. OLESEN (Danish Meteorological Inst., Copenhagen.), and P. STAUNING *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 10 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Ionosonde measurements in the vicinity of the dayside auroral oval are characterized by complex signal returns. These are thought to be associated with the structure of the electron density in the F-region attributed to processes associated with the polar cusp. The results of a comparison of simultaneous, incherent-scatter radar measurements and ionosonde measurements of the dayside auroral-zone ionization are given. This experiment takes advantage of the unique geometry of the Sondrestrom radar operated by SRI International at Sondre Stromfjord, Greenland, and the ionosondes operated by the Danish Meteorological Institute at Godhavn and Sondre Stromfjord, Greenland. The radar was operated while the antenna scanned in the magnetic meridian. The locations of the ionosondes are in that meridian. The radar data greatly assist in the interpretation of the complex ionograms. The F-region structure in electron density is closely associated with specific features in the plasma convection patterns. The F-region structure associated with the plasma convection reversal (polar-cap boundary) in the postnoon sector and its ionogram signature were studied. The ionograms are charact erized by oblique echoes when the convection reversal is either poleward or equatorward of the ionosonde. The radar data indicate that the gradient in the electron density enhancement is similar on the poleward and equatorward edges, and that the enhancement is extended along the convection reversal for many hours. Auther

N86-27553# Johns Hopkins Univ., Laurel, Md. Applied Physics Lab.
OBSERVATIONS OF VERY HIGH LATITUTDE IONOSPHERIC IRREGULARITIES WITH THE GOOD BAY HF RADAR
R. A. GREENWALD and K. B. BAKER *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 17 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

The Goose Bay HF radar is a sophisticated instrument capableof providing detailed information on very high latitude E and F region ionospheric electron density irregularities which act as a source of clutter on OTH radar systems. Through the use of two parallel phased array antennas, this instrument is able to image the ocation of these irregularities within a three-dimensional volume covering much of northeastern Canada and Greenland. It is also capable of following the temporal variability of these irregularities as well as determining unambiguously the Doppler shift and broadening of radar signals scattered by them. Initial results with a single phased array antenna which represent typical examples of the spatial intensity distribution of these irregularities at different local times are presented. Examples of Doppler spectra of the irregularities at different local times are given. Data of this type are of appreciable value in ascertaining the techniques that must be utilized to improve clutter mitigation on high latitude radar systems. Author

N86-27554# Utah State Univ., Logan. Center for Atmospheric and Space Sciences.
OBSERVATIONS OF THE MID-LATITUDE IONOSPHERIC TROUGH FROM ANTARCTICA
F. T. BERKEY and M. J. JARVIS (British Antarctic Survey, Cambridge (England).) *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 25 p (SEE N86-27531 18-32) Nov. 1985
(Contract NSF DPP-81-00220; NSF DPP-83-08044)
Avail: NTIS HC A25/MF A01

Measurements of the ionosphere using two identical digitally controlled high frequency radar systems have been conducted in the Antarctic from the Halley and Siple Stations. These stations are uniquely sited, both having essentially identical coordinates of

geographic and geomagnetic latitude. Furthermore, due to the large offset of the geographic and magnetic poles in Antarctica, the difference in magnetic local time is less than half the separation in local solar time. The locations of the minimum and poleward edge of the trough have been found for magnetically quiet intervals and mapped into invariant latitude. Simultaneous measurements of the trough location from Siple and Halley have been compared using magnetic, local and universal time coordinates. For geomagnetically quiet conditions, this analysis suggests that the invariant latitude of the poleward edge has a Universal Time dependence prior to local midnight. The presence of the ionospheric trough introduces a further degree of complexity to the subauroral ionosphere which, in turn, complicates automatic realtime processing of digital ionograms. Several examples of a technique termed elevation angle filtering are presented and the effect of the presence of the ionospheric trough on this process is examined. Author

N86-27555# British Antarctic Survey, Cambridge (England).
THE VARIABILITY AND PREDICTABILITY OF THE MAIN F-REGION TROUGH DETERMINED USING DIGITAL IONOSPHERIC SOUNDER DATA
A. S. RODGER and J. R. DUDENEY *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 11 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

The main F-region (or mid-latitude) electron density trough occurs near lambda = 60 degrees and is associated with significant meridional gradients in electron concentration. Despite many satellite studies of the trough, the causes of the variability of its shape as a function of time, geomagnetic and solar activity is still poorly understood. This is illustrated by the large discrepancies between the various empirical formulae tht have been developed to estimate the trough latitude for specified geomagnetic conditions. These problems arise partly because satellite data cannot be used to differentiate adequately between spatial and temporal variations. In 1981, a new and powerful research tool for trough studies has become available. The observations from this equipment have significantly improved our understanding of several features of trough morphology and in particular the causes of some of the variability. The four aspects of this variability that are discussed here are the orientation of the poleward edge of the trough with respect to Halley; the variation of the maximum plasma frequency of the poleward edge; the signature of the Harang discontinuity in the poleward edge and the latitudinal movement of the poleward edge as a function of time and geomagnetic activity. A framework is described for incorporating these aspects of trough morphology into a realistic model for predicting the location and maximum plasma density of the poleward edge as a function of time and the prevailing geomagnetic conditions. Author

N86-27556# Alaska Univ., Fairbanks. Geophysical Inst.
PROGRESS IN MODELLING THE POLAR IONOSPHERE FROM SOLAR AND MAGNETOSPHERE PARAMETERS
B. J. WATKINS, S. I. AKASOFU, and C. D. FRY *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 5 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Solar and magnetospheric parameters have been used as inputs to a three dimensional ionospheric model covering the polar cap and auroral zone latitudes for heights 120 to 500 km. The development of this model is reported. Using solar and magnetosphere parameters, the solar radiation and convective electric field structure are defined. Solutions to the momentum and continuity equations for ionization densities are obtained vertically along magnetic field lines as they move under the influence of convective electric fields. The critical measurements that are needed to use such a model to predict ionospheric conditions at polar regions are discussed. Author

N86-27557# Lancaster Univ. (England). Dept. of Environmental Science.
STATISTICS OF AURORAL RADIO ABSORPTION IN RELATION TO PREDICTION MODELS
J. K. HARGREAVES, M. T. FEENEY, and C. J. BURNS *In* AGARD Propagation Effects on Military System in the High Latitude Region 10 p (SEE N86-27531 18-32) Nov. 1985 Sponsored in part by Royal Aircraft Establishment, Farnborough, England, and by the Science and Engineering Research Council
Avail: NTIS HC A25/MF A01

The prediction of HF propagation conditions at high latitude requires a knowledge of the statistics of radio absorption in the auroral ionosphere, a highly variable phenomenon depending on local time, magnetic latitude, season and solar activity. Data from riometer stations may be compiled to provide statistics on the auroral radio absorption. Questions regarding the probability distribution and variations with latitude, solar and geomagnetic activity, and longitude are considered. Difficulties concerning the smallest absorption values are pointed out. Author

N86-27558*# Massachusetts Inst. of Tech., Cambridge. Dept. of Electrical Engineering and Computer Scien
FORMATION AND DETECTION OF HIGH LATITUDE IONOSPHERIC IRREGULARITIES
M. C. LEE, J. BUCHAU (Air Force Geophysics Lab., Hanscom AFB, Mass.), H. C. CARLSON, JR., J. A. KLOBUCHAR, and E. J. WEBER *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 14 p (SEE N86-27531 18-32) Nov. 1985
(Contract NAG5-270; F19628-83-K-0024)
Avail: NTIS HC A25/MF A01

Measurements of Total Electron Content (TEC) and airglow variations show that large scale plasma patches appearing in the high-latitude ionsophere have irregular structures evidenced by the satellite phase and amplitude scintillations. Whistler waves, intense quasi-DC electric field, and atmospheric gravity waves can become potential sources of various plamsa instabilities. The role of thermal effects in generating ionospheric irregularities by these sources is discussed. Meter-scale irregularities in the ionospheric E and F regions can be excited parametrically with lower hybrid waves by intense whistler waves. Ohmic dissipation of Pedersen current in the electron gas is able to create ionospheric F region irregularities in plasma blobs or plasma patches (i.e., high ambient plasma density environment) with broad scale lengths ranging from tens of meters to a few kilometers. Through the neutral-charged particle collisions, gravity waves can excite large-scale (less than tens of kilometers) ionospheric irregularities simultaneously with forced ion acoustic modes in the E region. The large-scale ionospheric density fluctuations produced in the E region can extend subsequently alogn the earth's magnetic field to the F region and the topside ionospheric regions. These mechanisms characterized by various thermal effects can contribute additively with other processes to the formation of ionospheric irregularities in the high latitude region. Author

N86-27559# Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau (West Germany).
DIRECT, IN-SITU MEASUREMENTS OF IRREGULARITIES IN THE MESOSPHERE (85 - 50 KM) AT 69 DEG N (ANDENES, NORWAY)
H. U. WIDDEL *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 10 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

One of the problems of the physics of the mesosphere which is apparently not yet completely solved is which hydrodynamic mechanisms can cause transient vertical and horizontal gradients of electron density and neutral air density. Such gradients give rise to scattered signals of radio waves at different frequencies. Well-known are the 'partial echoes' observed on short wave frequencies beluw about 100 km down to about 60 km. They seem to occur at certain 'preferred' heights which seem to change with season and latitude. Because the distribution of ionization at such low altitudes, once produced, is primarily controlled by the neutral atmosphere. Investigations of the dynamics of the neutral atmosphere combined with simultaneous radio wave measurements promise some advance of knowledge. It was shown that small lofl clouds, together with proper techniques of observation can be

used to study in detail a number of dynamic effects in the neutral atmosphere with high spatial resolution. This high spatial resolution revealed that some atmospheric structures seem to be very local. Further, the radar range gate echo records showed that the radar tracking data do not always tell the full story. To obtain a better picture, more than one chaff target, separated in space, should be tracked simultaneously. This calls for a 3D-multiacquisition-multitarget radar for tracking. Author

N86-27560# Rome Air Development Center, Hanscom AFB, Mass.
CONDUCTIVITY PROFILES OF THE DISTURBED POLAR IONOSPHERE FROM VLF REFLECTION DATA
P. A. KOSSEY, J. E. RASMUSSEN, E. C. FIELD (Pacifica-Sierra Research Corp., Los Angeles, Calif.), and C. R. WARBER *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 11 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Two independent techniques are used to determine conductivity profiles of the lower polar ionosphere during a strong solar proton event (SPE). The first method inverts reflection coefficients measured with a groundbased VLF sounder; the second uses proton fluxes measured on board satellites to calculate ion-pair production rates, which, in turn, are input to lumped-parameter de-ionization equations. Conductivities determined by the two methods exceed ambient by two or more orders of magnitude, but disagree by up to an order of magnitude at altitudes between fifty and sixty kilometers. Full-wave calculations are used to predict the effect of the SPE-disturbed profiles on long range VLF propagation in the earth-ionosphere waveguide. The SPE is found to suppress the geomagnetically converted transverse electric field radiated by a groundbased vertical electric dipole.

N86-27561# Bonn Univ. (West Germany). Radioastronomical Inst.
A STUDY OF ULF PROPAGATION AT HIGH SOUTHERN LATITUDES USING SFERICS
H. VOLLAND, M. SCHMOLDERS, G. PROELSS, and H. KROENINGER (National Electrical Engineering Research Inst., Pretoria (South Africa).) *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 10 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Sferics are electromagnetic pulses generated by lightning events. Their maximum spectrum energy is in the frequency range below 15 kHz. These powerful natural VLF transmitters can be used to determine the propagation characteristics of the atmospheric wave guide between earth and ionospheric D layer along virtually every propagation path. A VLF-sferics-analyzer was operating at the German antarctic Von Neumayer station from January to July 1983. This analyzer records sferics from distant lightning events in the frequency range between 5 and 9 kHz. The method of measurement is described. The data of June 1983 are evaluated, and the distances of the sources are determined by a comparison with rainfall records during the same month and, in addition, with sferics recordings from a station in Pretoria, South Africa. The data evaluation of the propagation conditions is compared with theoretical calculations. The main result is that the virtual reflection height of the ionospheric D layer is between about 78 km at noon and about 84 km during midnight in reasonable agreement with the theory. The difference between west-to-east and east-to-west propagation is smaller than the theory predicts indicating that the ionospheric D layer at high souther latitudes behaves more isotropic with respect to VLF propagation than at mid-latitudes. Author

N86-27562# Pacifica-Sierra Research Corp., Los Angeles, Calif.
EFFECTS OF THE IONOSPHERE ON ELF SIGNALS DURING POLAR CAP ABSORPTION EVENTS: COMPARISON OF THEORY AND EXPERIMENTS
E. C. FIELD, C. R. WARBER, and R. G. JOINER (Office of Naval Research, Arlington, Va.) *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 10 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

In order to calculate extremely low frequency (ELF) propagation when the earth-ionosphere waveguide is not stratified, a hybrid method is developed that uses full-wave theory to determine local parameters of the TEM mode, but uses ray theory to describe the field's horizontal variations. The method is applied to several model solar proton events (SPEs), including one based on the weak 23 November 1982 event. Calculations predict diminished fields near the Gulf of Alaska, where a submarine-borne receiver measured an unusually severe signal reduction. That behavior is caused by lateral refraction, which bends the signal away from the polar cap boundary and into the central cap where, during an SPE, the phase velocity of the TEM mode is slowest. The theory also predicts an enhanced field just inside the polar cap boundary, but no data are available to test that result. Author

N86-27563# Norwegian Telecommunications Administration, Oslo.
WORLD ATLAS OF GROUND CONDUCTIVITIES WITH PARTICULAR EMPHASIS ON THE HIGH LATITUDE REGION
K. N. STOKKE *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 12 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Methods of predicting the phase and amplitude of ground waves are discussed. An important feature concerning transmission of ground waves is the ground conductivity. Information about the ground conductivity has been, and is, important for the planning work in the International Telecommunication Union (ITU). Therefore very early in the work of IWP 5/1 the necessity of a ground conductivity atlas was recognized, and in 1978 the IWP 5/1 was formally given the task to produce a world atlas (CCIR Decision 3). Information about the ground conductivity has been received from about 50 countries, but there are some problems concerning the way in which the informations are presented. However, measuring campaigns will give better data and will also give better informations from other areas. The first edition of the Atlas is planned before the CCIR Final Studygroup Meetings September - November 1985. Author

N86-27564# Royal Aircraft Establishment, Farnborough (England).
METEOR SCATTER RADIO COMMUNICATION AT HIGH LATITUDES
P. S. CANNON, A. H. DICKSON, and M. H. ARMSTRONG *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 18 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

A brief historical and physical description of the meteor burst communications (MBC) technique is given together with a discussion of the advantages of very high frequency MBC, with respect to conventional high frequency communication, when used at high latitudes. A recently deployed high latitude MBC propagation experiment, between Bodo in Norway and Wick in Scotland (UK) is described and some of the early data gathered at frequencies close to 40 MHz and 70 MHz is presented. A theoretical description of the effects of Polarisation Rotation in a linearly polarised MBC system is developed and it is shown that at 40 MHz Polarisation Rotation, due to excess D-region ionization may cause the system performance to differ from its ambient level. Corroborative experimental results, over a temperature latitude path, are presented. Based upon the early high latitude experimental results and on the theoretical calculations, it is suggested that frequencies close to 40 MHz, in common use in atemperate latitude linearly polarised MBC systems, are too low for high latitude operation. Author

N86-27565# Danish Research Center for Applied Electronics, Hoersholm.
CHARACTERISTICS OF HIGH LATITUDE METEOR SCATTER PROPAGATION PARAMETERS OVER THE 45 - 104 MHZ BAND
J. C. OSTERGAARD, J. E. RASMUSSEN, M. J. SOWA, J. M. QUINN, and P. A. KOSSEY *In* AGARD Propagation Effects on Military Systems in the High Latitude Region 15 p (SEE N86-27531 18-32) Nov. 1985
Avail: NTIS HC A25/MF A01

Data be ng acquired on a high latitude test-bed, to assess the performance of meteor scatter propagation over the 45 to 104 MHz band, are described. Emphasis is on data obtained over a 1200 km path in northern Greenland, which includes initial estimates of the availability of usable meteor trails, the potential performance

of meteor scatter systems, and the application of adaptive data rates to improve system performance. The use of the data to validate and expand propagation prediction techniques for the polar region is also discussed. Author

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ELECTRONICS AND ELECTRICAL ENGINEERING

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

N86-28337# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
THE IMPACT OF VERY HIGH PERFORMANCE INTEGRATED CIRCUITS ON RADAR, GUIDANCE AND AVIONICS SYSTEMS
Loughton, England Aug. 1985 396 p In ENGLISH and FRENCH Symposium held in Lisbon, Portugal, 20-25 May 1985 (AGARD-CP-380; ISBN-92-835-0379-1; AD-A163151) Avail: NTIS HC A17/MF A01

Advances with silicon integrated circuit technology have demonstrated the feasibility of very large scale integration with gate densities of 10 to the 5th power/sq cm and with functional throughput rates in excess of 10 to the 12th power gate Hz/sq cm. These advances offer the prospect of compact, low power consumption, high throughput processors in a wide variety of roles throughout military electronic systems. This symposium aimed to involve integrated circuit experts who reviewed ththeir current and projected capabilities, circuit and subsystems designers who are exploiting the technology in implementing sophisted processing and data manipulation techniques and who reported on their progress, and system designers who described applications addressed by the advancing technology. For individual titles see N86-28338 through N86-28374.

N86-28338# Naval Research Lab., Washington, D. C.
VHSIC TODAY AND TOMORROW
D. O. PATTERSON and E. D. MAYNARD, JR. (Office of the Under Secretary of Defense for Research and Engineering, Washington, D. C.) *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 4 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The origin and objectives of the U.S. Department of Defense Very High Speed Integrated Circuits (VHSIC) Program are discussed. This document describes the several phases of the program schedule and give the status of each. The phase 1 contractors, their approaches, and highlights of the Phase 1 chip sets are given. Supporting programs ranging from design and fabrication to implementation are presented. The contractors of the Phases 2 submicron technology effort are listed with their projected results. Finally the technology insertion effort is discussed, listing some systems being implemented and the payoffs of the VHSIC program. Author

N86-28339# Department of Trade and Industry, London (England). Alvey Directorate.
VHPIC AND THE UK ALVEY PROGRAMME
W. FAWCETT *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 6 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Very high performance silicon integrated circuits (VHPIC) will be vital to future defense systems. In the UK, the required technology is being developed in the Alvey program and will be exploited in a Ministry of Defense VHPIC application demonstrator program. The organization and objectives of these programs are described in this paper. Author

N86-28340# Ferranti Electronics Ltd., Oldham (England).
BIPOLAR VLSI TECHNOLOGY
D. L. GRUNDY *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 14 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The fundamental aspects of speed, power dissipation, linear capability, nuclear radiation tolerance and manufacturability are discussed for bipolar VLSI technology. Ultimate speed limits for VLSI technology are considered. It is suggested that bipolar technology may ultimately prove to offer the lowest power dissipation for a given speed. Of increasing interest to users of VLSI chips is linear capability and the fundamental factors influencing linear performance. The performance of bipolar technology in the nuclear environment is discussed. MOST and bipolar technologies are compared. Finally, the practical ultimate limits of complexity for VLSI chips are discussed and the problems associated with achieving acceptable manufacturing yields are explored. Author

N86-28341# TRW Electronics and Defense Sector, Redondo Beach, Calif. Microelectronics Center.
THE FUTURE OF BIPOLAR TECHNOLOGY FOR AVIONICS
B. DUNBRIDGE *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 10 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

In the past 25 years, silicon integrated circuit (IC) device technology has been heavily utilized in military and avionics systems due to primary advantages in availability, versatility, environmental ruggedness/reliability, and speed/frequency performance. Silicon n-channel metal oxide semiconductor (NMOS) technology has also rapidly developed and has been dominant for commercial applications due to its previous advantages of cost and density in modest environments, especially for standard memory and microprocessor functions. Complementary metal oxide semiconductor (CMOS) LSI/VLSI has more recently rapidly emerged as the dominant MOS device technology of the the future. The long held speed performance advantage of silicon bipolar ICS is also being challenged by the superior switching speed of GaAs field-effect transistor (FET) ICs. The question arises as to the future competitiveness and role of silicon bipolar. The question is further examined in this paper, especially for future avionics systems applications having heavy realtime digital signal processing requirements. B.W.

N86-28342# Ruhr Univ., Bochum (West Germany). Inst. fuer Elektronik.
MONOLITHIC SILICON BIPOLAR CIRCUITS FOR GIGABIT APPLICATIONS
U. LANGMANN *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 4 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

This contribution presents examples of Si gigabit circuits for application in wide-band communication systems. Circuits recently implemented in a relatively conventional Si bipolar technology are reported and guidelines for the design of high-speed bipolar ICs are given. Performance data are compared to those of bipolar ICs using self-aligned process technologies. Author

N86-28343# Hughes Aircraft Co., El Segundo, Calif. Technology Dept.
HIGH LEVERAGE GAAS INTEGRATED CIRCUITS FOR MILITARY SYSTEMS
J. T. MENDEL *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 15 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

During the past fifteen years a substantial amount of funding has been devoted to the research and development of GaAs devices and circuits primarily by the space and military sectors of the U.S. Government. The remarkable characteristics of this compound semiconductor in terms of speed, radiation hardness, and the potential for low power consumption has caused many investigators to regard GaAS as a successor to silicon in high performance circuits for military applications. In spite of this promise there exists today very little usage of GaAs in military systems

with the exception of discrete microwave FETs and IMPATT diodes. Fundamental problems of material growth and processing technologies have created formidable barriers to the rapid exploitation of the III-V compounds except at levels of small scale integration. However, for very demanding military applications GaAs still remains the basic hope for the future. Particularly in the area of preprocessing for radar and EW systems the speed requirements are well beyond the capabilities of silicon. The unique capabilities of GaAs devices are discussed and their continued use in military applications is highlighted. Author

N86-28344# Sandia National Labs., Albuquerque, N. Mex.
A COMPARISON OF THE RADIATION HARDNESS OF VARIOUS VLSI TECHNOLOGIES FOR DEFENSE APPLICATIONS
C. F. GIBBON *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 8 p (SEE N86-28337 19-33) Aug. 1985 Previously announced as N85-30236
(Contract DE-AC04-76DP-00789)
Avail: NTIS HC A17/MF A01

In this review the radiation hardness of various potential very large scale (VLSI) IC technologies is evaluated. IC scaling produces several countervailing trends. Reducing vertical dimensions tends to increase total dose hardness, while reducing lateral feature sizes may increase susceptibility to transient radiation effects. It is concluded that during the next decade at least, silicon complimentary MOS (CMOS), perhaps on an insulating substrate (SOI) will be the technology of choice for VLSI in defense systems. Author

N86-28345# Rome Air Development Center, Hanscom AFB, Mass. Solid State Sciences Div.
THE IMPACT OF VLSI ON INTEGRATED CIRCUIT RADIATION HARDNESS
B. L. BUCHANAN *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 12 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The important constituents of energetic radiation and the effects of the radiation on semiconductor devices and integrated circuits are briefly summarized. The basic silicon material and device parameters which are sensitive to energetic radiation and can be controlled by the IC designer are delineated. The trends of the variation of hardness with the level of integration for commercial MOS and bipolar integrated circuits are examined. It is shown theoretically how the hardness will vary as a function of device size for total ionizing dose, ionizing dose rate, and single particle (cosmic ray) environments. Contrary to what the trends had been indicating, it is shown that the basic component devices theoretically and actually become more radiation resistant as the devices are scaled down in size for implementing higher levels of integration. However, the parasitic MOS and bipolar devices created in implementing VLSI designs may cause the overall hardness to decrease. The reasons for the radiation hardness of the GaAs integrated circuits are discussed and put into perspective with the silicon technology. Author

N86-28346# Plessey Co. Ltd., Romsey (England).
HARDWARE AND ARCHITECTURE DESIGN OF VLSI SYSTEMS
B. G. MARCHENT and D. F. BURROWS *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 11 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

An outline of a design methodology is presented. This methodology enables the system designer to capitalize upon the opportunities offered by advances in digital semiconductor technology without being overwhelmed by the VLSI complexity management problem. The paper commences with a brief description of a typical enabling technology, in this case Plessey Megacell. Then the areas to which this technology can be applied are suggested and illustrated by reference to a Radar System. A large gap is shown to exist in terms of complexity between the basic building blocks of a VLSI device and the sub systems into which a Radar is typically decomposed in the first attempt at design partitioning. In order to be able to put the Radar system onto VLSI, a structured, hierarchical approach is shown to be necessary. The building blocks of each stage in the design process are proposed and finally the design task itself is described which, at the lower level in the sub system design process, will consist of the structured instantation, parameterization and interconnection of the hierarchical building blocks. Author

N86-28347# Rome Air Development Center, Griffiss AFB, N.Y. Reliability and Compatibility Div.
THE USE OF FAULT TOLERANT AND TESTABLE HIGH PERFORMANCE INTEGRATED CIRCUITS FOR IMPROVED MILITARY ELECTRONIC SYSTEM AVAILABILITY
J. J. BART *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 4 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The rapid evolution of high performance Very Large Scale Integrated Circuits (VLSICs) has resulted in accelerated opportunities for improving the operational performance of military electronic systems. In addition, the microelectronics technology base also holds the promise of providing improvements in the operational availability, survivability and logistics supportability of these complex systems. The basics for these advances lies in the ability to design microelectronics based systems which are much more fault tolerant and more easily testable than those which have been developed to date. The current activities in the design of testable/fault tolerant integrated circuits are reviewed and areas for future emphasis are suggested. Author

N86-28348# Electronique Serge Dassault, St. Cloud (France).
VLSI CONTROL STRUCTURES [STRUCTURES DE CONTROLE DANS LES V.L.S.I.]
G. VALLAS *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 12 p (SEE N86-28337 19-33) Aug. 1985 In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

After some illustrated examples of the technological progress made in the past 30 years, this report shows the objectives for VLSI technology in the future, particularly for military applications (radar and homing devices) as well as the control of these circuits. The objectives for VLSI technology research are shown to include: satisfying the needs for the 90's; using suitable technology to reduce the cost; and increasing the efficiency by using appropriate system architecture. Author

N86-28349# Rensselaer Polytechnic Inst., Troy, N.Y. Center for Integrated Electronics.
GALLIUM ARSENIDE WAFER SCALE INTEGRATION
J. F. MCDONALD, G. TAYLOR, R. STEINVORTH, B. DONLAN, and A. S. BERGENDAHL *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 14 p (SEE N86-28337 19-33) Aug. 1985 Sponsored in part by the Fannie and John Hertz Foundation, and by IBM VLSI Fellowship
Avail: NTIS HC A17/MF A01

Gallium Arsenide (GaAs) digital MESFET technology has recently begun to appear in the semiconductor marketplace. The initial commercial offerings are at the small to medium scale integration levels. The high speed of these parts would seem to be very attractive for designers of high performance signal processing equipment. Persistent yield problems, however, have prevented the appearance of large scale integrated circuits. As a result, intrapackage and interpackage signal propagation problems such as coupling, parasitics and delay are likely to negate much of the benef..s of the fast MESFET logic devices for large systems constructed with such small scale building blocks. An early packaging concept, Wafer Scale Integration (WSI), which could possibly be used to address some of these limitations is reexamined. Author

N86-28350# Kaiserslautern Univ. (West Germany). Lehrstuhl fuer Grundlagen der Elektrotechnik.
DIGITAL CORRELATION PROCESSORS FOR SPREAD-SPECTRUM-COMMUNICATION-SYSTEMS
H. J. FISCHER and A. BAIER *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 10 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Some important correlators are presented and examined with respect to their applicability in spread-spectrum systems. The most suitable correlators are SAW TDL Filters, SAW Convolvers and Digital Matched Filters. The SAW devices have good performance and need only little space. Digital devices are easy to handle but hitherto suffer from a compromise between signal width, signal length and correlation rate. Nevertheless digital correlators are of great interest considering the advances in semiconductor technology. Two compact Digital Matched Filters for binary reference signals are presented, which show the possibilities of quantized recieved signals. The first DMF, called 4-phase DMF, is used for binarily quantized recieved signals. The second DMF can process received signals, which are quantized much finer.
Author

N86-28351# Defence Research Establishment, Ottawa. (Ontario).
A HIGH PERFORMANCE CHIP SET IMPLEMENTATION OF A FINITE IMPULSE RESPONSE FILTER
R. J. INKOL, K. D. SYMONS, and P. D. CLARKE *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 12 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The systolic properties of digital signal processing algorithms can most easily be exploited by specialized processors with simple architectures providing considerable parallelism and freedom from bottlenecks in the control and flow of data. The realization of such processors is facilitated by the availability of advanced IC process technologies, coupled with Computer Aided Design (CAD) techniques. A design example for a Finite Impulse Response (FIR) filter is presented. It consists of a small chip set; a multiplier-accumulator, a coefficient memory (consisting of Read Only Memory (ROM) or Random Access Memory (RAM) devices) and a Data Memory/Control Unit (DMCU). The latter, implemented with standard cell techniques, includes a 128 word x 16-bit data memory, generates all system control signals from a few simple external signals, and provides a simple asynchronous interface. The basis design concept is well suited for implementation using advanced technologies. Sub-micron silicon technology would provide improved performance and facilitate a single chip implementation, while gallium arsenide technology offers potential for real-time video signal processing. y would provide improved performance and facilitate a single chip implementation, while gallium arsenide technology offers potential for real-time video signal processing.
Author

N86-28352# AEG-Telefunken, Ulm (West Germany). Radar Div.
RADAR SIGNAL PROCESSING WITH HIGH SPEED LSI DEVICES
P. K. SCHMITT *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 10 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The basic structures of digital processing architectures using fast dedicated VLSI components are shown for two typical coherent signal processing operations: pulse compression and Doppler filtering. It is shown how these can be realized using currently available VLSI components and how future, more highly integrated components could be derived. A key role here is played by chips which perform fast multiplication of complex number pairs.
Author

N86-28353# Physics and Electronics Lab. TNO, The Hague (Netherlands).
REAL-TIME DIGITAL MATCHED FILTER FOR RADAR PULSE COMPRESSION
J. WILTSCHUT and G. A. BREEMS *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 8 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Digital processing of radar signals becomes more feasible by the advances in integrated circuit technology. A programmable matched filter for real-time compression of frequency modulated radar pulses, implemented with high speed LSI/MSI circuits is described. This matched filter, denoted as pulse compressor, forms part of an experimental radar system. The input signal consists of complex samples (2*12 bits) at a 10 MHz rate. The maximum pulse duration is 25 micro-seconds, which results in a time-bandwidth product of 250. The pulse compression is achieved through application of fast convolution with a transform size of 512 and a 50 percent overlap. The pulse compressor has a pipelined structure consisting of similar modules. The data is in 12 bit fixed point format and processing is done by integer arithmetic with block floating point scaling to avoid overflow. The internal data throughput rate is 20 MHz and more than 720 million multiplications per second are executed.
Author

N86-28354# AEG-Telefunken, Ulm (West Germany).
MONOLITHIC 6 BIT SUBCONVERTER FOR HIGH SPEED, HIGH RESOLUTION A/D CONVERSION SYSTEMS
F. BECK and G. BERGMANN *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 5 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The design of a subconverter for sequential flash A/D converters is presented. The subconverter consists of a 6 bit flash ADC, 64 pipeline latches, a 6 bit (64 current sources) D/A converter and 6 bit data register. It was integrated on a single die utilizing a high speed bipolar process with double layer metallization. Circuit details, simulation results, and chip design are described.
Author

N86-28355# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
HIGH SPEED DIGITAL IMAGE PROCESSING FUNCTIONS FOR A REALTIME SYNTHETIC APERTURE RADAR PROCESSOR
R. SCHOTTER and H. FROELICH *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 6 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Realtime Synthetic Aperture Radar Processing requires high speed implementation of basic image processing functions such as Lowpass/Bandpass Filtering, Correlation/Convolution, Fourier Transformation, Imaging Memories, Interpolation/Resampling, Complex Multiplication/Accummulation and Processing Control. The hardware concept is based on modular processing units which allow the construction of different algorithms by simply combining the appropriate modules of the processing family in a pipeline structure. Each module is designed by taking advantage of the most advanced integrated digital circuits like fast multiplier/accummulators, ALS TTL and High speed CMOS control logic, 64 K/256 K dynamic memories, fast CMOS memories and integrated signal processors. The basic architecture of some of the processing modules (FIR-Filter, Image Memory, FFT/IFFT) will be presented together with the practical results in terms of operational speed, work length, power consumption and board sizes. Additionally, the structure of the realtime SAR Processor based on these processing functions are discussed in detail showing the flexibility of the hardware approach.
Author

N86-28356# Standard Telecommunication Labs. Ltd., Harlow (England).
A SYSTOLIC ARRAY FOR HIGH PERFORMANCE ADAPTIVE BEAMFORMING
C. R. WARD and P. J. HARGRAVE *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 6 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

A new technique for adaptive antenna beamforming is described which provides very rapid adaptation. The technique avoids the explicit computation of the covariance matrix estimate and this

results in a reduced sensitivity to limited arithmetic precision. The proposed algorithm may be implemented in an efficient pipeline architecture using a triangular systolic array. Author

N86-28357# Communications Research Centre, Ottawa (Ontario).
PROCESSING REQUIREMENTS FOR RADAR DIGITAL BEAMFORMING
J. LITVA *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 16 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

An overview is given of the signal processing capabilities of radar DBF systems. Also, a description is given of advances required in existing hardware for implementing real-time signal processing on radar DBF systems. These include antenna elements, monolithic microwave integrated circuits and VLSI. A discussion is given of the advantages of novel architectures, such as systolic arrays or hypercubes using up to 10,000 processing elements. It is shown that the processing for a DBF system follows naturally from a set of basic matrix operations, running from matrix-vector multiplications to singular value decomposition of matrices and that these functions are best implemented using systolic-array type architectures. Finally, results will be presented from an existing near real-time DBF system which is capable of carrying out a 16-point complex FFT in 250 nanoseconds and produces 64 independent radar-beams in 4 microseconds.
Author

N86-28358# Norwegian Defence Research Establishment, Kjeller.
TWO-LEVEL DATA-FLOW ARCHITECTURE FOR PROGRAMMABLE SIGNAL PROCESSING
Y. LUNDH and O. SORASEN *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 10 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Signal processing tasks such as those encountered in radar systems can be highly demanding in terms of computer instructions per second. A multiprocessor architecture called Martinus is described, exploiting complexity to achieve high performance. Complex VLSI circuits are being specially designed for Martinus machines. A reconfigurable network consists of programmable processors, interconnected by buses of very high capacity. The processors may be of different types and can be of more or less task oriented design. One such class of types, Svop, is itself a multiprocessor, comprising a systolic array of programmable processing elements. Martinus-machines can be configured for high capacity. A 120 MIPS machine is in operation. Further developments aim to make capacities beyond 1 GFLOPS practical. The development comprises several application-specific integrated circuits including a bus circuit offering data transmission rates up to 2.5 Gbits/second. The article commences with a discussion of basic limiting factors of high performance computing. Author

N86-28359# Royal Signals and Radar Establishment, Malvern (England).
MIL-DAP: ITS ARCHITECTURE AND ROLE AS A REAL TIME AIRBORNE DIGITAL SIGNAL PROCESSOR
P. SIMPSON, J. B. G. ROBERTS, and B. C. MERRIFIELD *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 18 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Prototypes of a highly programmable digital processor, Mil-DAP, operating in excess of 300 MOPS and occupying less than a cubic foot will be available in 1985. Its architecture consisting of a large array of processing elements, controlled by a single control unit operating in a Single Instruction Muliple Data (SIMD) mode is described in some detail, including the provision of fast data input-output (up to 40 MBytes/sec), data buffering and programmable data reformation such as corner turning. Two programming languages exist; an assembler language for high efficiency and a higher level parallel form of FORTRAN. The ease of use of both these parallel languages is demonstrated with reference to simple examples. Mil-DAP's performance, size, weight and power consumption suit it well to the wide range of applications encountered in an avionics environment. For example, multimode, radar signal processing incorporating spectral analysis, constant false alarm rate processing and ambiguity resolution; speech recognition as in a voice driven cockpit; electronic support measures where very high speed association and recognition of received pulse information is needed; and reconnaissance image processing, are all potential real time applications. Benchmarks for these are given. Author

N86-28360# Tridex Systems, Inc., Nepean (Ontario).
A DISTRIBUTED ARRAY SIGNAL PROCESSOR WITH FAULT-TOLERANCE ATTRIBUTES
E. T. FATHI, C. V. W. ARMSTRONG, K. Q. T. NGUYEN, and A. W. BRIDGEWATER (Department of Communications, Ottawa, Ontario) *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 15 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

A fault-tolerant distributed array signal processor designed as a research tool to investigate fault-tolerance in the area of space-based radar signal processing is described here. Such applications require high reliability due to the closed system environment and high performance in order to reduce the bandwidth in data communication. These requirements exceed those required by commercial systems. The system described here is a multiple microprocessor-based system configured as a 3*3 array of identical processing modules. Each module consists of a data and communication subsystem and a signal processing subsystem, employing off-the-shelf state-of-the-art VLSI technology. Each subsystem has its own microprocessor, local program and data memory and operates independently to each other. The two subsystems operate asynchronously and also perform confidence tests on each other's performance. Communication between the processing modules is parallel at high data rates using dedicated DMA channels. A powerful virtual token-passing mechanism manages the arbitration for the parallel busses. The operating system is fully distributed and provides dynamic load sharing.
Author

N86-28361# Mitre Corp., Bedford, Mass.
A REVOLUTIONARY DESIGN METHOD FOR VLSI SIGNAL PROCESSORS
R. D. HAGGARTY, B. L. JOHNSON, and E. A. PALO *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 12 p (SEE N86-28337 19-33) Aug. 1985 Sponsored in part by Mitre Corp., Bedford, Mass.
(Contract F19628-84-C-0001)
Avail: NTIS HC A17/MF A01

This paper presents a new method of designing digital signal processors for very large scale integrated (VLSI) circuit implementation with residue number systems (RNS), as opposed to the binary number systems traditionally used. In an RNS, a number is represented by its residues, modulo a set of relatively prime integers. The basic operations of modulo addition and multiplication are simpler in RNS because they can be executed independently in each residue class. Consequently, a desired linear function can be executed in a set of parallel channels on a chip, where each channel performs the same calculation modulo the integer used in theat channel. Complexity is thus reduced by two mechanisms. Interconnections between parallel channels are eliminated and all operations are performed modulo the small integer used in each parallel channel of the RNS structure. The square law of circuit complexity applied to this set of small integers results in small, simple circuits. Speed of computation is increased because carry propagation delays are avoided. Further, the RNS design is combined with systolic arrays in such a way that the desired function becomes a parallel set of nearest neighbor--connected identical cells, each of which is minimally complex. The regularity minimizes interconnections and design time--only one master VLSI macrocell that can be optimized and replicated under computer-aided design (CAD) control is needed. In addition, two levels of redundancy can readily be incorporated to achieve concurrent test and fault tolerance: (1) redundant parallel residue channels can be used, and (2) error detection techniques can be efficiently incorporated into each of the systolic array cells that compose the parallel RNS channels. Author

N86-28362# Hughes Aircraft Co., Canoga Park, Calif.
POTENTIAL IMPACT OF VLSI TECHNOLOGIES ON GUIDED MISSILE DESIGN
H. A. MAURER and K. S. KONGELBECK *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 6 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Some aspects of the anticipated impact of emerging VLSI technologies on tactical missiles, present and future generations are discussed. VLSI evolution represents a unique example of a very dynamic and pervasive trend in commercial and military applications. It is our opinion, however, that the characteristics of this trend are quite different in tactical missiles, not only compared to commercial electronics but even to strategic or space missiles. Considering the particular objectives and constraints as they seem common to most tactical guided missiles and smart munitions, the VLSI technologies should be almost tailored to this application. However, there are some perequisites to be considered to make the introduction of VLSIs successful. Here are some examples: careful planning to be in step with the maturity of the VLSI technology, sensible selection of targets for insertion or new designs and - quite importantly - consideration of program stability in terms of volume, rates, and changes. From a technical viewpoint alone, the current trend to light and small, 4- to 8-inch-diameter configuration whether ground or air-launched encourages an early insertion of VLSIs. Electronic packaging with unusual form factors, e.g., having a central hole for warhead effectiveness, high density and low weight, and low power dissipation, poses conflicting requirements to the missile designer. With very few exceptions, such as in magnetics or battery chemistry, the electronics sections cannot benefit from other technological breakthroughs. It is the evolution of monolithic large scale integration of circuits on Silicon and to a lesser degree on Gallium Arsenide which bears the main load to meeting these criteria of processing density at minimum power dissipation, and of providing an ever-increasing functional throughput. Those VLSI embodiments which appear to be most likely to influence missile electronics are defined. They may be divided into four categories, with some ranking indicated regarding their maturity and avaliability, as well as nonrecurring cost weight: (1) Memories (RAM and ROM); (2) Catalog special devices (ADC, DAC, (CP); (3) Semicustom (CGAs); and (4) Full custom. Author

N86-28363# AEG-Telefunken, Ulm (West Germany). Design Center for Integrated Circuits.
CHARGE PROCESSING IN INFRARED CCD-SENSOR-ARRAYS
G. KOHLBACHER and P. NOTHAFT *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 7 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Caused by the rapid progress in solid state technologies, especially in the field of VLSI components, infrared thermal imaging is more and more attractive for a lot of military applications. Tactical missile systems, target aquisition, fire control, airborne threat warning, airborne reconnaissance and spaceborne surveillance besides tank-mounted or man-portable night-vision cameras are important examples for military systems with infrared sensor-arrays. The physical principles of infrared detectors witha sufficient sensitivity and resolution demand an operating temperature in the range of liquid nitrogen, i.e., about 77 K. Due to the low operating temperatures MOS technologies are the best choice for the multiplexer circuits. The system designers need together with the multiplexer function the ability to integrate the individual detector signals during one frame period. These two functions may be easily combined in Charge Coupled Devices (CCD) and therefore for the most IR sensor-arrays described in the literature CCDs had been used. A CCD is an analog delay line where signals are handles as charge packets, which will be clocked through an arrangement of MOS capacitors. Two methods packets, which will be clocked through an arrangement of MOS capacitors. Two methods of detector-CCD coupling are described. A novel design of a monocithic 32x32 element array with Si:In detectors sensitive in the 3-5 micron range at an operating temperature of 55 k is described. Author

N86-28364# British Aerospace Dynamics Group, Hatfield (England). Software Engineer.
THE IMPLEMENTATION OF IMAGE PROCESSING ALGORITHMS
D. A. PELLATT *In* AGARD The Impace of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 8 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The purpose of this paper is to describe a specific set of image processing problems, different classes of algorithms applicable to those problems and the efficient implementation of such algorithms using advanced processor architectures. The first section of the paper contains a brief description of the requirements of a typical image processing system operating in a particular scenario. The second section contains descriptions of various algorithms applicable to such a system; the techniques described having been selected in order to demonstrate the contrasting hardware requirements of different types of algorithms. The third, and final, section suggests ways in which the various algorithms may be implemented in Emerging Technology hardware. The applicability of systolic processors, reduction machines and data - flow architectures are discussed. Author

N86-28365# Texas Instruments, Inc., Lewisville.
MISSION BENEFITS OF A VERY HIGH THROUGHPUT IMAGE TRACKER SYSTEM
J. K. MCWILLIAMS and J. H. PRIDGEN *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 9 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The launch and leave, air-to-ground, autonomous class of weapons with imaging sensors is considered. Processor throughput is coupled very closely to many areas of system design for this class of weapon. A typical weapon requires midcourse guidance and must search a relatively large uncertainity area by the time it is close enough to the target for reliable detection. The detection processing time is proportional to the number of pixels in the search area. One can alleviate the detection processing time by allowing the imager to have coarse resoltuion, but that is done at the expense of detection range. If the detection range is inadequate, the terminal accuracy will be degraded due to insufficient time for guidance. The situation is that processor throughput limits resolution for searching the uncertainty area, and resolution limits detection range. While increasing the number of resolution elements in a given search area is one way to use additional processor throughput, this paper considers a less obvious way to make use of higher throughput, which is reducting the size of the search area for the mission. This reduction is accomplished by using an imaging tracker system at the st art of midcourse to significantly reduce two of the contributors to the size of the uncertainty area. By using an image tracking system to track the ground immediately after launch, the actual attitude of the boresight with respect to horizontal and vertical can be determined with more precision than it could be by using airframe attitude and gimbal angle measurements. The better boresight reference effectively reduces the uncertainty in both the airframe attitude reference and the measurement of the platform position with respect to the airframe. The equations necessary to infer true horizontal and vertical from the ground tracking submage motions are shown. A throughput analysis shows the level of throughput required to solve the equations. The accuracies to which the boresight angle can be measured by this method are shown. The method offers a double benefit, as the reduced search area allows more latitude in other system design trades concerning the use of increase throughput. Author

N86-28366# MATRA Espace, Paris-Velizy (France). Div Equipements.
A FLOATING POINT PROCESSOR FOR MISSILE GUIDANCE
F. PLISSON and A. DANTEE *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 12 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The results of the study for the definition of a new missile guidance, highly integrated processing unit are analysed. An overview of advanced algorithms and software architectures required is given, available technologies are reviewed and the rationale for building a dedicated processor is discussed. The

design methodology using the standard cells approach is explained. Data processing needs for missile guidance have increased significantly over past years. These trends are confirmed for the new development, with the introduction of high speed, highly integrated digital circuits. Author

N86-28367# British Aerospace Dynamics Group, Hatfield (England). Dynamics Group.

NEW SYSTEM DESIGN METHODOLOGIES IN THE DESIGN OF MODERN IMAGING MISSILE SYSTEMS STIMULATED BY THE INTRODUCTION OF VLSI DEVELOPMENT TOOLS

A. DENT and G. BRIANT *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 16 p (SEE N86-28337 19-33) Aug. 1985

Avail: NTIS HC A17/MF A01

There is a trend towards increasing complexity of modern missile systems, particularly with regard to the guidance algorithms that will be used in future imaging systems. In some applications the use of general purpose computing elements is prohibited because of performance requirements. In these cases dedicated hardware designs are necessary. Increasingly these designs are implemented in semi-custom LSI/VLSI technology. As the use of this type of approach increases there are consequences that propagate into the total missile system design philosophy. Some of the advantages and disadvantages of using these newer design techniques, based on experience gained in the design of advanced imaging guidance systems, are discussed, in particular the architectures associated with image processing. The major advantages of a LSI/VLSI solution, whether a general purpose computing element or a dedicated hardware element are: (1) increased computational performance; (2) Reduced size; (3) Lower cost; (4) Reduced power consumption; and (5) greater reliability. For a one off type development system, and small scale production quantities, the cost of VLSI is always thought to be prohibitive. However, because of the computational performance required when implementing the complex algorithms associated with imaging guidance systems, the architectural advantages associated with VLSI become the dominant factor. For designs of this complexity it is argued that the cost and timescales involved for the LSI approach have significant advantages at the end of the development cycle provided that the appropriate design procedures are adopted. The requirements for a design procedure will be discussed for both the total missile system and the electronic subsystems. Author

N86-28368# Royal Signals and Radar Establishment, Malvern (England).

ADVANCED SIGNAL PROCESSING TECHNOLOGY FOR FUTURE RADAR SYSTEMS

C. PELL, A. C. FAIRHEAD, and M. B. THOMAS *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 15 p (SEE N86-28337 19-33) Aug. 1985

Avail: NTIS HC A17/MF A01

This paper reviews and discusses the likely technology requirements of the signal processing functions of future radar systems. The technology considerations are largely confined to digital functions, starting at the analogue-to-digital interface. In order to focus the technology discussion, some of the candidate modes of operation of future radars are stated together with the key processing functions that need to be supported. The processing functions include adaptive array antenna processing and programmable digital pulse compression. Using these functions as examples, assessments have been made of the technology requirements and it is shown that both digital beamforming and digital pulse compression are particularly demanding of fast arithmetic operations such as complex multiplication. The advanced VLSI technology functions that are considered to be most important for future radar processing are discussed. Author

N86-28369# Thomson-CSF, Montrouge (France). Div. Equipements Avioniques.

THE APPLICATION OF HIGH-PERFORMANCE INTEGRATED CIRCUITS FOR AIRPORT FIRE CONTROL RADARS [INTERET DES CIRCUITS INTEGRES DE HAUTES PERFORMANCES POUR LES RADARS AEROPORTES DE CONDUITS DE TIR]

J. C. MARCHAIS *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 4 p (SEE N86-28337 19-33) Aug. 1985 In FRENCH; ENGLISH summary

Avail: NTIS HC A17/MF A01

The number of functional modes needed for airport fire control radars, together with the need for high-performance characteristics, indicates that high-performance integrated circuits will have significant applications in such radar. It is shown that multi-function and multi-mode radars which combine air-to-air combat, air-to-ground and air-to-sea modes will comprise the basis for the next generation of fire control radars. Other applications for such radars are shown to include anti-collision, air navigation and air-to-air pursuit modes. Author

N86-28370# Elektronik-System G.m.b.H., Munich (West Germany).

AN INTEGRATED APPROACH TOWARD RECOGNIZING, LOCATING AND COMBATING TARGETS FROM A MODERN INTERCEPTOR AIRCRAFT

E. G. MEYHOFF and H. W. KLOECKNER *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 16 p (SEE N86-28337 19-33) Aug. 1985

Avail: NTIS HC A17/MF A01

Interceptor aircraft of the future will find themselves in an environment which will not only be significantly more hostile than today but also far more difficult to assess. On the one hand the requirement will be to reduce the detectability of the own aircraft and on the other to enhance the capability of destroying enemy targets. Reduction of detectability can be achieved through a variety of measures such as lowering the radar cross section, the IR emission or the RF emission. Enhancement of the capability to destroy enemy target requires, next to better weapons, longer detection and identification ranges as well as quicker reaction times. Faster reaction times are not only required to gain advantages in combating the designated enemy targets but also to respond to threat situations which may emanate from sources other than the targets. The requirement will exist for an avionic system capable of correlating all relevant data and either reaching decisions itself or presenting the pilot with information in such a way that they support his own making process. This paper describes a typical set of aircraft equipments which would be involved in the data acquisition and decision making processes; it quantifies data volumes and rates and, based on these figures, attempts to define processing and correlation requirements. It then proposes a system architecture which might be suitable for the tasks at hand. The emphasis of the paper will be on assessing the impact of LSI/VHSIC technology on those portions of the avionics system which are utilized in the processes described above. Author

N86-28371# Aeritalia S.p.A., Caselle Torinese (Italy). Gruppo Sistemi Avionici ed Equipaggiamenti.

POSSIBLE IMPACTS OF VHSIC ON MIL-STD-1553B DATA TRANSMISSION MANAGEMENT

L. BERARDI and M. MERLANO *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 12 p (SEE N86-28337 19-33) Aug. 1985

Avail: NTIS HC A17/MF A01

High performance integrated circuit technologies allow for dramatic improvement in speed and reduction in size of the integrated circuits. This fact results in the possibility to pack in a denser way the computing and decision making functions of the avionics systems. Nevertheless it is still necessary to connect together the various sytem components, spread through the airframe, by means of an interfunction data transmission system. For these reasons the application of the new technologies to a MIL-STD-1553B data transmission system is considered. In particular the data management task allocated to the Bus Controller is described in four increasing levels of complexity, ranging from the minimum requirement to an 'expert' function including an high degree of configurability. The performance obtainable by implementing the functions in the current or new technologies,

and with two different architectural solutions, are measured or estimated. The comparison among the obtained results shows that the new technologies not only improve the performances of the data transmission system, but also allow to include an higher degree of intelligence in the function, extending in this way the application of MIL-STD-1553B to future advanced avionic systems. Author

N86-28372# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
THE IMPACT OF VHPIC ON AVIONIC SYSTEM ARCHITECTURE, PACKAGING AND MAINTAINABILITY
L. T. J. SALMON and D. E. OLDFIELD *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 5 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

The advent of high performance integrated circuit technology will have a far reaching effect on avionic systems. Currently, the impact is being mainly felt at a high bandwidth, signal processing level where the benefits are self-evident, however, unless the effect of the technology is considered across the whole of the avionic system then there is little doubt that much of the improved mission effectiveness promised by the new, high bandwidth systems will not accrue. A wider, system level approach is therefore needed which not only encompasses the technical aspects of individual sensors but also considers the remainder of the airborne data processing system and more traditional topics such as maintainability, packaging and architecture. This paper highlights some of the areas in which very high performance integrated circuits (VHPIC) could have a major impact on avionics systems and indicates some of the factors that will need to be considered during the design of future systems. Author

N86-28373# Westinghouse Electric Corp., Baltimore, Md. Advanced Technology Div.
THE IMPACT OF VERY HIGH PERFORMANCE INTEGRATED CIRCUITS ON AVIONICS SYSTEM READINESS
G. STRULL *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 2 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Very high performance integrated circuits (VHPIC) represent more than an integrated circuit technology advance- VHPIC really represents a new systems/technology culture. With a philosophy of top-down design and bottom-up build, a vehicle is provided to avoid rapid obsolescence so prevalent in the fast moving integrated circuit industry. However, to successfully and effectively design advanced systems in this manner, a design methodology is required that adequately addresses the challenge. Since everything from chip definition through application analysis is interactive with everything else, the challenge is to adequately keep track of all the perimeters and their relationship. The methodology by which design and analysis are accomplished is discussed. The starting point is the systems architecture and its application software. From the architecture and application software the partitioning of the system into appropriate modules can be derived. From this an idea of the integrated circuits needed can be determined. The elements of system readiness are described. They are design, implementation, insertion, maintenance, and (Preplanned Product Improvement). Author

N86-28374# British Aerospace Aircraft Group, Woodford (England). Aircraft Group.
THE IMPACT OF ARTIFICIAL INTELLIGENCE ON AIRBORNE MARITIME RECONNAISSANCE
J. SHEPARD and R. J. SCOTT-WILSON *In* AGARD The Impact of Very High Performance Integrated Circuits on Radar, Guidance and Avionics Systems 14 p (SEE N86-28337 19-33) Aug. 1985
Avail: NTIS HC A17/MF A01

Some of the problems arising out of the introduction of VHPIC to the sensor and data processing systems of Maritime Reconnaissance aircraft are susceptible to solution by conventional computing techniques within mission time constraints. Some may be more susceptible to the use of artificial intelligence techniques. This paper identifies those aspects of artificial intelligence relevant to the Airborne Maritime Reconnaissance task and the areas of the current task where artificial intelligence can be usefully applied. It reviews the current state of the art in the relevant aspects of artificial intelligence and indicates how they might be employed in the near, medium and long term. It indicates some future applications and concludes that, artificial intelligence will play an important role in the future Maritime Reconnaissance aircraft. Author

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FLUID MECHANICS AND HEAT TRANSFER

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

N84-33757# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SPECIAL COURSE ON STABILITY AND TRANSITION OF LAMINAR FLOW
Loughton, England Jun. 1984 227 p refs Course held in Rhode-Saint-Genese, Belgium, 26-30 Mar. 1984; sponsored by AGARD and the Von Karman Inst. of Fluid Dynamics
(AGARD-R-709; ISBN-92-835-0355-4; AD-A147243) Avail: NTIS HC A13/MF A01

Stability and transition of laminar flows to understand laminar turbulent transition was studied. Incompressible two dimensional and compressible flows in transonic, supersonic, and hypersonic regimes and available results for three dimensional flows were discussed. Material presented and discussed at the Special Course held at the von Karman Institute, Belgium sponsored by the Institute and the AGARD fluid dynamics panel. For individual titles, see N84-33758 through N84-33764.

N84-33758# Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Centre d'Etudes et de Recherches.
DESCRIPTION AND PREDICTION OF TRANSITION IN TWO-DIMENSIONAL, INCOMPRESSIBLE FLOW
D. ARNAL *In* AGARD Spec. Course on Stability and Transition of Laminar Flow 71 p (SEE N84-33757 23-34) Jun. 1984 refs
Avail: NTIS HC A13/MF A01

Transition problems in two dimensional, incompressible flows were surveyed. The phenomena which lead to turbulence under the influence of various factors are described: free stream turbulence, sound, pressure gradient, oscillations of the external flow, roughness, suction, wall curvature. Linear and nonlinear stability theories are discussed. Results of the application of the structure and to the growth of turbulent spots and the progressive disappearance of intermittency phenomenon are reviewed. Practical methods for calculating the transition onset and the transition region itself are described. Methods based on linear stability theory, empirical criteria, intermittency methods and turbulence models are presented. E.A.K.

N84-33759*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
BOUNDARY-LAYER LINEAR STABILITY THEORY
L. M. MACK *In* AGARD Spec. Course on Stability and Transition of Laminar Flow 81 p (SEE N84-33757 23-34) Jun. 1984 refs
Avail: NTIS HC A13/MF A01 CSCL 20D

Most fluid flows are turbulent rather than laminar and the reason for this was studied. One of the earliest explanations was that laminar flow is unstable, and the linear instability theory was first developed to explore this possibility. A series of early papers by Rayleigh produced many notable results concerning the instability of inviscid flows, such as the discovery of inflectional instability. Viscosity was commonly thought to act only to stabilize the flow, and flows with convex velocity profiles appeared to be stable. The investigations that led to a viscous theory of boundary layer instability was reported. The earliest application of linear stability theory to transition prediction calculated the amplitude ratio of the most amplified frequency as a function of Reynolds number for a Blasius boundary layer, and found that this quantity had values between five and nine at the observed Ret. The experiment of Schubauer and Skramstad (1947) completely reversed the prevailing option and fully vindicated the Gottingen proponents of the theory. This experiment demonstrated the existence of

instability waves in a boundary layer, their connection with transition, and the quantitative description of their behavior by the theory of Tollmien and Schlichting. It is generally accepted that flow parameters such as pressure gradient, suction and heat transfer qualitatively affect transition in the manner predicted by the linear theory, and in particular that a flow predicted to be stable by the theory should remain laminar. The linear theory, in the form of the e9, or N-factor is today in routine use in engineering studies of laminar flow. The stability theory to boundary layers with pressure gradients and suction was applied. The only large body of numerical results for exact boundary layer solutions before the advent of the computer age by calculating the stability characteristics of the Falkner-Skan family of velocity profiles are given. When the digital computer reached a stage of development which permit the direct solution of the primary differential equations, numerical results were obtained from the linear theory during the next 10 years for many different boundary layer flows: three dimensional boundary layers; free convention boundary layers; compressible boundary layers; boundary layers on compliant walls; a recomputation of Falkner-Skan flows; unsteady boundary layers; and heated wall boundary layers. E.A.K.

N84-33760# *Case Western Reserve Univ., Cleveland, Ohio. Dept. of Mechanics and Aerospace Engineering.*
ENVIRONMENT AND RECEPTIVITY
E. RESHOTKO *In* AGARD Spec. Course on Stability and Transition of Laminar Flow 11 p (SEE N84-33757 23-34) Jun. 1984 refs
Avail: NTIS HC A13/MF A01

In an environment where initial disturbance levels are small, the transition Reynolds number of a boundary layer is dependent upon the nature and spectrum of the disturbance environment, the signatures in the boundary layer of these disturbances and their excitation of the normal modes, receptivity, and finally the linear and nonlinear amplification of the growing modes. The progress in understanding receptivity to free stream vorticity and acoustic disturbances is reviewed. The technique of the initial value problem, which promises to be a significant additional tool for providing guidance toward the resolution of receptivity issues is outlined. E.A.K.

N84-33761# Cranfield Inst. of Tech., Bedford (England).
TRANSITION DESCRIPTION AND PREDICTION IN THREE-DIMENSIONAL FLOWS
D. I. A. POLL *In* AGARD Spec. Course on Stability and Transition of Laminar Flow 23 p (SEE N84-33757 23-34) Jun. 1984
Avail: NTIS HC A13/MF A01

The implications of mean flow three dimensionality which have a high priority in design engineering systems in which boundary layer transition is an important factor are examined. Two projects are under development which illustrate the importance of three dimensional effects; these are the swept laminar flow wing and the space shuttle projects. Leading edge problems and the consequences of three dimensional mean flow are discussed in the context of transition taking place in the immediate vicinity of the leading edge of a swept wing, which is a situation where the transition process has particular engineering significance. The mechanisms and principles discussed are examined in relation to more complex situations and also to transition in compressible flows with heat transfer. E.A.K.

N84-33762# *Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.*
NONLINEAR EFFECTS IN HYDRODYNAMIC STABILITY
T. HERBERT *In* AGARD Spec. Course on Stability and Transition of Laminar Flow 10 p (SEE N84-33757 23-34) Jun. 1984 refs
Avail: NTIS HC A13/MF A01

Nonlinear effects which are caused by insufficient agreement between observation and results of the linear theory for the prototypes of Taylor-Couette flow and plane Poiseuille flow are analyzed. The principal methods for the analysis of nonlinear problems are characterized. The weak nonlinear theory for a single normal mode and the calculation and use of high order Landau constants is discussed. Weakly nonlinear models of observed phenomena are surveyed. E.A.K.

N84-33763# Virginia Polytechnic Inst. and State Univ., Blacksburg Dept. of Engineering Science and Mechanics.
SECONDARY INSTABILITY OF SHEAR FLOWS
T. HERBERT *In* AGARD Spec. Course on Stability and Transition of Laminar Flow 13 p (SEE N84-33757 23-34) Jun. 1984 refs
Avail: NTIS HC A13/MF A01

The appearance of secondary instability in shear flows was reviewed. The mixing layer, the flat plate boundary layer, and plane Poiseuille flow are considered as prototype flows. The computational and analytical work which produced conceptual enlightenment is discussed. A theory of secondary instability is presented: the almost periodic flow that develops in the presence of finite-amplitude traveling waves is used as a basic flow for a linear stability analysis with respect to spanwise periodic, three dimensional disturbances. The Hill type stability equations with periodic coefficients allow for various classes of normal modes that are associated with different types of resonance. A numerical method for solving the secondary stability problem is discussed. Results for fundamental and subharmonic modes in plane Poiseuille flow are reviewed. The present scope of the theory and its potential for future extensions are discussed. E.A.K.

N84-33764# *Case Western Reserve Univ., Cleveland, Ohio. Dept. of Mechanics and Aerospace Engineering.*
LAMINAR FLOW CONTROL - VISCOUS SIMULATION
E. RESHOTKO *In* AGARD Spec. Course on Stability and Transition of Laminar Flow 10 p (SEE N84-33757 23-34) Jun. 1984 refs
Avail: NTIS HC A13/MF A01

Laminar flow control which offers the possibility of major reductions in aircraft drag is described. The theoretical background for the possible stabilizations of the laminar boundary layer due to shaping, suction and cooling is presented. The effects of vehicle and environmental factors on the implementation of that technology are examined. Viscous simulation is the technology of adjusting boundary layer conditions on a wind tunnel model so that results can be reliably extrapolated to flight conditions. The need for an underlying simulation methodology, some alternate methodologies, the needed boundary/layer controls/trips for implementation, and the process of scaling wind tunnel results to flight conditions are outlined. E.A.K.

N85-25784# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THREE-DIMENSIONAL BOUNDARY LAYERS
Loughton, England Feb. 1985 118 p refs Proc. of the Round Table Discussion on 3D Boundary Layers, Brussels, 24 May 1984
(AGARD-R-719; ISBN-92-835-1491-2; AD-A153279) Avail: NTIS HC A06/MFA01

Progress in understanding three dimensional boundary layers is reported and guidance for future work in this field is provided. Turbulence modelling, which is unsatisfactory in 2-D flows, is even less suitable for three-dimensional boundary layers. More sophisticated models do not appear to work better in many cases than simple ones. The situation is even less satisfactory for separated flows where the validity of certain computations is in question. Lack of accurate, extensive data hampers efforts to comprehend important flow mechanisms and validate computational results. The paucity of high-quality experimental data is remarkable. For individual titles see N85-25785 through N85-25789.

N85-25785# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Aerothermodynamique.
THREE-DIMENSIONAL BOUNDARY LAYERS AND SHEAR FLOWS ACTIVITIES AT ONERA/CERT
R. MICHEL *In* AGARD Three-Dimensional Boundary Layers 15 p (SEE N85-25784 15-34) Feb. 1985 refs
Avail: NTIS HC A06/MF A01

Experimental and theoretical research activities devoted to three-dimensional boundary layers and turbulent shear flows are reviewed. Emphasis is on (1) development, application and control studies of calculation methods for turbulent boundary layers and wakes; (2) corner flows; and (3) stability and transition in three-dimensional flows. Typical results are presented. A.R.H.

N85-25786# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. fuer Experimentelle Stroemungsmechanik.

THREE-DIMENSIONAL BOUNDARY LAYERS: A REPORT ON WORK IN GERMANY

H. HORNUNG *In* AGARD Three-Dimensional Boundary Layers 22 p (SEE N85-25784 15-34) Feb. 1985 refs

Avail: NTIS HC A06/MF A01

The work of selected industrial, university and research establishment groups on three-dimensional boundary layers is summarized and presented as a guide to the quoted references in which details may be found. The approaches used include numerical techniques, experimental techniques, and data base experiments. A.R.H.

N85-25787# National Aerospace Lab., Amsterdam (Netherlands).

THREE-DIMENSIONAL BOUNDARY LAYER RESEARCH AT NLR

B. VANDENBERG *In* AGARD Three-Dimensional Boundary Layers 17 p (SEE N85-25784 15-34) Feb. 1985 refs

Avail: NTIS HC A06/MF A01

The experimental and theoretical research work on three-dimensional boundary layers, carried out at NLR between 1970 and 1984, or presently under development is reviewed. The development of a practical calculation method and its extension to compressible laminar and turbulent boundary layers on developable as well as nondevelopable surfaces is discussed. The main features of the improved method are: (1) an arbitrary non-orthogonal curvi-linear surface coordinate system can be chosen by the user; (2) the organization of the calculation method was designed with the emphasis on the users-oriented properties; (3) an efficient finite-difference method is employed for the whole boundary layer, including the wall layer; and (4) an algebraic eddy viscosity turbulence model is used, because the model is simple, while for boundary layer flows, no other current turbulence models do a significantly better job. A.R.H.

N85-25788# London Univ. (England). Dept. of Aeronautical Engineering.

BRIEF REVIEW OF CURRENT WORK IN THE UK ON THREE DIMENSIONAL BOUNDARY LAYERS

A. D. YOUNG *In* AGARD Three-Dimensional Boundary Layers 17 p (SEE N85-25784 15-34) Feb. 1985 refs

Avail: NTIS HC A06/MF A01

Work in progress in industry, the universities and the R.A.E is summarized. Areas of study include theoretical work on laminar boundary layers (flow round obstacles, outside streamwise corners, internal flows in turbo-machinery), transition effects on bodies at large angles of incidence associated with cross flow and leading edge contamination, experimental and theoretical work on turbulent boundary layers (swept wings with and without separation, curvature and cross flow, blunt trailing edges, wakes with large cross flow, flow outside streamwise corners, integral and finite difference prediction methods both direct and inverse). It is increasingly appreciated that more work is needed on the fundamental effects of cross flow on the dynamics of turbulence. Author

N85-25789# Douglas Aircraft Co., Inc., Long Beach, Calif. Fluid Mechanics and Heat Transfer Div.

PROBLEMS AND OPPORTUNITIES WITH THREE-DIMENSIONAL BOUNDARY LAYERS

T. CEBECI *In* AGARD Three-Dimensional Boundary Layers 35 p (SEE N85-25784 15-34) Feb. 1985 refs Sponsored by ONR, NSF and NASC Prepared in cooperation with California State Univ., Long Beach

Avail: NTIS HC A06/MF A01

Research activity concerned with three-dimensional boundary layers is reviewed. Emphasis is on the flows over the components of airplanes, missiles and ships. In each case, the objective is to develop understanding of the flow characteristics and of the influence of important parameters including geometry, Reynolds number and Mach number, and to make use of this understanding to improve design procedures. The choice of a coordinate system, criteria for selecting a turbulence model, solution and interaction procedures, and the nature of three-dimensional separation are considered. Computational and experimental research needed is indicated. A.R.H.

N85-32293# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

THREE-DIMENSIONAL TECHNIQUES APPLIED TO INTERNAL FLOWS IN PROPULSION SYSTEMS

Loughton, England May 1985 200 p refs Lectures held in Rome, 6-7 Jun., in Cologne, 10-11 Jun., and in Paris, 13-14 Jun. 1985

(AGARD-LS-140; ISBN-92-835-1503-X; AD-A157407) Avail NTIS HC A09/MF A01

Various topics related to 3-D computation techniques applied to internal flows in propulsion systems are discussed. The different mathematical models starting from the most complete one (time average Navier-Stokes equations with turbulent modeling) to the simplest one (small potential disturbance equation) are discussed. For viscous flows, different approximation levels are discussed. full averaged Navier-Stokes equations, thin shear layer approximation, parabolic approximation, boundary layer equations with coupling methods, and distributed losses model. The calculation of 3D rotational inviscid flow by a method based on the CLEBSCH representation is described. The equation for the potential is discretized with a classical finite element technique. Pressure correction calculation procedures for 3-D viscous steady flow are given. In this method the velocity field is calculated from momentum equation assuming that the pressure is given. The exact solution is obtained by adjusting the pressure distribution in order to satisfy the continuity equation. A discretization technique which leads to a reduction of numerical mixing is given. The pressure correction methods for partially parabolic and elliptic flow are used to evaluate the performance of different blade rows and cascades. A review is given of the different approaches for the numerical solutions of the complete Navier-Stokes equations. The problem of grid generation for 3-D applications is discussed as well as the treatment of boundary conditions for internal flows. A computer program for the solution of the 3-D Euler equations by means of a time marching method with a finite volume discretization is described. The treatment of boundary conditions by a technique based on the use of some selected compatibility relations associated to the time hyperbolic Euler system is discussed. For individual titles see N85-32294 through N85-32301.

N85-32294# Cambridge Univ. (England). Dept. of Engineering.

THE CALCULATION OF FULLY THREE DIMENSIONAL FLOW THROUGH ANY TYPE OF TURBOMACHINE BLADE ROW

J. D. DENTON *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 20 p (SEE N85-32293 21-34) May 1985 refs

Avail: NTIS HC A09/MF A01

Various approximation levels, enabling the simplification of the full system of Reynolds averaged Navier-Stokes equations, are presented. The latter are considered as the highest level model of flow description and depend heavily on the turbulence models. Viscous approximations such as the thin shear layer and the parabolized Navier-Stokes models are discussed. The disturbed loss model, applied in turbomachinery applications, is intermediate between the viscous and inviscid approximations. The Euler equations, rotational flow models and the simplest potential flow are further discussed and their limitations are printed out. R.J.F.

N85-32295# Vrije Universiteit, Brussels (Belgium). Dept. of Fluid Mechanics.

AN ANALYSIS OF FLOW MODELS: FROM NAVIER-STOKES TO POTENTIAL FLOW EQUATIONS

C. HIRSCH *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 28 p (SEE N85-32293 21-34) May 1985 refs

Avail: NTIS HC A09/MF A01

A method to calculate the three dimensional, rotational flow of an inviscid, compressible fluid in turbomachines is presented. The approach is based on a finite element formulation and results are presented for the flow in a rectangular bend, a turbine stator and a centrifugal impeller. Author

N85-32296# Vrije Universiteit, Brussels (Belgium). Dept. of Fluid Mechanics.
COMPUTATION OF THREE-DIMENSIONAL, INVISCID, ROTATIONAL FLOWS
C. HIRSCH and C. LACOR *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 28 p (SEE N85-32293 21-34) May 1985 refs
Avail: NTIS HC A09/MF A01

Pressure correction calculation procedures for 3-D viscous flow are described. The conservation equations and the types of pressure correction methods are described. The advantages of the pressure correction approach are discussed. Calculations are compared with measurements for three turbulent 3-D flows, each requiring a more general calculation method than the last. Comparison of calculations with well documented, realistic, experimental test cases is essential and demonstrates the engineering usefulness of the methods. A fully elliptic calculation procedure is described in detail by using a simple example. This example is so simple (16 grid points) that a variety of calculation procedures can be explored with only the aid of a hand held calculator or small personal computer. Comparison with the SIMPLE algorithm is discussed and the advantages of parabolic and partially parabolic methods are discussed. R.J.F.

N85-32297# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
AN ELLIPTIC CALCULATION PROCEDURE FOR 3-D VISCOUS FLOW
J. G. MOORE *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 16 p (SEE N85-32293 21-34) May 1985 refs Sponsored in part by Rolls-Royce Ltd.
Avail: NTIS HC A09/MF A01

The computation of 3-D internal transonic flows by means of a 3-D Euler Code is discussed. A multidomain approach for time hyperbolic system is presented. This technique, based on the decomposition of the computational domain into several subdomains which may overlap one another, makes it possible to simplify some mesh generation problems and to fit discontinuities such as shocks and slip surfaces. A description of the 3-D Euler Code is given. The space discretization method and the treatment of boundary conditions are emphasized. Various applications of this code in turbomachinery are discussed. R.J.F.

N85-32298# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).
A 3-D EULER METHOD FOR INTERNAL TRANSONIC FLOWS COMPUTATION WITH A MULTI-DOMAIN APPROACH
J. P. VEUILLOT and G. MEAUZE *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 21 p (SEE N85-32293 21-34) May 1985 refs
Avail: NTIS HC A09/MF A01

The results of calculations of three dimensional viscous flow in two centrifugal compressor impellers and in two linear turbine cascades are considered and answers to thermodynamic questions are obtained. For the impellers, the calculations give the work and the losses, the total pressure ratio and the efficiency, and show where the inefficiency arises. The results for the turbines show the increase in loss within and downstream of the cascades and allow the buildup and decay of secondary kinetic energy to be followed. Author

N85-32299# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
PERFORMANCE EVALUATION OF FLOW IN TURBOMACHINERY BLADE ROWS
J. MOORE *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 26 p (SEE N85-32293 21-34) May 1985 refs Sponsored in part by Rolls-Royce Ltd.
Avail: NTIS HC A09/MF A01

The numerical solution of the complete Navier-Stokes equations for two dimensional nonsteady flow has only been accomplished in the last decade. Most of the computations have been for external flows. However, in the past few years this capability has been extended to internal flows for relatively simple configurations. Both implicit and explicit approaches have been used in developing methods for computing internal flows. These methods are discussed briefly with emphasis on MacCormack's explicit finite difference algorithm. The capabilities and limitations of these approaches are discussed. In particular, attention is focused on grid generation, formulation of boundary conditions for internal flows, and constraints imposed by limited computer storage and speed. Results for axisymmetric and 3-D flows are presented. In addition, developments currently in progress are noted. Finally, future developments of this capability are addressed, along with their impact on the development of advanced propulsion systems. R.J.F.

N85-32300# Dayton Univ., Ohio. Dept. of Mechanical Engineering.
NUMERICAL SOLUTION OF THE NAVIER-STOKES EQUATIONS FOR 3-D INTERNAL FLOWS: AN EMERGING CAPABILITY
J. N. SCOTT *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 24 p (SEE N85-32293 21-34) May 1985 refs
Avail: NTIS HC A09/MF A01

The accuracy of 3-D flow calculations is discussed. A good calculation procedure solves a set of finite difference equations reasonably quick. However, if the finite difference equations do not accurately reflect the governing differential equations, poor results will be obtained. For example, it is common practice in three dimensional flow calculations to use upwind differencing or more direct forms of numerical mixing to obtain well posed finite difference equations which are needed to maintain a stable calculation procedure. The erroneous numerical viscosity introduced can be of the same order as the natural laminar or laminar plus turbulent viscosities in the flows calculated. When numerical mixing is present a proper evaluation of viscosity or turbulence models cannot be made because the effects of numerical and physical mixing cannot be distinguished. A simple 2-D example is used to demonstrate a practical method of obtaining the finite difference form of the convection term in momentum or other conservation equations. The 2-D example introduces no numerical mixing, yet results in well posed, (i.e., strong center point coefficient) finite difference equations. The method consists of central differencing to eliminate numerical mixing and upwinded control volumes to obtain finite difference equations with strong point coefficients. An upwinding procedure for the control volumes which may be applied to three dimensional flow is given. Inviscid calculations of horseshoe vortex flow about a Rankine half body are presented. R.J.F.

N85-32301# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mechanical Engineering.
CALCULATION OF 3-D FLOW WITHOUT NUMERICAL MIXING
J. G. MOORE *In* AGARD 3-D Computation Tech. Appl. to Internal Flows in Propulsion Systems 15 p (SEE N85-32293 21-34) May 1985 refs Sponsored in part by Rolls-Royce Ltd.
Avail: NTIS HC A09/MF A01

A suite of computer programs was developed to calculate the fully 3D inviscid flow through any type of turbomachine blade row. The method is based on a pseudo time dependent solution of the Euler equations with convergence accelerated by a multigrid approach. It is shock capturing and has no Mach number limitations. The basic version of the program can cope with any type of single blade row, compressor or turbine, with axial, mixed or radial flow. Special versions of the code were developed for blade rows with part pitch or part span splitter blades and also for two blade rows in relative rotation i.e., a complete stage. Viscous effects may be approximated by a transpiration type of boundary layer displacement model or by the inclusion of a body force term in the momentum equations. R.J.F.

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INSTRUMENTATION AND PHOTOGRAPHY

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

N84-15530# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
CALIBRATION OF AIR-DATA SYSTEMS AND FLOW DIRECTION SENSORS. AGARD FLIGHT TEST TECHNIQUES SERIES, VOLUME 1
J. A. LAWFORD (Aeroplane and Armament Experimental Establishment, Salisbury, England) and K. R. NIPPRESS (Aeroplane and Armament Experimental Establishment, Salisbury, England) Sep. 1983 67 p refs
(AGARD-AG-300-VOL-1; AD-A137367) Avail: NTIS HC A04/MF A01

The calibration of air-data and flow direction measurement systems is discussed. The available flight test calibration methods are described and their applicability, accuracies, and limitations are reviewed. Author

N85-25801# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TRAJECTORY MEASUREMENTS FOR TAKE-OFF AND LANDING TESTS AND OTHER SHORT-RANGE APPLICATIONS, VOLUME 16
P. DAGUT (Centre d'Essais en Vol, Bretigny-sur-Orge, France), H. RIEBEEK (Fokker B.V., Amsterdam), and A. POOL, ed. (National Aerospace Lab., Amsterdam) Jan. 1985 86 p refs 16 Vol.
(AGARD-AG-160-VOL-16; AGARDOGRAPH-160; ISBN-92-835-1487-4) Avail: NTIS HC A05/MF A01

A review of the methods that are used for short-range trajectory measurements is presented. This report also reviews the instrumentation requirements of the applications: take-off and landing performance measurement, autoland performance measurement, noise measurement and flight inspection of radio beacons. Optical methods (including lasers), methods using radio or radar and methods using inertial sensing are discussed. B.W.

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MECHANICAL ENGINEERING

Includes auxiliary systems (non-power); machine elements and processes; and mechanical equipment.

N86-19627# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
ARTIFICIAL INTELLIGENCE AND ROBOTICS
Loughton, England Sep. 1985 141 p refs Lecture series held in Trondheim, Norway, 26-27 Sep. 1985, in The Hague, Netherlands, 30 Sep. - 1 Oct. 1985, and in Lisbon, Portugal, 3-4 Oct. 1985
(AGARD-LS-142; ISBN-92-835-1511-0; AD-A161905) Avail: NTIS HC A07/MF A01

The renewed interest in the allied fields of Robotics and Artificial Intelligence is addressed. Both of these areas are studied with emphasis on robotics, beginning with a review of the state-of-the-art and concluding with applications and a view of the future for each. Selected specialized subjects covered include vision and tactile sensors, robotics software, solid modelling, and expert systems. For individual titles see N86-19628 through N86-19635.

N86-19628# National Bureau of Standards, Washington, D.C.
ROBOTICS: PAST, PRESENT, AND FUTURE
J. S. ALBUS *In* AGARD Artificial Intelligence and Robotics 16 p (SEE N86-19627 10-37) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

Robotics is a systems science that attempts to integrate artificial intelligence with feedback control of mechanical devices. It draws on work in pattern recognition, scene analysis, geometrical reasoning, world modeling, language and speech understanding, planning, problem solving, goal seeking, task decomposition, manipulator control, mobility, and navigation. A brief history is given. A brief history of robotics is presented the following current research topics are examined: (1) kinematics, dynamics, and mobility; (2) vision, kinesthetic, tactile, and acoustic sensing and sensory processing; (3)sensory-interactive task decomposition, planning, and problem solving; (4) world modeling; (5) programming techniques and learning; and (6) system integration. Future applications are discussed. Author

N86-19629# Technische Hogeschool, Delft (Netherlands). Dept. of Applied Physics.
SENSORS: VISION AND TACTILE
F. C. A. GROEN and P. W. VERBEEK *In* AGARD Artificial Intelligence and Robotics 17 p (SEE N86-19627 10-37) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

Several techniques are presented to obtain 2D grey-value images and distance images. In these sensor systems different principles may be used to select the image points of which the grey-value is measured. The scanning may be presented in the light source, in the sensor, in the movement of the object or in a combination of these. Distance images may be obtained by triangulation of points in the scene between lightbeam and sensor. The sensors are based on scanning beams, planes of light or space encoding. Commonly used vision sensors such as video pick-up tubes, CCD arrays and Position Sensitive Detectors (PSD) are discussed. Tactile sensors are based on the measurement of surface deformation by optoelectronic, capacitive, magnetic, piezoelectric or piezoresistive transduction. Tactile arrays offer the possibility of obtaining pressure images which can be processed in the same way as if they are the result of a vision sensor.
Author

N86-19630# Lehigh Univ., Bethlehem, Pa. Inst. for Robotics.
ROBOT SOFTWARE: CURRENT STATE-OF-THE-ART, AND FUTURE CHALLENGES
R. N. NAGEL and S. R. GARRIGAN *In* AGARD Artificial Intelligence and Robotics 9 p (SEE N86-19627 10-37) Sep. 1985
Avail: NTIS HC A07/MF A01

Robot software system and their complexity currently are growing at an incredible rate. A complexity hierarchy covering the simplest methods of robot programming up through first and second generation robot programming languages is defined. Methods of graphical robot programming are described, and an assessment is made of the current state of the art of robotic software systems. The next generation of robot software systems which will be task level languages is described. That is, the elements of the programming language will be statements of tasks to be accomplished rather than statements with regard to robot motions. Technical challenges in achieving task level languages and current research approaches to overcoming these challenges are also *described.* Author

N86-19631# Rensselaer Polytechnic Inst., Troy, N.Y. Dept. of Electrical, Computer, and Systems Engineering.
THE SENSING AND DISPLAY OF THREE-DIMENSIONAL INFORMATION WITH EMPHASIS ON SOLID MODELLING: STATUS AND APPLICATIONS
L. A. GERHARDT *In* AGARD Artificial Intelligence and Robotics 8 p (SEE N86-19627 10-37) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

The sensing of three dimensional information is addressed, the display/representation of three dimensional information is considered. With respect to the sensing of three dimensional information, a variety of approaches are discussed including the use of structured light, the use of displaced sensors to develop stereo pairs, and coherence processing and time of flight measurement. Other techniques described are interpretation of object motion as a measurement of depth perception, and general methods for utilizing depth of field. The advantages and disadvantages of each are discussed and comparisons made. Three dimensional display techniques is also discussed. The *approaches covered include graphics, stereo pairs, holograms,* vibrating mirrors, and other optical systems. Applications are

reviewed with examples of results such as the use of vibrating mirror technology for the three dimensional display of compterized tomography. Solid modelling as an approach to the display and representation of three dimensional information is reviewed. Following a definition of solid modelling, the advantages of this generic approach are reviewed and analyzed. The relationship of solid modelling to robotics and artificial intelligence is made, and trends cited with respect to hardware costs, portability of software, computational efficiency, display resolution, and neutral data bases. The paper concludes by giving examples of some of the key applications of solid modelling in the automative industry, aircraft industry and CAM, among others. Author

N86-19632# IBM United Kingdom Labs. Ltd., Winchester, (England).
CRT INSTALL AND SECURE STATIONS FOR THE GENERIC MONITOR LINE
D. C. TEALE *In* AGARD Artificial Intelligence and Robotics 9 p (SEE N86-19627 10-37) Sep. 1985
Avail: NTIS HC A07/MF A01

Illustrations of the product from an assembly point of view are presented. Briefly shown are the problems were expected and where these stations fit in the line. How the station was designed is discussed from a generic automation viewpoint, highlighting the areas which are common to most automation stations. The work in the CRT install is used to illustrate the various stages of automation design, with particular emphasis on the areas which are common to all automation stations. The problems which were experienced in working with a PMC group located remotely from the laboratory is covered along the various differences in national standards which must be solved in order to attain two identical lines. Author

N86-19633# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Wesseling (West Germany). Inst. fuer Dynamik der Flugsysteme.
SENSORY FEEDBACK STRUCTURES IN ROBOTICS
G. HIRZINGER *In* AGARD Artificial Intelligence and Robotics 15 p (SEE N86-19627 10-37) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

The problems when trying to feed back on-line sensory signals in a robot control system are outlined. Special emphasis is laid on the question how to teach a robot a sensor-based task that must be repeated under changing environment. Feedback structures as they have proposed in literature especially for force-feedback are discussed. Generalizing definitions relating positions/orientations and (pseudo)-forces/torques are introduced. Sensor programming concept is outlined that refines any rudimentary robot command given by a human teacher or a CAD system via the sensory reaction with the environment. In this scheme motion commands and sensor data are stored together. The sensor data are then available as reference values for the repetition mode in a possibly changing environment. Techniques for teacher induced on-line improvements as well as self improvements of the robot are presented. The sensor-ball technique or programming robots is outlined as a special realization of these concepts. Author

N86-19634# Royal Signals and Radar Establishment, Malvern (England). Integrated Air Defence Systems Div.
APPLICATIONS OF EXPERT SYSTEMS
P. R. WETHERALL *In* AGARD Artificial Intelligence and Robotics 17 p (SEE N86-19627 10-37) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

An Expert System contains a knowledge base, an inference engine, an explanation system, a model of the real world and a man machine interface. The types of reasoning include interpretation, monitoring, prediction and design, together with specializations of these, such as diagnosis and planning, and aggregations, such as debugging, instruction and control. A range of possible applications are described to illustrate these general tasks. The nature of the knowledge available, and some implementation problems, are identified. The applications include examples in the area of tactical decision aids, specifically sensor data interpretation, data fusion, threat assessment and resource allocation. Other topics include cockpit environments and intelligent tutoring. Finally, some of the problems that limit the immediate widespread adoption of the technology are discussed. Author

N86-19635# George Mason Univ., Fairfax, Va.
APPLYING AI TO THE DIAGNOSIS OF COMPLEX SYSTEM FAILURES
K. DEJONG *In* AGARD Artificial Intelligence and Robotics 4 p (SEE N86-19627 10-37) Sep. 1985 refs
Avail: NTIS HC A07/MF A01

The expert system technology from the artificial intelligence (AI) community is being applied to a wide variety of problems including fault isolation in complex man made systems. The use of expert systems was explored in the automatic test equipment (ATE) area (with particular interest in applications to Navy avionics gear). Several protype expert systems were built and discarded in the process of understanding how this technology can be usefully applied in the ATE world. The current views on these issues are summarized and an overview of the architecture of our latest prototype is required. Author

N86-24994# *Advisory Group for Aerospace Research and* Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
FATIGUE RATED FASTENER SYSTEMS
H. H. VANDERLINDEN, ed. Loughton, England 1985 96 p refs
(AGARD-R-721; ISBN-92-835-1512-9) Avail: NTIS HC A05/MF A01

In recent years the aerospace industry has developed many ways of joining parts together; despite all innovations, however, the most common means of doing this remains the mechanical fastener. The designer needs to know which fastener systems are the most efficient from his point of view; this report is the outcome of a collaborative program (sponsored by the Structures and Materials Panel of AGARD) which aimed to evaluate some of the available Fatigue-rated Fastener Systems. The program studied a number of systems; tests covered not only the fasteners themselves but also the preparation of the holes and the quality of fit. Author

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STRUCTURAL MECHANICS

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

N83-31061# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SOME CONSIDERATIONS ON SHORT CRACK GROWTH BEHAVIOUR IN AIRCRAFT STRUCTURES
Loughton, England Mar. 1983 30 p refs
(AGARD-R-696; ISBN-92-835-1446-7; AD-A130952) Avail: NTIS HC A03/MF A01

The two papers included in this Report were presented at the 52nd Meeting of the Structures and Materials Panel as the first stage of a study of the problems encountered in predicting the behavior of short cracks. The fracture mechanics approach is being used for fatigue life assessment and durability evaluation of aircraft structures. Conventional crack growth prediction methods applied to smaller crack length ranges have met limited success so far. Short cracks may grow somewhat faster than expected by predictions using fracture mechanics data obtained from long crack specimens. The behavior of short cracks obviously is affected by some analysis and additional secondary loading effects not normally accounted for in the stress intensity determination but having likely effects in short crack growth. For individual titles, see N83-31062 through N83-31083.

N83-31062# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
EVALUATION OF SMALL CRACKS IN AIRFRAME STRUCTURES
H. A. WOOD (Aeronautical Systems Div.), J. L. RUDD, and J. M. POTTER *In* AGARD Some Considerations on Short Crack Growth Behaviour in Aircraft Struct. 12 p (SEE N83-31061 19-39) Mar. 1983 refs
Avail: NTIS HC A03/MF A01

Small crack technology applications to airframe structures are discussed. Cracks with the size range of 1/10mm to 1mm have been used as the starting point for evaluating the safe and durable operational limits of older in-service aircraft and as criteria for the design of new structures. The development of these criteria are presented. Evidence of service cracking obtained from teardown inspections is presented to illustrate the characteristic sizes and shapes of cracks at structural fastener holes. Current methods for predicting growth are judged to be less developed than for cracks in larger size ranges. A limited comparison of test and prediction is included. Finally, the influence of small cracks on residual strength and the potential degradation of fail safety are discussed with specific reference to a large transport aircraft. The authors conclude that the analysis of small crack growth behavior is far more complex than for intermediate and large sizes, and suggest additional research particularly the development of experimental data to support methodology development. Author

N83-31063# Royal Aircraft Establishment, Farnborough (England).
A REVIEW OF CRACK GROWTH THRESHOLD AND CRACK PROPAGATION RATES AT SHORT CRACK LENGTHS
R. F. W. ANSTEE and P. R. EDWARDS *In* AGARD Some Considerations on Short Crack Growth Behaviour in Aircraft Struct. 12 p (SEE N83-31061 19-39) Mar. 1983 refs
Avail: NTIS HC A03/MF A01

An initial flaw of 0.127 mm (0.005 inch) is specified to exist at every hole, with larger flaws at the most critical locations. This does not mean however that no account is taken of fatigue crack initiation time; since the flaw specified is in practice an equivalent initial flaw which, using current crack propagation prediction techniques, gives a fatigue life which is equivalent to lives typical of service experience. Author

N83-34374# National Aerospace Lab., Amsterdam (Netherlands).
THE APPLICATION OF FRACTURE MECHANICS TO THE GROWTH OF CREEP CRACKS
H. P. VANLEEUWEN Jun. 1983 58 p refs
(AGARD-R-705; ISBN-92-835-1453-X; AD-A132953) Avail: NTIS HC A04/MF A01

The application of fracture mechanics to the growth of creep cracks is discussed. It is shown that linear elastic fracture mechanics were successfully applied to the residual strength of brittle materials, crack growth due to stress corrosion and crack growth due to fatigue. The methods are discussed to account for plasticity. A survey is made of the attempts to correlate the crack growth rate under creep conditions with the stress intensity factor, the net section stress, the reference stress, the crack opening displacement rate, the contour integral J and the contour integral J*. Alternative methods to calculate J and J* are considered. A survey is also made of theoretical predictions of crack growth rate as a function of parameters that are considered to be determined. S.L.

N85-24321# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
FATIGUE CRACK TOPOGRAPHY
Loughton, England Nov. 1984 238 p refs Conf. held in Sienna, Italy, 1-6 Apr. 1984
(AGARD-CP-376; ISBN-92-835-1480-7; AD-A152368) Avail: NTIS HC A11/MF a01

Available methods for determining the growth rate of cracks from their topography are reviewed and any shortcomings in these methods are noted. Further research and development is recommended. Phenomenological aspects of fatigue fractures; methods and means of crack front marking and fracture surface analysis techniques are emphasized. For individual titles see N85-24322 through N85-24336.

N85-24322# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
ESSENTIAL FEATURES IN FATIGUE FRACTURES AND REMARKABLE PHENOMENA IN FATIGUE CRACK GROWTH
H. KLINGELE (Institute for Scanning Electron Microscopy, Munich, West Germany) *In its* Fatigue Crack Topography 28 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

Fatigue fracture is defined as the separation of material in small steps with the least possible consumption of energy. Every solid material that shows even the smallest amount of remaining deformation before breaking can be separated by fatigue fracture including the mineral layers of Earth. Fatigue fracture always begins in the point of minimum strength, and avoids regions of high strength as well as obstacles. Fatigue fracture characteristics and origin are discussed. How to select the measuring line and the proper areas for quantitative evaluation is examined. Estimating invisible striations and finding the order of magnitude in destroyed fatigue fracture surfaces are explained. Examples of fatigue fractures in Earth's crust are cited. A.R.H.

N85-24323# Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.
FATIGUE FRACTURE TOPOGRAPHY
P. J. E. FORSYTH *In* AGARD Fatigue Crack Topography 13 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

The texture of a fatigue fracture can vary between the extremes of a bright reflective surface (with facets that may approach planarity) to a rough highly irregular surface. Roughness is imparted by microstructural heterogeneity in its various forms and represents tortuous fragmented crack paths. The degree of roughness generally increases with increasing stress and degree of triaxiality. The crack tip plastic zone is bound to increase with stress and inasmuch as the larger zone will encompass more off plane particles that initiate further microcracks, so the fracture becomes rougher. *On a finer* scale of the fatigue striations, whether they relate to individual loads or to flight loads, i.e., (a ground *air ground* cycle), crack front deviation or tilting from and to the general fracture plane occurs in a periodic manner. This can be demonstrated for both metals and polymers and frequently this deviation is considerably greater than the crack tip opening displacement. Abrupt changes in fracture reflectivity or abrupt changes in crack front tilt make very effective crack position markers, and the loading conditions to produce these can be optimized. Author

N85-24324# National Aerospace Lab., Emmeloord (Netherlands).
FATIGUE CRACK PROPAGATION AND FRACTURE IN 7050 AND 7091 ALUMINUM ALLOY FORGINGS
R. J. H. WANHILL, H. J. KOLKMAN, and L. SCHRA *In* AGARD Fatigue Crack Topography 14 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

The fatigue crack propagation and fracture behavior of 7050-T736 and 7091-T7E69 aluminum alloy die forgings was investigated. Under spectrum loading, the fatigue crack propagation resistance of 7091-T7E69 was greatly inferior owing to early commencement of tensile crack jumping, which also occurred under constant amplitude loading with R = 0.5. Early crack jumping could be explained by application of Thomason's theory of tensile fracture. Fractographic and microstructural analysis provided support to this explanation and indicated that the oxides due to air atomization of the powder have a profound effect on the fatigue and fracture properties of 7091-T7E69. It is concluded that the poor fatigue crack propagation behavior of 7091-T7E69, which is a major limitation to its use in engineering structures, might be remedied by preparing the powder in inert environments. However, this may lead to unacceptable losses in strength. Author

N85-24325# Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
TWO RECENT CASES OF MARKER LOAD APPLICATIONS ON CARGO/FIGHTER AIRCRAFT FATIGUE TESTS
D. R. ERSKINE and J. L. HOPKINS *In* AGARD Fatigue Crack Topography 20 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF [en1] A01

Two applications of marker cycles under distinctly different loading spectra are discussed. The first spectrum represents a cargo aircraft load environment, with a maximum load case of 60% limit. The other spectrum represents a fighter usage with the usually high frequency of near limit load cycles. Examples are presented of the crack growth, the marking and the engineering approaches. The effects of the marker cycles on the natural growth are shown to be insignificant. Good fractographic correlation was found in both component and full scale tests. E.A.K.

N85-24326# Centre d'Essais Aeronautique Toulouse (France).
EFFECT OF FLIGHT SEQUENCES IN COMPLEX LOAD HISTORIES ON CRACK FRONT MARKING
A. LIBERGE and C. BLEUZEN *In* AGARD Fatigue Crack Topography 25 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

Some modifications of FALSTAFF were studied to promote the use of this loading spectrum in the case of structural large specimens testing, for which it is critical to assess a good fractrographic traceability of the crack surface. Some modifications of FALSTAFF were studied for four spectra: (1) omission of the smallest load ranges of FALSTAFF; (2) gathering of severes flights of spectrum; (3) FALSTAFF with an overload to 8, lg; and (4) FALSTAFF with an overload to 8, 5g. Aluminum alloys were tested for fatigue on open hole specimens, joint specimens - no load transfer specimens - single shear specimen, high load transfer and secondary bending, and crack growth test on ASTM CT specimens. Spectrum (1) gives approximately the same fatigue tests results as FALSTAFF but its crack surface is not readable in fractography. Spectra (2), (3) and (4) look traceable in the range of crack rates from 3.10/5 to 10/2 mm per flight, but they have increased fatigue lifes comparatively to FALSTAFF. E.A.K.

N85-24327# Messerschmitt-Boelkow-Blohm/Vereinigte Flugtechnische Werke G.m.b.H., Bremen (West Germany).
GENERATION OF MARKER LINES BY MEANS OF MARKER LOADS
K. HOFFER and R. HILLBRECHT *In* AGARD Fatigue Crack Topography 7 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

Investigation fatigue damages revealed that it is extremely difficult to pursue the crack formation whenever the tests simulate flight by flight loads. Various methods to generate marker lines were proposed. Fatigue tests (FALSTAFF flight by flight loads) were performed, i.e., const.-amplitude tests interspersed in their crack propagation phase at regular intervals. The number of simulated flight by flight cycles is reduced. These procedures aim at achieving damage equivalence. The following requirements have to be met: (1) the crack propagation rates produced by interspersed constant amplitude loads must be equal to the rates that would have been produced by the load sequences not simulated in the flight by flight program; (2) the marker lines caused by the interspersed constant amplitude loads must be visible on the fatigue fracture surface. E.A.K.

N85-24328# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).
GENERATION OF MARKER LINES ON FATIGUE FRACTURE SURFACES
M. KALWEIT *In* AGARD Fatigue Crack Topography 5 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

A flight by flight loading program for a predominantly maneuver loaded military aircraft structure it was proposed, with respect to the generation of marker lines, to alter the more or less arbitrary arrangement of the loading sequence which is representative for normal service operation. The 45 most severe load cycles in each particle sequence comprising of 250 flights were interspersed into the first 45 flights of each of the partial sequences. Fatigue tests with simple test specimens were run to investigate it, with the proposed loading arrangement, easily visible, clearly identifiable marker lines could be operated. It was investigated if the concentration of the high load cycles in the first flights of a partial load sequence would create any misleading test results with respect to crack propagation and fatigue life. Flight by flight fatigue tests with a total of nine notched AL specimens, loaded uniaxially in tension and compression, were performed. From these nine specimens, five were used to generate marker lines and the remaining four were used to determine fatigue life. The tests were conducted with two loading programs which differed only in the selected sequence of load cycles. E.A.K.

N85-24329# Lockheed-California Co., Burbank.
PERIODIC LOADING SEQUENCES FOR THE SYSTEMATIC MARKING OF FATIGUE CRACK FRACTURE SURFACES
J. C. EKVALL, L. BAKOW, and T. R. BRUSSAT *In* AGARD Fatigue Crack Topography 9 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

Periodic loading sequences which leave characteristic markings on the fracture surface are used for evaluating the results of crack growth tests. These markings aid in the evaluation of crack growth rates and prediction formulations, and define the shape of cracks at specific times during the test. To illustrate how loading sequences are used to produce regularly spaced fracture surface markings in crack growth tests, three examples are presented. These include a fighter spectrum, a transport spectrum, and constant amplitude loading sequences. The composition of each of the loading sequences is discussed, and photographs of some of their resultant fracture surfaces are shown. The fracture surface markings produced by the three loading sequences are visible to the naked eye and photographed without magnification Author

N85-24330# National Aerospace Lab., Amsterdam (Netherlands).
MODIFICATIONS OF FLIGHT BY FLIGHT LOAD SEQUENCES TO PROVIDE FOR GOOD FRACTURE SURFACE READABILITY
H. H. VANDERLINDEN *In* AGARD Fatigue Crack Topography 22 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

In order to establish an inspection schedule for fatigue, critical fastener holes in the wing lower skin of a fighter aircraft, crack growth data under realistic loading was required. Experimental determination of these data was a logical choice since a representative specimen was available. However, the spectrum and load sequence, representative for the Dutch usage of the aircraft, do not mark the fracture surface well enough. Methods to identify markers were evaluated: scanning electron microscopy gives the best results. Goals, means of accomplishment and detailed results are described of a pilot program in which modifications of the load sequences were investigated. Simple center notched and complex representative specimens were used. A marker version of the original sequence was validated. Author

N85-24331*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ON THE USE OF MARKER LOADS AND REPLICAS FOR MEASURING GROWTH RATES FOR SMALL CRACKS
M. H. SWAIN and J. C. NEWMAN, JR. *In* AGARD Fatigue Crack Topography 17 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

The initiation and growth of small cracks (5-500 microns m) from edge notches in 2024-T3 aluminum alloy sheets were studied under constant amplitude loading. Two methods were used to measure crack shape and size. In the first method, striation marker bands were periodically formed along the crack front by interrupting the constant amplitude loading by either an elevated R-ratio load sequence, or by an overload sequence. In the second method, the surface crack length was monitored by taking surface replicas at regular intervals. The marker band techniques did not provide reliable crack length and crack shape information for cracks smaller than 2 mm. The replica technique provided accurate information for surface crack length at all crack lengths, and fracture tests on specimens with small cracks provided crack-shape information. Crack growth rates were plotted against the stress intensity factor ranges. The results exhibited the small crack effect, in that the small cracks grew faster than large cracks at the same

stress-intensity factor range. A crack closure model was also used to analyze the growth of small cracks from small (inclusion) defects at the notch surface. Author

N85-24332# Aeronautical Research Inst. of Sweden, Bromma.
ON THE USE OF MARKER LOADS FOR FATIGUE CRACK GROWTH MEASUREMENTS
B. PALMBERG *In* AGARD Fatigue Crack Topography 12 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

The possibility of using blocks of constant amplitude loading to produce macroscopic marks in the fracture surfaces is investigated. The parameters to be selected are the maximum marker load, the marker load ratio, the number of marker load cycles and the periodic interval between marker blocks. An optical stereo microscope is used to detect marker bands in the fracture surface. The parameters are chosen in order to obtain marker bands which appear as striation free when observed through a scanning electron microscope. Marker loads were added to both constant amplitude and spectrum loading during testing of two aluminum alloys. It was found that detectable marker bands can be produced and that the interaction effects seems to be small except when TWIST loading spectrum is used. Author

N85-24333# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
FATIGUE CRACK TOPOGRAPHY AND CRACK GROWTH ANALYSIS
J. M. POTTER, W. R. GARVER (General Dynamics, Fort Worth, Tex.), K. M. KOEPEL (General Dynamics, Fort Worth, Tex.), and B. G. W. YEE (General Dynamics, Fort Worth, Tex.) *In* AGARD Fatigue Crack Topography 6 p (SEE N85-24321 14-39) Nov 1984 refs
Avail: NTIS HC A11/MF A01

Stepped blocks, repeating tensile loads, and minimal compression loading are features of flight-by-flight load histories shown to be effective in providing distinguishable marks on crack surfaces during spectrum-fatigue loading. A reflected-light optical microscope equipped with stage micrometers can be used to trace crack growth histories in a variety of materials. This method of data collection is low cost, enabling economical investigation of random variations in crack growth behavior and statistical characterization. The distribution of time for a crack population to reach a given size in wrought aluminum is found to be adequately modeled by the Weibull distribution. Crack growth rates are found to be log-normal. A method is presented to determine crack growth rate populations when fracture surface markings are fragmentary, as in aluminum castings. Author

N85-24334# National Research Council of Canada, Ottawa (Ontario).
APPLICATION OF OPTICAL AND ELECTRON MICROSCOPIC TECHNIQUES IN THE FRACTOGRAPHIC DETERMINATION OF FATIGUE CRACK GROWTH RATES
R. V. DAINTY *In* AGARD Fatigue Crack Topography 26 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

The fractographic derivation of fatigue crack growth information is entirely dependent on the fractographer's ability to correlate accurately the striated fracture surface topography with the applied test or service loads. Some techniques developed to acquire this type of quantitative information through the application of optical and electron microscopy are reviewed. Fractographic analyses of fatigue specimens and components that failed during laboratory and full-scale aircraft fatigue tests are presented. These analyses show how the identification and correlation of various fatigue load application formats, i.e., constant amplitude, programmed block, flight-by-flight and random loading, can be utilized to derive this type of experimental crack growth data. Author

N85-24335# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).
NEW ANALYSIS ASPECTS OF THE FATIGUE CRACK PROPAGATION BEHAVIOR BY SEM IN SITU MICROSCOPY
K. SCHULTE, K. H. TRAUTMANN, and H. NOWACK *In* AGARD Fatigue Crack Topography 10 p (SEE N85-24321 14-39) Nov 1984 refs
Avail: NTIS HC A11/MF A01

In situ analyses of fatigue crack propagation in a SEM enable a more detailed observation of the fatigue process. This is of special value for variable amplitude loading conditions, where pronounced crack accelerating and decelerating effects occur. Results of the in situ observation are shown and are compared to the fracture surface morphology in the interior of the specimen and in the vicinity of the specimen surface. Author

N85-24336# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany).
CRACK PROPAGATION UNDER CONSTANT AND VARIABLE STRESS AMPLITUDES: A COMPARISON OF CALCULATIONS BASED ON THE STRIATION SPACING AND TESTS
J. FOTH and W. SCHUETZ *In* AGARD Fatigue Crack Topography 9 p (SEE N85-24321 14-39) Nov. 1984 refs
Avail: NTIS HC A11/MF A01

The striation spacing was determined from fractographic examinations and compared to the crack growth rates in experiments both for constant amplitude and variable amplitude loadings for 6 different typical commercial aircraft alloys (Ti6Al4V, 7075-T7351, 2024-T3, AZ 74.61, HP 9-4-30, INCONEL 718). The following conclusions can be drawn: (1) under constant amplitude loadings striations are observed only in a limited region of crack growth rate and stress intensity range, respectively, depending upon the material, (2) for constant amplitude loading the striation spacing follows a straight line when plotted vs. crack growth rate (log-log plot) for all materials under consideration, (3) the crack growth behaviour is inhomogeneous over the entire fracture surface for a given crack length leading to considerable scatter of the striation spacing, which has to be taken into account when assessing the crack growth rate from striation spacing measurements, (4) for a tactical aircraft flight-by-flight loading sequence a correspondence of striation patterns on the fracture surface and typical sections of the loading sequence could not be achieved, and (5) an assessment of the stresses having acted from fractographic striation spacing measurements leads to good to fair results for constant amplitude but not for variable amplitude loading. A.R.H.

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EARTH RESOURCES

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

N84-15646# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
PROPAGATION FACTORS AFFECTING REMOTE SENSING BY RADIO WAVES
Loughton Aug. 1983 399 p refs In ENGLISH and FRENCH Symp. held in Oberammergau, West Germany, 24-28 May 1983 (AGARD-CP-345; ISBN-92-835-0257-4; AD-A137559) Avail: NTIS HC A17/MF A01

The purpose of the symposium was to survey progress in the field, and to bring together scientists and engineers working the different wavelength regions to encourage cross fertilization and to enable performance comparisons between systems. Satellite system factors and high frequency system factors are discussed. Radar tracking ice mapping, over the horizon radar, and backscattering are among the topics discussed. For individual titles, see N84-15647 through N84-15675.

R.J.F.

N84-15647# European Space Agency. Centre Spatial de Toulouse (France). Remote Sensing Programme Div.
THE EUROPEAN SPACE AGENCY'S EARTH OBSERVATION SATELLITE PROGRAMMES
In AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 9 p (SEE N84-15646 06-43) Aug. 1983
Avail: NTIS HC A17/MF A01

The European Space Agency's Earth observation programs are discussed. The Sirio-2 program, a system for meteorological data distribution mainly over Africa, and a laser synchronization experiment for time standards, is discussed. Emphases is placed on the elements of the remote sensing program in which mainly polar and quasi-polar, Sun-synchronous satellite orbits are used. The Earth network of ground stations, Spacelab, and ERS-1 are described. R.J.F.

N84-15648*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
REMOTE SENSING WITH SPACEBORNE SYNTHETIC APERTURE IMAGING RADARS: A REVIEW
J. B. CIMINO and C. ELACHI *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 16 p (SEE N84-15646 06-43) Aug. 1983 refs
(Contract NAS7-100)
Avail: NTIS HC A17/MF A01 CSCL 17I

A review is given of remote sensing with Spaceborne Synthetic Aperture Radars (SAR's). In 1978, a spaceborne SA was flown on the SEASAT satellite. It acquired high resulution images over many regions in North America and the North Pacific. The acquired data clearly demonstrate the capability of spaceborne SARs to: image and track polar ice floes; image ocean surface patterns including swells, internal waves, current boundaries, weather boundaries and vessels; and image land features which are used to acquire information about the surface geology and land cover. In 1981, another SAR was flown on the second shuttle flight. This Shuttle Imaging Radar (SIR-A) acquired land and ocean images over many areas around the world. The emphasis of the SIR-A experiment was mainly toward geologic mapping. Some of the key results of the SIR-A experiment are given. R.J.F.

N84-15649# Marconi Co. Ltd., Chelmsford (England).
OCEAN WAVE IMAGING BY SAR
S. ROTHERAM *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 20 p (SEE N84-15646 06-43) Aug. 1983 refs
Avail: NTIS HC A17/MF A01

SAR imagery of the sea surface contains wave-like features. The direct imaging problem is to describe the image of a given sea surface. Four approaches are given. These are linear imaging, Fourier series, functional expansion and asymptotic methods. Of particular interest is the loss of wave modulations due to nonlinear velocity bunching. The image power spectrum is analyzed using functional expansions and the azimuthal banding is explained by stochastic nonlinear velocity bunching. The theoretical results agree closely with SEASAT data and some examples are given. The inverse sea imaging problem is to describe the sea surface corresponding to a given image. Some preliminary results using linear inversion techniques are given. R.J.F

N84-15650# SRI International Corp., Menlo Park, Calif.
PROPAGATION EFFECTS IN SATELLITE-BORNE SYNTHETIC APERTURE RADARS
C. L. RINO and V. H. GONZALEZ *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 12 p (SEE N84-15646 06-43) Aug. 1983 refs
(Contract DNA001-51-C-0010)
Avail: NTIS HC A17/MF A01

Satellite-borne synthetic aperture radars (SAR), such as SEASAT, can map large segments of the Earth's surface with a resolution better than 10 m. This high resolution is achieved by processing data coherently from a 10-to-20 km path along the satellite orbit. SEASAT operates at L band, where severe, naturally occurring propagation disturbances are rare except near the geomagnetic equator. On the other hand, because of the large aperture involved, loss of spatial coherence of phase can occur even when no significant amplitude scintillation is present. Computations were made that model the distortion of a point target for typical high-latitude scintillation conditions. The results show that severe degradation of reconstructed SAR images can occur, on occasion, from natural ionospheric disturbances. To confirm these results, the SEASAT data base was searched for obvious examples of the kind of distortion expected. Several examples were found. Through a fortunate coincidence, incoherent-scatter radar data were available in which the likely source region of one of the disturbances was identified. R.J.F.

N84-15651*# Kansas Univ., Lawrence. Remote Sensing Lab.
RADAR AND INFRARED REMOTE SENSING OF TERRAIN, WATER RESOURCES, ARCTIC SEA ICE, AND AGRICULTURE
A. W. BIGGS *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 22 p (SEE N84-15646 06-43) Aug. 1983 refs
Avail: NTIS HC A17/MF A01

Radar range measurements, basic waveforms of radar systems, and radar displays are initially described. These are followed by backscatter from several types of terrain and vegetation as a function of frequency and grazing angle. Analytical models for this backscatter include the facet models of radar return, with range-angle, velocity-range, velocity-angle, range, velocity, and angular only discriminations. Several side-looking airborne radar geometries are presented. Radar images of Arctic sea ice, fresh water lake ice, cloud-covered terrain, and related areas are presented to identify applications of radar imagery. Volume scatter models are applied to radar imagery from alpine snowfields. Short pulse ice thickness radar for subsurface probes is discussed in fresh-water ice and sea ice detection. Infrared scanners, including multispectral, are described. Diffusion of cold water into a river, Arctic sea ice, power plant discharges, volcanic heat, and related areas are presented in thermal imagery. Multispectral radar and infrared imagery are discussed, with comparisons of photographic, infrared, and radar imagery of the same terrain or subjects.
R.J.F

N84-15652# Laboratoire d'Etude des Transmissions Ionospheriques, Cachan (France).
ADAPTIVE PROTECTION OF DETECION SYSTEMS OPERATING BY SPREAD SPECTRUM [PROTECTION ADAPTIVE DES SYSTEMES DE DETECTION FONCIONNANT PAR ETALEMENT DE SPECTRE]
C. GOUTELARD and A. JOISEL *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 13 p (SEE N84-15646 06-43) Aug. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

Spectral congestion in the decametric range (3 - 30MHz) is such that jamming (whether voluntary or involuntary) is now an important parameter in propagation. To reduce or eliminate such jamming effects, frequency filtering or spatial filtering (with or without nulling antennas) may be used, separately or together. The spectral spreading technique is well known in telecommunications and teledetection. Whenever the perturbing signal spectrum range is smaller than that of the useful signal, a simple band filter reduces jamming, but this alters the spectrum of the received signal and that modifies its ambiguity function. Such deterioration may be avoided by introducing a non-linear operator. The limiting factors are essentially the technological constraints for the material, in particular treatment time and dynamic. The system performance is illustrated in experimental results and may be compared with the results obtained using classical techniques. Author

N84-15653# Laboratoire d'Etude des Transmissions Ionospheriques, Cachan (France).
CONTENDING WITH JAMMING IN DECAMETRIC WAVES IN AN ADAPTIVE SYSTEM OF ALL-DIRECTIONAL ANTENNAS [LUTTE CONTRE LE BROUILLAGE EN ONDES DECAMETRIQUES DANS UN SYSTEME D'AERIENS ADAPTIF ORIENTABLE TOUT AZIMUT]
C. GOUTELARD and A. JOISEL *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 14 p (SEE N84-15646 06-43) Aug. 1983 refs In FRENCH; ENGLISH summary
Avail: NTIS HC A17/MF A01

Panoramic observation in space using decametric wave radar raises the problem radiating lobe orientation. The desired angular resolutions (about 1 deg) fix the system dimensions, and necessitate electronic orientation of the beam. Two major techniques are employed. The first consists in an alignment array

which allows a limited sector to be explored with resolutions of less than one degree. Panoramic exploration requires the use of several systems. The second technique consists in the use of networks possessing rotational symetry and equiped with omnidirectional radiation antennas, or "log periodic" type antennas. Resolution is of the order of a few degrees and secondary lobe protection is only modest. An all-directional exploration system is described, using a surface array. Resolution is of the order of a few degrees but there is considerable protection of the secondary lobes. The "nulling pattern antennas" technique can be associated with the system to ensure jamming protection. Author

N84-15654# Rome Air Development Center, Hanscom AFB, Mass. Electromagnetic Sciences Div.

HF OVER-THE-HORIZON MAPPING OF THE GREENLAND ICECAP

G. S. SALES *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 12 p (SEE N84-15646 06-43) Aug. 1983

Avail: NTIS HC A17/MF A01

Continuous observation of the Greenland area using a high frequency over-the-horizon Sounding system in the North Atlantic region produced a data base for the analysis of backscatter reflectivity at high frequencies (6-30 MHz) from the Greenland Icecap. The proximity of these observations to the auroral region generated the additional complication of excess losses due to D-region absorption. This statistical data base produced a mapping of the icecap thickness, with backscatter reflectivities that vary from -5 dB to -15 dB below the signals returned from the surrounding sea water. A statistically meaningful daytime absorption of the order of 5 dB was measured over Greenland. At night the significantly increased auroral absorption and atmospheric noise, reduced the system's sensitivity, making mapping impossible.

R.J.F

N84-15655# Birmingham Univ. (England). Dept. of Electronic and Electrical Engineering.

A REVIEW OF PROPAGATION AND SCATTERING FACTORS IN REMOTE-SENSING AND SHIP-TRACKING BY HF RADAR

E. D. R. SHEARMAN *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 13 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

The propagation-loss, noise and scattering mechanisms involved in ground-wave radar for sea state sensing and ship-tracking are first reviewed, taking as an example a coastal installation in the U.K. Techniques for extracting surface-current, surface-wind and directional sea-wave spectrum from first and second-order sea-echo are described, with reference to the influence of the antenna directivity and propagation factors. The special factors affecting ship-tracking in range, azimuth and Doppler are illustrated. The use of sky-wave radar for sea-state sensing and for assessing the ionospheric layer configuration and propagation mode patterns is discussed. Sea-state sensing is shown to require real-time propagation assessment for effective frequency-management. Rapid sweep frequency, sweep-azimuth and Doppler analysis are shown to be desirable. R.J.F.

N84-15656# Science Research Council, Chilton (England).

IONOSPHERIC FACTORS AFFECTING THE PERFORMANCE OF HF SKY-WAVE SEA-STATE RADARS

P. A. BRADLEY, E. N. BRAMLEY, A. J. GIBSON, and J. W. KING *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 10 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

This paper contains an assessment, partly theoretical and partly based on observations, of the impact of various ionospheric factors on the usefulness of the HF sky-wave sea-state radar technique. The points discussed include the following: (1) The ionospheric propagation modes available will not permit all parts of the ocean which it is desired to investigate to be illuminated at all times in such a way that good-quality Doppler spectra are obtained. Es-mode propagation generally results in good-quality Doppler spectra from which information about the sea waves can be inferred, but F-mode propagation yields poor spectra which can only be used to deduce the surface wind direction. (2) Doppler shifts associated with vertical ionospheric motions give spectral contamination which limits the amount of information that can be derived. Spectral contamination also arises under conditions of multi-mode propagation and when high- and low-angle rays are present. (3) Lack of knowledge of the height of reflection of the sky-wave signals means that the area of ocean probed cannot be located accurately. (4) The azimuthal spreading (arising because of the antenna beam width) and range spreading (caused by ionospheric tilts and corrugations and associated with the finite radar pulse width) both result in Doppler contamination of the returned signals. Author

N84-15657# Communications Research Centre, Ottawa (Ontario).

THE CANADIAN PROGRAMME OF EXPERIMENTAL MEASUREMENT OF SEA-STATE CHARACTERISTICS BY SKY-WAVE RADAR

E. L. WINACOTT, C. ROCHE (Centre for Cold-Ocean Resources Engineering, St. Johns, Newfoundland), and J. Y. K. CHAN (Miller Communications Systems, Ottawa) *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 17 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

In June, 1980, a limited programs of sky-wave radar measurements was undertaken to investigate the feasibility of measuring sea-state characteristics off the coast of Newfoundland. The program involved the collection of data by the Communications Research Centre's (CRC) Sampled Aperture Receiving Array (SARA) facility at Ottawa, the compilation of ground-truth maps of wave height, wind velocity and ice coverage by the Centre for Cold-Ocean Resources Engineering (C-CORE) in Newfoundland, and data analysis and interpretation by both agencies. A number of day-time experimental runs were made between October, 1980, and April, 1982. Because it was felt that ionospheric disturbances would preclude the recording of useful results, runs were made, as much as possible, only during periods of relatively quiet ionospheric conditions. As was expected from the earlier experience of U.S. workers, maps of wind direction usually could be derived from the data, but maps of wave heights were quite sparse: less than one-quarter of the data were useful. In fact, since the acceptance criterion developed by the U.S. workers was found to reject virtually all of the Canadian data, a manual acceptance technique had to be employed. While this technique has made possible the recovery of experimental results, it would be impractical in an operational radar. Determination of other sea-state characteristics, such as sea-wave spectra, the magnitude of the swell component or independent measurement of wind speed, was not possible from the data collected. B.W.

N84-15658# Naval Ocean Systems Center, San Diego, Calif. Ocean and Atmospheric Sciences Div.

F-REGION VARIABILITY AND HF-PROPAGATION

A. K. PAUL *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 13 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

A program conducted during the winter 1980/1981 in Brighton, Colorado, with a modern digital ionosonde was aimed towards improvement of knowledge regarding the temporal variations. Rapid sequences of ionograms were taken in irregular intervals and the analysis concentrated mainly on the maximum usable frequency MUF (3000) as a very sensitive combined indicator for variations in height and electron density. This quantity could be computed automatically with very high precision. Other quantities obtained were the critical frequency of the F-region, estimates for its height of maximum and half thickness, Doppler velocity and angle of arrival. Some of the results are: short term variations of the MUF (3000) can have much larger amplitudes than previously expected from hourly data. Changes close to 50 percent within half an hour were observed. No correlation between gravity wave activity and magnetic activity could be found. There is some indication that high gravity wave activity is caused by severe weather systems. Local tilts of 5 deg and more were observed during periods of high gravity wave activity. The area of high or low gravity wave activity seems to be very large (more than 1000 km radius).

B.W.

N84-15659# Lowell Univ., Mass. Center for Atmospheric Research.

AUTOMATIC ELECTRON DENSITY PROFILES FROM DIGITAL IONOGRAMS

B. W. REINISCH, R. R. GAMACHE, and J. S. TANG. *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 11 p (SEE N84-15646 06-43) Aug. 1983 refs

(Contract F19628-80-C-0064)

Avail: NTIS HC A17/MF A01

Over-the-horizon HF radar detection and sea state monitoring require fairly precise knowledge of the ionospheric reflection point. Automatic scaling of ionograms and calculation of the vertical electron density profile can provide the reflection point characteristics in real time if adequate ionosondes are available at the expected mid-points. The automatic scaling algorithm developed at the University of Lowell extracts the E and F region traces from Digisonde ionograms without any human intervention and automatically produces the corresponding electron density profiles. The algorithm was tested on several thousand Digisonde ionograms covering the four seasons, day, night, quiet and disturbed conditions, as observed at the AFGL Ionospheric Observatory, Goose Bay, Labrador. All important ionospheric parameters are automatically retrieved: foF2, foF1, fminF, MUF(3000), M(3000), range spread, frequency spread, h'F, h'F2, foE, foEs, fminE, h'Es, and signal amplitude as function of frequency. The electron density profile algorithm uses a polynomial profile-fitting method and is part of the automatic procedure.

Author

N84-15660# Hulburt (E. O.) Center for Space Research, Washington, D.C. Ionospheric Effects Branch.

DETERMINATION OF PROPAGATION LIMITATIONS AT HF BY REAL-TIME UPDATE OF A COMPUTER MODEL FROM OBLIQUE SOUNDER DATA

D. R. UFFELMAN. *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 12 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

The Naval Research Laboratory has an active program which involves an assessment of the HF propagation channel by coupling computer models of the channel to data obtained from oblique sounders. Currently, this technique draws upon models of maximum usable frequency (MUF) resident in programs such as IONCAP and the Naval Ocean Systems Center (NOSC) PROPHET SYSTEM (MINIMUF 3.5) and relates this model to real-time measurements of the maximum observed frequency (MOF) over a reference path. Measurements from the reference path are used to update the models and the driving parameters which are ascertained from this process are used to access the maximum observed frequency over paths disjoint from the reference path. In the experimental approach, NRL employs a network of oblique sounders to determine the success of the technique. One link in the network is designated the control path and the other links are designated as experimental paths to which the results of the model update are compared. The comparison criterion is rms error between the modelled parameters and the measurements of those same parameters over the various links. Initial results indicate that for F-region propagation near the maximum observed frequency under benign and moderately disturbed conditions, update of the MINIMUF model improves performance by as much as a factor of four. The results for the IONCAP are much less encouraging, at least in this case, however. It is suggested that this approach could be utilized in selective calling systems as well as automated frequency control of systems such as that being developed for Project Cross Fox.

Author

N84-15661# Hulburt (E. O.) Center for Space Research, Washington, D.C. Ionospheric Effects Branch.

ON THE UTILIZATION OF IONOSPHERIC DIAGNOSTICS IN THE SINGLE-SITE LOCATION OF HF EMITTERS

J. M. GOODMAN and D. R. UFFELMAN. *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 13 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

The Naval Research Laboratory conducted an experiment during the latter half of calendar year 1982 which dealt with the problem of HF Single-Site-Location (SSL) as envisioned for the U.S. Army Rear Echelon HF Comint System (RECS). This experiment was conducted for the purpose of certifying a baseline SSL system and the test was identified simply as the SSL-BCT (Baseline Certification Test). Two specific approaches to SSL were examined during the experiment which was conducted from a base station located at Fort Ord, California. For the most part the desire was to examine two competing SSL techniques in an environment which simulated an actual operational situation, viz., a single-blind experiment. As control, however, there was a period (Phase 1) during which each competing technique was calibrated against known HF emitters. Measurements were made using a variety of emitters located at short, medium, and moderately long ranges to the east of Fort Ord. The results of these tests, in which systems developed by Southwest Research Institute and Technology for Communications International were exercised, have not yet been released. However, generalized conclusions have been reached. To be assured that the ionospheric channel was properly specified, the SSL-BCT test range was instrumented as fully as possible. Oblique ionosondes, vertical incidence ionosondes, Faraday rotation polarimeters, and satellite-borne topside sounders were used for the purpose of ionospheric specification. This paper describes the general SSL-BCT approach and the type of results which were obtained but it emphasizes the various approaches to ionospheric specification required for optimum SSL operation.

Author

N84-15662# General Electric Co., Syracuse, N.Y.

EXTRATERRESTRIAL RADIO NOISE AND ITS EFFECT ON RADAR PERFORMANCE

G. H. MILLMAN. *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 8 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

In this paper, the flux densities of radio frequency radiation from the quiet Sun and other cosmic noise sources are presented as a function of frequency. The conversion of flux density to apparent antenna temperature is discussed. An evaluation is made of UHF radar system degradation, i.e., the reduction of radar-range capability, due to the presence of the Sun, discrete radio stars and distributed noise sources in the Galaxy.

Author

N84-15663# Royal Norwegian Council for Scientific and Industrial Research, Kjeller. Environmental Surveillance Technology Programme.

MULTIFREQUENCY SCATTERING FOR TARGET CHARACTERIZATION AND IDENTIFICATION: A SUMMARY OF RECENT RESULTS

D. T. GJESSING. *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 8 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

An optimum illumination and detection system which is capable of adapting itself to target against a terrestrial background through an adverse propagation medium is described in depth. This is multifrequency radar system, lends itself directly to simple computer control in a manner which is very familiar to the computer scientist. Results from simple mathematical models are presented and some preliminary experimental verifications are offered.

B.W.

N84-15664# Illinois Univ., Urbana-Champaign. Dept. of Electrical Engineering.

THE EFFECT OF TURBULENT ATMOSPHERE ON BACKSCATTERED WAVES

K. C. YEH and C. H. LIU. *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 6 p (SEE N84-15646 06-43) Aug. 1983 refs

(Contract NSF ATM-82-08931)

Avail: NTIS HC A17/MF A01

In radar detection of targets the backscattered waves are traveling through the same region as the incident wave. When the region is occupied by a turbulent atmosphere, the backscattered wave is therefore expected to be correlated with the incident wave. As a matter of fact, these two oppositely traveling waves are related through a reciprocity theorem. This reciprocity theorem is shown to be valid by using the Feynman path integral solution of the parabolic equation. For the problem at hand the path integral is just the propagator which enters naturally in calculations of the mutual coherence function. This mutual coherence function is evaluated for several cases: when the incident wave is a narrow

or broad beam wave, and when the target is a single point or a random reflecting screen with finite correlation size. The aperature averaged mutual intensities are also evaluated. The results show that under certain conditions the backscattered power can be intensified to above the free space value. The turbulent atmosphere can also broaden the apparent target size under some other conditions. These and other results will be presented and discussed in the paper. Author

N84-15665# TRW Space Technology Labs., Redondo Beach, Calif.

THE NATURE OF MICROWAVE BACKSCATTERING FROM WATER WAVES

S. W. KWOH and B. M. LAKE *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 16 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

A recent laboratory study shows that Bragg scattering by itself is not a adequate description for microwave backscattering from water waves. It may account for part of the scattering, but reflection from specular facets and wedge-like diffractive scattering from small radius crests of waves can predominate. Two experiments were performed. The first experiment was performed on wave paddle-generated short gravity waves. Using a scanning laser slope gauge to measure the surface and the moments method to compute the scattering, it was found that the small radius crests of such waves can be the more dominant source of scattering and that the description of such scattering is closer to wedge diffraction than Bragg scattering. The second experiment was performed on wind waves. It was found that at low wind the Doppler spectrum is narrow peaked but it gradually evolves to become a doubly peaked spectrum at high wind. Analysis shows that low wind scattering is indeed Bragg scattering. At high wind, the lower frequency peak again is due to Bragg scattering from rough patches, whereas the higher frequency peak is due to scattering from waves not unlike the paddle-generated short gravity waves. B.W.

N84-15666# Laboratoire Central de Telecommunications, Paris (France).

MULTIPLE PATHS ON THE OCEAN SURFACE [TRAJETS MULTIPLES SUR LA SURFACE DE LA MER]

M. FOURNIER *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 17 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

A realistic model of propagation affected by multiple paths on the sea surface is considered in an effort to develop a computer program for use in studying systems work operating in such an environment. The compatibility of laws of hydrodynamics with those of statistics are examined in order to obtain an appropriate description of the sea surface. A linear model is proposed and its validity is assessed. The statistics of a diffuse signal in the ocean surface environment are obtained for direct signals, coherent signals, and diffuse signals. The choice of an electromagnetic theory to describe the effects of backscattering is explored. The model proposed describes as correctly as possible the spatio-temporal correlation of the signal and introduces oceanographic data from experiments. Transl. by A.R.H.

N84-15667# Racal-Decca Ltd., Chessington (England).

10 CM RADAR GROUND CLUTTER MEASUREMENTS TAKEN FROM A COASTAL STEAMER RADAR ON PASSAGE FROM BERGEN TO NORTH CAPE IN MAY 1982

P. D. L. WILLIAMS *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 15 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

The range of R.C.S. values from a high rising natural coastline viewed by radar on a ship proceeding along that coast from 1 to 10 miles away. The range of R.C.S. values from the mountainous country just inland of the first coastal echo. The likely range of spatial filling factor of inland ground clutter and radar detection of aircraft flying overland in these regions using interclutter visibility rather than classic DOPPLER MTI methods of "sub clutter" detection are addressed. Author

N84-15668# Segnalamento Marittimo ed Aereo S.p.A., Florence (Italy).

STATISTICAL DATA ON ANOMALOUS PROPAGATION IN THE TYRRHENIAN SEA USING AN X-BAND LINK

V. SACCO, P. P. LOMBARDINI, and G. MARSIGLIA *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 7 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

Anomalous propagation is heavily dependent on climate. The Mediterranean climate is particularly rich on ducting phenomena. An X-band link has been established between Vesima, near Genoa (transmitter) and Leghorn (receiver) with the intent of gathering data on existence and repeatibility of ducting in the Tyrrhenian Sea. The link distance is 87.5 nautical miles. The heights of the transmitting and the receiving antenna are 5 mt. over the sea level. Data of signal intensity are recorded every half hour. Data and evaluations from a first period of working are presented. Also a relationship between ducting and climatic stability is presented. Author

N84-15669# Marconi Co. Ltd., Great Baddow (England).

A LONG RANGE PROPAGATION EXPERIMENT TO INVESTIGATE THE INCIDENCE OF ANOMALOUS PROPAGATION IN THE NORTH ATLANTIC

G. C. RIDER and J. CLARKE (Royal Signals and Radar Establishment, Malvern, England) *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 12 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

The significance of enhanced range on air to ground paths is reviewed and the paper describes an experiment to collect maximum range data on an oversea path. A Secondary Surveillance Radar sited in the Hebrides was used to observe civil air traffic crossing the North Atlantic, and a cumulative distribution of range extending to 0.1% of the year is presented as a result of 14 months of observation. The modifications made to the radar antenna and display *in order* to provide sufficient system sensitivity, are described. About 99% of the observations are shown *to be* satisfactorily modelled by employing an exponential atmosphere with linear N profiles as measured by a suitably sited radiosonde station, Ocean Weather Ship 'L', to model the first 1 Km. of height. The remaining 1% of observations, the extreme range cases, are examined in some detail and are attributed with reasonable confidence to ray bending in passage through elevated layers. Author

N84-15670# Arete Associates, Inc., Encino, Calif.

LIDAR REMOTE SENSING OF INTERNAL WAVES AND OPTICAL PROPERTIES

S. C. LUBARD, L. R. THEBAUD, and R. F. LUTOMIRSKI (Pacific Sierra Research Corp., Los Angeles) *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 13 p (SEE N84-15646 06-43) Aug. 1983 refs

Avail: NTIS HC A17/MF A01

The theoretical basis and recent experimental results on the remote sensing capability of a lidar probing down into the ocean are summarized. The emphasis will be on the detection of modulations in the lidar return induced by the internal wave displacement field. The experiment included a high precision lidar operated through a plexiglass window flush with the keel of a drifting ship. Internal waves were measured simultaneously and nearly coincidentally with a chain of thermistors. Measured ocean optical properties included vertical profiles of beam attenuation coefficient, (spectral) diffuse attenuation coefficient, point spread function and local particulate backscattering versus time at several depths. Coherences between the lidar return at various depths and internal wave displacements have been determined for several blocks of data and indicate detections of internal wave induced modulations in the lidar return. Author

43 EARTH RESOURCES

N84-15671# Science Applications, Inc., San Diego, Calif.
SATELLITE MEASUREMENTS OF MARINE AEROSOLS
M. GRIGGS *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 5 p (SEE N84-15646 06-43) Aug. 1983 refs
(Contract N00014-77-C-0489; N00228-82-C-6199; MO-A01-78-00-4092)
Avail: NTIS HC A17/MF A01

The ability to measure atmospheric aerosols over ocean surfaces was demonstrated using several different satellite sensors. LANDSAT data originally showed that a linear relationship exists between the upwelling visible radiance and the aerosol optical thickness. Analysis of NOAA-6 AVHRR data obtained at several different locations, in coincidence with ground truth measurements, show that the Channel 1 (0.65 microns) radiances can be used to determine the aerosol optical thickness. The good agreement between the results at different locations suggests that the technique could be used in an operational system. A technique using Channel 1 and Channel 2 (0.86 microns) radiances to determine the aerosol size distribution is discussed, and, in spite of uncertainties in the satellite and ground truth data, a preliminary analysis shows that useful estimates of the size distribution can be obtained. Author

N84-15672# Tetra Tech, Inc., Pasadena, Calif.
TECHNIQUES FOR MEASURING RADIANCE IN THE AIR AND SEA
W. H. WELLS *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 17 p (SEE N84-15646 06-43) Aug. 1983 refs
Avail: NTIS HC A17/MF A01

Measurements of scattered sunlight often employ simple radiometers that are incapable of scanning azimuth phi and zenith angle theta. Instead, they measure integral moments of the radiance. Consider a set of N+1 meters designed to measure moments lambda sub 1 through lambda sub N+1. If each meter is judiciously designed, then the lambda sub j may be processed quite simply to deduce inherent properties of the scattering medium, namely N moments of the volume scattering function. In the optimum design, each meter has an angular response that approximates a polynomial of degree N in cos theta. The theory of these meters is based on Boltzmann's equation of radiative transfer expressed in terms of spherical harmonics, a form in which this equation is particularly simple. Author

N84-15673*# Scripps Institution of Oceanography, La Jolla, Calif. Visiblity Lab.
PASSIVE REMOTE SENSING OF OCEAN OPTICAL PROPAGATION PARAMETERS
R. W. AUSTIN and B. L. MCGLAMERY *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 11 p (SEE N84-15646 06-43) Aug. 1983 refs
(Contract NAS5-26249; N00014-78-C-0566)
Avail: NTIS HC A17/MF A01

A method is described for producing a global data of ocean optical properties through the exploitation of optical remote sensing techniques. The diffuse attenuation, K, and the radiance reflectance factor R sub L, of the ocean surface waters can be derived from the radiance data provided by the Coastal Zone Color Scanner and compiled into a computer based atlas of these properties. While these remotely sensed values can only be directly related to the water properties in the first or upper attenuation length, extensive in water measurements have demonstrated that a useful correlation exists between the K that applies to the upper attenuation length, for example, and the mean K over the upper 100 or 200 meters of the ocean. Such an empirical finding greatly enhances the usefulness of this remotely sensed propagation parameter. Examples of the type of information being produced and archived for the atlas are presented. Author

N84-15674# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
REMOTE SENSING OF ATMOSPHERIC PRESSURE AND SEA STATE FROM SATELLITES USING SHORT-PULSE MULTICOLOR LASER ALTIMETERS
C. S. GARDNER, B. M. TSAI, and J. B. ABSHIRE *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 11 p (SEE N84-15646 06-43) Aug. 1983 refs Prepared in cooperation with Illinois Univ., Urbana
(Contract NSG-5049)
Avail: NTIS HC A17/MF A01 CSCL 20E

Short pulse multicolor laser ranging systems are currently being developed for satellite ranging applications. These systems use Q-switched pulsed lasers and streak tube cameras to provide timing accuracies approaching a few picoseconds. Satellite laser ranging systems was used to evaluate many important geophysical phenomena such as fault motion, polar motion and solid earth tides, by measuring the orbital perturbations of retroreflector equipped satellites. Some existing operational systems provide range resolution approaching a few millimeters. There is currently considerable interest in adapting these highly accurate systems for use as airborne and satellite based altimeters. Potential applications include the measurement of sea state, ground topography and atmospheric pressure. This paper reviews recent progress in the development of multicolor laser altimeters for use in monitoring sea state and atmospheric pressure. Author

N84-15675# SRI International Corp., Menlo Park, Calif.
IN SITU CHARACTERIZATION OF SEAWATER USING A COMPUTERIZED SUITE OF OPTICAL INSTRUMENTS
R. C. HONEY and C. A. MOORE *In* AGARD Propagation Factors Affecting Remote Sensing by Radio Waves 12 p (SEE N84-15646 06-43) Aug. 1983 refs
Avail: NTIS HC A17/MF A01

A suite of instruments is described that measures the parameters required as sea truth for a shipborne lidar system. Novel optical configurations are used with digital electronics to efficiently measure beam transmission, backscattering, beam spread function, and diffuse spectral attenuation. All sensors are linked to a single desktop computer for data collection and analysis in near real time at sea. The instrumentation is described, and representative data are presented. Author

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AEROSPACE MEDICINE

Includes physiological factors; biological effects of radiation; and weightlessness.

N83-22999# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
MEDICAL ASPECTS OF SURVIVAL: TRAINING FOR AIRCREW
T. VERHEIJ Loughton, England Jan. 1983 23 p refs
(AD-A128157; ISBN-92-835-1442-4; AGARD-AG-283) Avail: NTIS HC A02/MF A01

Maintenance of health, medical aid to survivors, general management of injuries, heat and cold exposure, specific injuries, survival illnesses, and medical aspects of escape and evasion are discussed. Author

N84-15787# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
MEDICAL ASPECTS OF SURVIVAL: TRAINING FOR AIRCREW
T. VERHEIJ Jun. 1983 23 p refs In FRENCH English version document was announced as N83-22999
(AGARD-AG-283(FR); AGARD-AG-283(ENG); ISBN-92-835-1442-4) Avail: NTIS HC A02/MF A01

Maintenance of health, medical aid to survivors, general management of injuries, heat and cold exposure, specific injuries, survival illnesses, and medical aspects of escape and evasion are discussed. Author

N84-15788# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SLEEP AND WAKEFULNESS HANDBOOK FOR FLIGHT MEDICAL OFFICERS
A. N. NICHOLSON (Inst. of Aviation Medicine, Farnborough, England) and B. M. STONE (Inst. of Aviation Medicine, Farnborough, England) Nov. 1983 103 p In FRENCH Previously announced as N82-27972
(AGARD-AG-270(FR)) Avail: NTIS HC A06/MF A01

Sleep and wakefulness related to aircrew and the aviation environment are discussed. Eight topics are covered: alertness and sleep, sleep, Circadian rhythms, shiftwork, transmeridian flight, air operations and irregularity of work, disorders of sleep and arousal, and hypnotics. N.W.

N84-21062# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SUSTAINED INTENSIVE AIR OPERATIONS: PHYSIOLOGICAL AND PERFORMANCE ASPECTS
Loughton, England Nov. 1983 220 p refs In ENGLISH and FRENCH Conf. held in Paris, 18-22 Apr. 1983
(AGARD-CP-338; ISBN-92-835-0343-0; AD-A139324) Avail: NTIS HC A10/MF A01

The symposium addressed the aeromedical and human factors aspects of the capabilities of aircrew and ground crew to perform their duties at high intensities at irregular times of the day and night over many days or weeks under military operational conditions. Laboratory studies on the measurement of aircrew workload, the effects of disturbances of circadian rhythms and deprivation of sleep and the use of hypnotics and stimulants to influence sleep and wakefulness are reported. The effects of protective equipment and procedures on air and ground crew with particular reference to fast jet and helicopter operations are examined. Field studies of fatigue, performance and physiological disturbances in aircrew and ground personnel engaged in sustained air operations are described. For individual titles, see N84-21063 through N84-21081.

N84-21063# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
CONCEPTUAL FRAMEWORK FOR THE DEVELOPMENT OF WORKLOAD METRICS IN SUSTAINED OPERATIONS
R. D. ODONNELL (Wright State Univ.) and F. T. EGGEMEIER (Systems Research Labs., Inc.) *In* AGARD Sustained Intensive Air Operations 10p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

In sustained operations, the cumulative effect of workload may lead to unpredicted, catastrophic human failure. Workload assessment, however, has suffered from the lack of an overall, standardized framework which would permit development of sensitive, predictive metrics. Such a general framework is developed based on the view that workload is a multiply-determined hypothetical construct conveniently summarizing the interactions which limit task performance. Major task, operator, and response factors are presented, and related to metrics available or being developed for assessing these factors. The framework is then utilized to suggest the broad outlines of a research program leading to standardization of workload assessment in sustained operations environments. M.G.

N84-21064# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio. Workload and Ergonomics Branch.
THE U.S. AIR FORCE NEUROPHYSIOLOGICAL WORKLOAD TEST BATTERY: CONCEPT AND VALIDATION
R. D. ODONNELL *In* AGARD Sustained Intensive Air Operations 10p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

In order to provide measures of specific human capabilities and resources, the U.S. Air Force Aerospace Medical Research Laboratory is developing workload metrics spanning the entire spectrum, from task analysis through subjective and behavioral measures. In addition, neurophysiological measures have been investigated for a number of years with respect to their sensitivity in assessing workload. As a result of these studies, a test battery consisting of six different electrophysiological measures in eleven different forms was constructed. The tests selected were based on extensive laboratory data which indicated some probability that each measured an aspect of workload and might be appropriate and practical in applied settings. This test battery is currently undergoing validation studies in simulator environments and successfully validated tests will be incorporated into a second generation neurophysiological test battery to be used in field workload assessment. The overall rationale of the tests selected, as well as some of the experimental evidence supporting their use as workload assessment devices are detailed. Validation studies and plans for future test modifications are also presented. M.G.

N84-21065# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio. Workload and Ergonomics Branch.
BEHAVIORAL AND SUBJECTIVE WORKLOAD METRICS FOR OPERATIONAL ENVIRONMENTS
C. A. SHINGLEDECKER *In* AGARD Sustained Intensive Air Operations 10p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

The assessment of crew performance capability under conditions of sustained intensive air operations requires the use of specialized measures of operator workload which are matched to the nature of the investigation and to the environment in which the workload evaluation must be conducted. In many cases, the effects of severe combined stressors and of aircrew performance requirements on mental workload cannot be studied in the laboratory, and must be addressed in high fidelity simulation or during operational test exercises. The advantages and limitations of traditional subjective report and behavioral measures of workload for application in operational environments are examined. In addition, efforts at the U.S. Air Force Aerospace Medical Research Laboratory to develop improved field-usable subjective and behavioral secondary task metrics are described. M.G.

N84-21066# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio. Human Engineering Div.
LABORATORY STUDIES OF AIRCREW CHEMICAL PROTECTIVE ENSEMBLE: EFFECTS ON PILOTS' PERFORMANCE
G. R. MCMILLAN, W. J. CODY (McDonnell-Douglas Astronautics Co.), and R. G. MILLS *In* AGARD Sustained Intensive Air Operations 18p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

The results of a U.S. Air Force program designed to quantify the effects of current and near-term chemical protective gear on pilot performance are described. The first phase of the program consisted of a sensitivity analysis to determine which aspects of pilot performance should be evaluated, the anticipated performance decrements, the stress mechanisms presumed to be operating, and the flight simulations required to quantify the effects of the protective ensemble. To date, two full-mission laboratory experiments have been completed. These experiments evaluated the currently fielded USAF aircrew ensemble and a proposed Integrated Chemical Defense System. Reductions in pilot performance were observed with both systems under simulated hot environmental conditions. However, the pilots strongly preferred the Integrated Chemical Defense System's eye-respiratory protective gear. The data suggest that thermal stress, produced by the multiple layer body protective gear, caused the performance reductions. M.G.

N84-21067# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt Cologne (West Germany). Inst. fuer Flugmedizin.
CIRCADIAN RHYTHMS AND SUSTAINED OPERATIONS
H. M. WEGMANN and K. E. KLEIN *In* AGARD Sustained Intensive Air Operations 7p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

Sustained operations necessarily conflict with the circadian system in several ways: changes in the habitual work-rest cycle, shifts in meal- or sleep-timing, intense activity during night hours, sleep deprivation and disruptions of the normal synchrony between body functions and environment. When these rhythm disturbances affect performance, they become operationally significant. Their consequences are discussed and factors are described which influence the range of performance oscillation. Of particular operational relevance are motivation, sleep and physical exercise. Under certain conditions they can help to overcome deficits in performance and periods of diminished efficiency. M.G.

N84-21068# Centre de Recherches du Service de Sante des Armees, Lyons (France).
VARIATIONS IN STATES OF ALERTNESS DURING CONTINUOUS OPERATIONS AT THE CONTROL POST LEVEL [VARIATIONS DES ETATS DE VIGILANCE AU COURS D'OPERATIONS CONTINUES AU NIVEAU D'UN POSTE DE COMMANDEMENT]
J. FOURCADE, A. BUGUET (Niamey Univ.), R. BUGAT (Centre d'Etudes et de Recherches Biophysiologiques Appliques a la Marine), and C. RAPHEL *In* AGARD Sustained Intensive Air Operations 16p (SEE N84-21062 11-52) Nov. 1983 refs In FRENCH
Avail: NTIS HC A10/MF A01

The evolution of certain mental and decision making capacities of control post personnel was observed and two officers were chosen as representative of the group for neurophysiological studies of sleep and wakefulness as well as psychological and psychoergonomic evaluation. Urinalyses were also performed. Hypnograms from the neurophysiology of sleep tests show a difference in sleep deprivation for the two subjects because of the hours worked and the degree of comfort during sleep. Occipital and temporal deprivation obtained by EEG is plotted and results of the urinalysis are discussed. It is concluded that persons responsible for cognitive and decision making tasks at a control post must have a nearly normal amount of sleep.
Transl. by A.R.H.

N84-21069# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
THE EFFECTS OF SLEEP LOSS AND SUSTAINED MENTAL WORK: IMPLICATIONS FOR COMMAND AND CONTROL PERFORMANCE
R. G. ANGUS and R. J. HESLEGRAVE *In* AGARD Sustained Intensive Air Operations 21p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

During sustained military operations was investigated. Subjects were required to perform continuous cognitive work in an environment modelled after a command post during sustained battle. They assumed the role of operations duty officers and were required to handle message traffic during a 54-hour period of wakefulness. Performance was evaluated by monitoring the subjects' message-processing ability and by other objective tests embedded in and interspersed around the messages. Data are presented to show that sleep loss and sustained mental work can have dramatic effects on cognitive functions, even during the first night to sleep loss. The data also revealed that under this continuous cognitive workload, performance systematically declined. After 18 hours, performance declined substantially and remained at this lower lever for approximately another 24 hours. Performance then declined again to a level that would generally be viewed as unacceptable. Author

N84-21070# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
ADAPTATION TO IRREGULARITY OF REST AND ACTIVITY
A. N. NICHOLSON, B. M. STONE, R. G. BORLAND, and M. B. SPENCER *In* AGARD Sustained Intensive Air Operations 6p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

The adaptation to conventional shiftwork is discussed in reference to circadian rhythmicity, quality of sleep, and general effectiveness of the individual during air operations. Observations of sleep parameters, physiochemical tests, and performance results provided evidence that during a lengthy period of irregular sleep and work, efficiency impairment increases. Circadian rhythmicity, the length of time on a task and cumulative sleep loss contributed to the impaired ability of the individuals. The most adverse effects were minimized by avoiding prolonged periods of work extending to the latter part of the night and by avoiding sleep loss. M.A.C.

N84-21071# Institute for Perception RVO-TNO, Soesterberg (Netherlands).
SOME ISSUES IN RESEARCH ON EFFECTS OF SUSTAINED WORK AND SLEEP LOSS ON PERFORMANCE
A. F. SANDERS *In* AGARD Sustained Intensive Air Operations 8p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

The effects of sustained operations, sleep loss and diurnal rhythms in relation to human performance demands was examined. Performance impairment, sleep loss, alertness, motivation, reaction time, and task duration were used to establish performance guidelines. Short term tests suggested that directly interpreting input and handling output was impaired after sleep loss. The effects on performance of actual time-at-work are minor as compared to those of sleep loss and disturbance of diurnal rhythms. M.A.C.

N84-21072# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
HYPNOTICS AND AIR OPERATIONS
A. N. NICHOLSON *In* AGARD Sustained Intensive Air Operations 8p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

The selection and use of hypnotics for personnel involved in air operations is discussed. Diazepam (5 to 10 mg) is an excellent hypnotic when used occasionally for both night time and day time sleep, but it should not be ingested more than once every 48 hours and more than twice in 7 days. Temazepam and oxadepam are also useful, but oxazepam (15 to 30 mg) is unlikely to shorten sleep onset. Triazolam (0.125 to 0.25 mg) can be used daily - if this is essential - and this is so with the other trazolodiazepine, brotizolam (0.25 to 0.25 mg). Midazolam (10 to 20 mg) with its very short short elimination half-life is a promising hypnotic in the context of shiftwork. If hypnotics are to be used in the mangement of sleep difficulties in those who carry out skilled work a drug with which the individual is familiar must be used. It should be given at the lowest dose, and as infrequently as possible. There should be an interval of 24 h between ingestion and commencement of duty their use is supervised. Under these circumstances the interval may be reduced to 12 hours. M.A.C.

N84-21073# Centre de Recherches du Service de Sante des Armees, Lyons (France).
PSYCHO-ERGONOMIC PROBLEMS PRESENTED BY THE PROLONGED WEARING OF GAS MASKS [PROBLEMES PSYCHO-ERGONOMIQUES POSES PAR LE PORT PROLONGE DE MASQUES A GAZ]
J. FOURCADE and C. RAPHEL *In* AGARD Sustained Intensive Air Operations 13p (SEE N84-21062 11-52) Nov. 1983 refs In FRENCH
Avail: NTIS HC A10/MF A01

The adaptation of man to the gas mask and the constraints that wearing this protective device continuously from 16 to 48 hours imposes on his living and working were investigated in 34 subjects over a two year period without simulating a toxic chemical environment. The relation of the mask wearer with his environment, with other mask wearers, with the mask itself, and with nourishment were investigated. Results discussed cover the effects of the mask on visual tasks, sensorimotor adjustment (writing, walking, driving, use of instruments, etc.), verbal communication, and the making of medical examinations. The opinions of the subjects on their affective and mental states are examined including individual dynamics, sociability, the tendency for isolation, annoyance with the mask during work, manifestations of pain, sleeping conditions, and general comfort. Liquid feeding, caloric intake, and gastric system disturbances are also covered. A.R.H.

N84-21074# Army Aeromedical Research Lab., Fort Rucker, Ala. Biomedical Applications Research Lab.
SELECTED FACTORS AFFECTING AIRCREW PERFORMANCE DURING SUSTAINED OPERATIONS
K. A. KIMBALL *In* AGARD Sustained Intensive Air Operations 17p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

Six graduates of initial rotary wing training flew a UH-1H helicopter for up to 4 hours while wearing each of clothing ensembles. Each aviator wore the standard flight suit, the US chemical defense (CD) ensemble, and the United Kingdom (UK) CD ensemble in hot weather (mean WBCT 29 C). Skin temperatures

(chest, thigh, upper arm, and calf), rectal temperature, heart rate, and preflight and postflight body weights were recorded. Cognitive testing was conducted preflight, postflight, and on nonflight days. Aviator performance measures were also obtained during flight. Well acclimatized aviators were able to fly at least 2 hours without serious physiological impairment. Three of the six aviators terminated flight for medical reasons (heart rates 40 bpm or nausea) while wearing the US ensemble. The susceptible subjects tended to be older and heavier. Heart rate was judged to be the most sensitive indicator of heart stress. Cognitive testing and flight performance data obtained during this exercise did not demonstrate changes as a function of the type of flight ensemble worn during the test, nor did flight performance serve as a predictor of heart stress. Author

N84-21075# School of Aerospace Medicine, Brooks AFB, Tex. Crew Technology Div.
AIRCREW FATIGUE DURING EXTENDED TRANSPORT, TACTICAL, AND COMMAND POST OPERATIONS
W. F. STORM *In* AGARD Sustained Intensive Air Operations 16p (SEE N84-21062 11-52) Nov. 1983
Avail: NTIS HC A10/MF A01

Self ratings of subjective fatigue and sleep logs provide a simple and useful means of evaluating aircrew during real world operations involving large numbers of participants working irregular schedules. Evaluations of extended USAF operations involving transport, tactical, and airborne command post systems are reviewed. Following outboard crew rest on C-141 transport aircraft flying 8 to 9 hour missions, aircrew performance in simulator missions was significantly deteriorated and accompanied by reports of severe fatigue. Tactical aircrews are being trained and evaluated in unit flying at the fast pace expected in the first crucial days of an armed conflict. Flying 2 to 3 sorties a day for a week or more resulted in reports of only moderate fatigue. Daily fatigue was ameliorated by a night of quality sleep. During a 10 hour airborne command post mission, crew fatigue was moderate and not suggestive of compromises in performance. After mission completion, severe levels of fatigue were reported. Author

N84-21076# Bergen Univ. (Norway).
ATTENTION, PERFORMANCE, AND SUSTAINED ACTIVATION IN MILITARY AIR TRAFFIC CONTROLLERS
H. URSIN, S. GRAHNSTEDT, I. HANSEN, K. MYHRE, P. K. OPSTAD, B. WALTHER, and H. ANDERSEN (Inst. of Aviation Medicine) *In* AGARD Sustained Intensive Air Operations 10p (SEE N84-21062 11-52) Nov. 1983 refs Prepared in cooperation with the Norwegian Defense Research Establishment, Kjeller (Norway)
Avail: NTIS HC A10/MF A01

Trained military air traffic controllers report increased anxiety following, and demonstrate increased heart rate and urinary levels of epinephrine during a session of ground control interception. This type of activation has no detrimental effects on health, and is probably necessary for efficient performance even in well trained and coping personnel. There was also some rise in plasma levels of cortisol, but no other endocrine signs of any general activation. However, if the coping potential of the men is threatened, in a real life situation, the activation picture is expected to be totally different, with a general activation which is far more taxing both on the information treating capacity and on the brain biochemistry. Psychological defense mechanisms will then be activated, which also impede performance. These psychological and physiological mechanisms are difficult to mimic, and occur only when the individual feels a real danger and threat to his or her coping potential. Author

N84-21077# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).
SUSTAINED PHYSICAL ACTIVITY IN DIVERSE SITUATIONS: METABOLIC AND HORMONE DATA [L'AVTIVITE PHYSIQUE SOUTENUE DANS DIVERSES SITUATIONS DONNEES METABOLIQUES ET HORMONALES]
P. C. PESQUIES and C. Y. GUEZENNEC *In* AGARD Sustained Intensive Air Operations 8p (SEE N84-21062 11-52) Nov. 1983 refs In FRENCH
Avail: NTIS HC A10/MF A01

Physical activity undergone or repeated during more than three hours, at a level corresponding to more than 50% of VO2 maximum, involves a hormonal table characterized by an elevation of cortisol and a lowering of testicular androgens. The intimate mechanisms which led to this hormonal table, characterized by an antagonism between the catabolic and anabolic hormones as well as the consequences of the metabolism is demonstrated in studies of white Wistar rats. The regulation of metabolism during environmental constraints encountered by military personnel is discussed with emphasis on physical exercises, exposure to cold, and deprivation of food. A.R.H

N84-21078# Centre d'Essais en Vol, Bretigny-Air (France). Lab de Medecine Aerospatiale.
THERMAL CONSTRAINTS IN A HELICOPTER DURING LONG DURATION FLIGHTS UNDER EXTREME CLIMATIC CONDITIONS [CONTRAINTES THERMIQUES EN HELICOPTERE AU COURS DES VOLS DE LONGUE DUREE EN AMBIANCES CLIMATIQUES EXTREMES]
C. BOUTELIER, E. MAURICE, C. LEFIEVRE, and G. GUERIN *In* AGARD Sustained Intensive Air Operations 7p (SEE N84-21062 11-52) Nov. 1983 refs In FRENCH
Avail: NTIS HC A10/MF A01

The physiological and psychophysiological effects of extreme climatic conditions on helicopter crews were observed and analyzed. It is concluded that the operational efficiency of flight crews can be obtained by adopting four measures: (1) preliminary acclimatization of the crews; (2) limitation of hours of flight with a possibility for rest between flights in a climatized environment; (3) improvement of the comfort and ergonomics of the pilot station; and (4) improvement of equipment and a partial or total individual acclimatization. A.R.H.

N84-21079# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
WORKLOAD OF PERSONNEL ENGAGED IN AIR DEFENCE
R. G. BORLAND and A. S. ROGERS *In* AGARD Sustained Intensive Air Operations 6p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

Workload is defined in many ways and the methods employed to quantify workload are a legion. Jahns (1972) suggested the subject should be divided into the three broad areas of input load, operator effort and work result, while Hartman (1961) has defined input load as the sum of all requirements imposed on an operator at any instant by the system. In the past it was common practice to limit the system to the local environment or crew station and to consider the engineerings, physiological and psychological factors affecting the operator, and little attention was given to studying the workload imposed by the daily pattern of work and rest, for as Selye (1974) points out, stress is a reasonably normal component in every day life and can be adaptive, but cumulative stress becomes maladaptive and ultimately then stress becomes distress. The three studies reported were designed to establish the normal pattern of work and rest of selected personnel from operational units engaged in air defense and to identify possible areas of high workload or stress. R.J.F.

N84-21080# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
HUMAN FACTORS OF AIR OPERATIONS IN THE SOUTH ATLANTIC CAMPAIGN
J. A. BAIRD (Royal Air Force Strike Command) and A. N. NICHOLSON *In* AGARD Sustained Intensive Air Operations 4p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

The role of human factors engineering in the management of the invasion of the Falkland Islands by the United Kingdom in April 1982 is discussed. Sorties of very long duration and intensive rates of work were two particular problems that were studied. During the South Atlantic Campaign advice on human factors proved of great significance in determining the frequency of sorties and the number of sorties flown by each crew. Flight Supervisors were given clear directives about crew scheduling and flight medical officers monitored all aircrew. The aircrew on Ascension Island were given priority for accommodation to ensure good rest facilities and their feeding was closely supervised. Hypnotics were extensively used for the first time with very beneficial results. A total of some 1,000 RAF aircrew were involved in Operation

Corporate and morale and motivation remained at a very high level throughout the campaign. R.J.F.

N84-21081# Institut fuer Wehrmedizin und Hygiene, Koblenz (West Germany). Physiology and Ergonomics Div.
SUSTAINED MILITARY OPERATIONS WITH PARTICULAR REFERENCE TO PROLONGED EXERCISE
G. KLEINHANSS and G. SCHAAD *In* AGARD Sustained Intensive Air Operations 8p (SEE N84-21062 11-52) Nov. 1983 refs
Avail: NTIS HC A10/MF A01

The effects of sleep deprivation and intense work are studied in the context of military operations. Motivation was found to be an important factor in task performance. R.J.F.

N84-21082# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
NON-INVASIVE METHODS OF CARDIOVASCULAR EXPLORATION IN AEROSPACE MEDICINE
R. CARRE (Centre Principal d'Expertise Medicale du Personnel Navigant de l'Aeronautique), R. AMORETTI, A. COIGNARD, J. COLIN, A. DIDIER, J. DRONIOU, J. F. GAILLARD, C. HILTENBRAND, H. ILLE, P. LANTRADE et al. Loughton, England Dec. 1983 213 p refs
(AGARD-AG-277(E); ISBN-92-835-1464-5; AD-A138965) Avail: NTIS HC A10/MF A01

Noninvasive methods of cardiography used in determining flight fitness for flight personnel were examined. These methods include standard electrocardiogram and cardiac radiography analysis of heart abnormalities, continuous electrocardiograph monitoring, study of ventricular pre-excitations syndromes, X ray fluorescence of the cardiovascular system, and information on the exercise electrocardiogram. The merits of each technique as it applies to aerospace medicine in general and flight crew fitness in particular is discussed. For individual titles, see N84-21083 through N84-21097.

N84-21083# Centre Principal d'Expertises Medicales du Personnel Navigant de l'Aeronautique, Paris (France).
MAIN ELECTROCARDIOGRAPHIC ABNORMALITIES IN THE MEDICAL EXAMINATION OF FLYING PERSONNEL
R. CARRE, A. DIDIER, and H. ILLE *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 1-12 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The electrocardiographic tests that qualify flight personnel for duty on very high performance aircraft were examined. Tests included electro-cardiographic recordings for certain arrhythmias, right and left bundle blockage or deviation, Wolff-Parkinson-White syndrome, atypical ventricular repolarization, and sequella of myocardial infarctus. The significance of each disorders as it applies to flight personnel was discussed. M.A.C.

N84-21084# Hopital d'Instruction des Armees, Paris (France).
VENTRICULAR PRE-EXCITATION SYNDROMES
J. DRONIOU *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 13-24 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

Ventricular Pre-Excitation (VPE) syndrome in flight personnel was discussed. Current understanding of the disorder as well as diagnosis, prognosis, classification, and mechanisms of the disease as it applies to flight personnel was presented. Electro cardiographs detailing characteristic tachyarrhythmias of the syndrome were included. M.A.C.

N84-21085# Hopital d'Instruction des Armees, Versailles (France).
THE EXERCISE ELECTROCARDIOGRAM
G. LEGUAY and A. SEIGNEURIC *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 25-63 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The use of the exercise electrocardiogram (EECG) in the determination of physical fitness was thoroughly discussed. Factors effecting the results of the EECG such as maximum oxygen consumption, cardiac output, and basic techniques of EECG use were presented. A comparison between a normal EECG and that of a graph showing coronary failure was included. The EECG must be interpreted by taking into account the intensity of exertion, nature of the ST shift, HRxBP product, age, sex, and risk factor such as smoking or hypertension. In an asymptomatic population such as military personnel, the EECG cannot be used as a reliable means of mass screening for coronary failure. M.A.C.

N84-21086# Hopital d'Instruction des Armees, Versailles (France).
CONTINUOUS ECG MONITORING BY THE HOLTER METHOD
G. LEGUAY and A. SEIGNEURIC *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 65-81 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The Holter method of continuous electrocardiograph (ECG) recording in the active subject was discussed with primary focus on heart arrhythmias and repolarization disorders. The technical aspects of the recorder, lector, and computer were examined. The method aids in the indication of antiarrhythmic medication efficiency, including the speed and duration of drug action. Continuous ECG recording allows close monitoring of coronary artery disease treatment and patients with heart pace makers. M.A.C.

N84-21087# Hopital d'Instruction des Armees, Versailles (France).
THE HOLTER METHOD IN AERONAUTICAL MEDICINE
G. LEGUAY and A. SEIGNEURIC *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 83-86 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The Holter method was discussed as a means of monitoring pilot and flight crew cardiac performance during all the operations of different mission types. Emphasis was placed on fighter pilots subject to extreme accelerations and transport aircraft crews effected by circadian rhythm disruption. The Holter method could provide information on inflight malaises, cardiac tolerance, and flight adaptation that would contribute to air safety. M.A.C.

N84-21088# Centre Principal d'Expertises Medicales du Personnel Navigant de l'Aeronautique, Paris (France).
CONTRIBUTION OF STANDARD X-RAY TO CARDIOVASCULAR EXPLORATION DURING THE CLINICAL EXAMINATION OF FLYING PERSONNEL
M. PUECH and P. J. METGES (Hopital d'Instruction des Armees, Saint Mande, France) *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 87-92 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The use of teleradiography and televised fluoroscopy in the cardiovascular examinations of flight personnel was discussed. Heart fluoroscopy allows analysis of the shape and dynamic features of the heart cavities, aorta, and the pulmonary arteries. Normal heart anatomy and physiology was described and compared with minor abnormalities found in flight crews. Four position teleroentgenography and televised fluoroscopy remain the usual methods for the analysis and kinetic investigation of the cardiovascular silhouette and pulmonary vascularisation and are now also part of the battery of tests used to assess flight fitness. M.A.C.

N84-21089# Centre Principal d'Expertises Medicales du Personnel Navigant de l'Aeronautique, Paris (France).
CONTRIBUTION OF CARDIAC MECHANOGRAMS IN THE EXPERT EXAMINATION OF FLYING PERSONNEL
R. CARRE, R. AMORETTI, A. DIDIER, and H. ILLE *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 93-112 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

Non-invasive cardiac mechanograms are easily reproducible at each examination and provide recordings which can be added to the pilot's medical record and compared from one examination to another. Cardiac mechanograms provide three types of information: (1) analysis of cardiac murmurs, determining the type of heart disease on the basis of phonocardiography; (2) study of arterial distension from the carotid pulse cardiogram; and (3) chronocardiographic determinations based on the systolic time intervals which give some idea of the contraction of the myocardial muscle. Techniques for the analysis of various murmurs, aortic

stenosis, mitral defect, pulmonary stenosis, and aortic coarctation are described. M.G.

N84-21090# Hopital d'Instruction des Armees, Paris (France).
ECHOCARDIOGRAPHY IN THE EXPERT EXAMINATION OF FLYING PERSONNEL
J. DRONIOU and A. COIGNARD *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 113-142 (SEE N84-21082 11-52) Dec. 1983
Avail: NTIS HC A10/MF A01

The technical principles of echocardiography are reviewed and the various types and imaging capabilities are described. The use of echocardiography in the detection and analysis of pathological heart conditions is discussed. Finally, the practical modalities of the application of echocardiography to the expert examination of flying personnel are considered. M.G.

N84-21091# Centre Principal d'Expertises Medicales du Personnel Navigant de l'Aeronautique, Paris (France).
EXPLORATION OF ARTERIAL FUNCTION USING DOPPLER FLOW DETERMINATION. APPLICATION TO AERONAUTICAL AND SPACE MEDICINE
A. DIDIER, H. ILLE, C. RIBADEAU-DUMAS, P. LANTRADE, and C. HILTENBRAND *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 143-156 (SEE N84-21082 11-52) Dec. 1983 refs Prepared in cooperation with Hopital d'Instruction des Armees, Paris
Avail: NTIS HC A10/MF A01

The instrumentation and capabilities of continuous and pulse emission arterial dopplerography are discussed. The Doppler ultrasonic determination of the blood flow rate makes use of the Doppler-Fizeau principle by determining the change of frequency of an ultrasonic beam directed onto the vessel under study. The beam is reflected by solid elements within the blood, the flow rate of which is the same as that of the bloodstream as a whole. The change of frequency is a function of the blood flow but also of the angle (theta) of incidence at which the ultrasonic beam strikes the vessel. The data obtained is in the form of a velocity and its exact determination depends on knowing the angle theta. Calculation of the blood flow rate depends on determination of the cross-section of the vessel. The accuracy of the data obtained and the total lack of risk of the method suggests that it should have a place in aeronautical and space medicine, in the medical examination of flying personnel and the investigation of physiological changes of arterial flow in the body during aeronautical and space pressures. M.G.

N84-21092# Hopital d'Instruction des Armees, Paris (France).
THE CONTRIBUTION OF NUCLEAR MEDICINE TO CARDIOLOGY
J. F. GAILLARD *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 157-164 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

Isotopic methods of exploration have developed greatly over the last twenty years and now constitute important complementary cardiological examinations. In 1948 PRINZMETAL introduced the radiocardiogram by external detection recording of the dilution curve of a radioactive indicator in the cardiac cavities. In 1964 CARR introduced static scintigraphy, followed by a link-up of the gamma camera to a computer which from the 1970's made possible the development of rapid dynamic investigations and computer-processing of the image obtained. Recently gamma or positron emission tomography has provided results in detailed studies of the vascularization and metabolism of the myocardium. Isotopic methods provide information which was generally not available previously except by means of invasive radiological explorations using contrast media and recently by ultra-sound. The non-invasive functional investigation of an organ is the main contribution of nuclear medicine. The possibility of quantifying organ function, of describing it by means of graphs, diagrams and image remains unrivalled. The contribution of nuclear medicine to the examining expert is important because of the non-invasive nature of most of the methods. Author

N84-21093# Rome Univ. (Italy). School of Aerospace Medicine.
HALLISTOCARDIOGRAPHY: A NON-INVASIVE METHOD ADVANCING TOWARDS CLINICAL APPLICATION
A. SCANO *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 165-170 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The evolution of ballistocardiographic (BCG) methods is reviewed. Ballistocardiography can be defined as a non-invasive method of recording and studying periodic accelerations of the body mass due to the inertia reaction it presents at every ventricular systole. The typical sequence of waves which constitutes the BCG tracing differs quantitatively according to the bodily axis (the ones recorded along the longitudinal axis are generally more ample), according to the state of rest or physical exercise, the age and pathological conditions of the heart and/or the large arterial vessels. Specific applications are discussed. M.G.

N84-21094# Centre de Recherches du Service de Sante des Armees, Clamart (France).
USE OF CHANGES IN ELECTRICAL IMPEDANCE IN CARDIOLOGY
J. COLIN *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 171-179 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The investigation of variations of electrical impedance is of particular value amongst the non-invasive methods used in physiological and clinical study of heart function because of the absence of risk, ease of the procedure and the possibility of repeating determinations or carrying out continuous determinations over long periods. The physical bases of the method of determining electrical impedance are reviewed along with the required instrumentation. The analytic capabilities of thoracic, aortic, and cardiac plethysmography are discussed. M.G.

N84-21095# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).
VALUE OF THE TILT TABLE IN THE EXPLORATION OF CIRCULATORY FUNCTION
J. TIMBAL *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 183-187 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

Any change of position from the inclined to the upright position or vice versa results in important hemodynamic changes which result mainly from the rapid transfer of part of the total blood from one territory to another. The value of this type of maneuver in exploring circulatory system functions is discussed. The tilt table makes it possible to standardize observation conditions and to eliminate any muscular effect. If properly carried out, the method provides a passive orthostatic or antiorthostatic test. In practice, it is the orthostatic tests which are most commonly used in both functional exploration during the selection or medical check up of aeronautical teams and for more fundamental research. Antiorthostatic tests have been used particularly in the Soviet Union for the selection of cosmonauts. The short term effects of passage from the horizontal to the vertical position are considered. M.G.

N84-21096# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
VALUE OF THE LOWER BODY NEGATIVE PRESSURE TEST IN AEROSPACE MEDICINE
B. VETTES and H. VIELLEFOND *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 189-192 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The lower body negative pressure (LBNP) test is of two-fold interest in aerospace medicine. First, it provides an excellent method for investigation of the cardiovascular and respiratory changes associated with weightlessness and secondly it provides a method of preventing these problems during flight. The daily use of the LBNP during a period of one month of total bedrest is very effective in preventing the loss of plasma, reducing the increase in heart rate and maintaining the cardiac index at a more satisfactory level during the LBNP. It is therefore not surprising that use of the LBNP has been extended to the training of

astronauts and to the prevention of the severe orthostatic syndromes which occur after a return from a mission. However, aeronautical medicine can also benefit from the lower body negative pressure test not only as a clinical orthostatic test but especially as a means of investigating cardiovascular adaptation capacity to the positive longitudinal accelerations known as + Gz. The physiopathological disturbance produced by + Gz accelerations are of vascular origin and the mechanism by which they occur is fairly similar to that underlying LBNP. M.G.

N84-21097# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
METHODS AND MAJOR FINDINGS OF CARDIOVASCULAR EXPLORATION INVOLVING THE HUMAN CENTRIFUGE
B. VETTES and H. VIEILLEFOND *In* AGARD Non-Invasive Methods of Cardiovascular Exploration in Aerospace Med. p 193-201 (SEE N84-21082 11-52) Dec. 1983 refs
Avail: NTIS HC A10/MF A01

The cardiovascular effects of accelerations as produced by human centrifuge experiments are discussed. Particular attention is given the evasive and non-evasive techniques used to monitor heart rate, arterial pressure, venous pressure, cardiac output, and local blood flow. The use of visual field criteria as a way of assessing hemodynamic tolerance is also addressed. M.G.

N84-26279# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AEROMEDICAL SUPPORT IN MILITARY HELICOPTER OPERATIONS
Apr. 1984 99 p refs Lecture series held in Soesterberg, Netherlands, 4-5 Jun., Fuerstenfeldbruck, West Germany, 7-8 Jun., and Oslo, 12-13 Jun. 1984
(AGARD-LS-134; ISBN-92-835-1468-8; AD-A145809) Avail: NTIS HC A05/MF A01

The medical aspects of military helicoper operations are discussed. Emphasis is placed on pilot performance and the physiological and psychological stresses that effect flight operations. Visual and acoustic perception is discussed with methods of protection against hazardous environments included. Specifics such as *flight crew back injuries, emergency medical* evacuation, and crash injury analysis are also investigated. For individual titles, see N84-26280 through N84-26289.

N84-26280# Army Aeromedical Research Lab., Fort Rucker, Ala.
AEROMEDICAL SUPPORT IN MILITARY HELICOPTER OPERATIONS
D. R. PRICE *In* AGARD Aeromed. Support in Mil. Helicopter Operations 2p (SEE N84-26279 16-52) Apr. 1984
Avail: NTIS HC A05/MF A01

A comprehensive update for the flight medical officer and other personnel providing aeromedical support for military helicopter operations is given. Areas that are addressed include: stressful missions such as nap-of-the-earth flying, night operations, and operations under other unfavorable circumstances; extended operations, aircrew fatigue, and its monitoring and prevention: visual protection and enhancement; perceptual illusions, their generation and disorienting effects in helicopter flight; acoustical hazards, auditory injury, hearing protection, and communications noise reduction; applied countermeasures for environmental extremes and the chemical warfare environment; helicopter accident and *crash injury analysis; epidemiology, etiology, and prevention of* back pain in helicopter pilots; and helicoper medical evacuation and rescue operations including evacuation of combat casualties. M.A.C.

N84-26281# British Army, Detmold (West Germany). Medical Centre.
STRESSFUL MISSION PROFILES, PART 1
S. J. DURNFORD *In* AGARD Aeromed. Support in Mil. Helicopter Operations 8p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

The stressors in those types of flights that are considered particularly stressful - NOE Nap Of the Earth flying, night flying with and without aids, mountain flying, flight over water, flight in Nuclear, Biological, and Chemical NBC clothing, instructional flying peacetime and flight in adverse weather conditions are described and analyzed. The stressors invoked by these flight profiles are set against the stressors found in all helicopter flying. M.A.C.

N84-26282# British Army, Detmold (West Germany). Medical Centre.
STRESSFUL MISSION PROFILES, PART 2: WORKLOAD AND FATIGUE
S. J. DURNFORD *In* AGARD Aeromed. Support in Mil. Helicopter Operations 8p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

The way that stressors combine with factors within the man *(such as previous training) and the demands of the actual flying* mission to produce an overall workload are investigated. The manner in which different levels of workload may affect performance are discussed and methods that might be used by flight surgeons to reduce aircrew workload levels are covered. The impact of future technology is briefly considered. M.A.C.

N84-26283# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
VISUAL PROBLEMS IN HELICOPTER OPERATIONS
D. H. BRENNAN *In* AGARD Aeromed. Support in Mil. Helicopter Operations 11p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

The importance of ocular physiology, visual standards, transparency optics and cockpit lighting systems in ensuring an adequate level of performance is discussed. Ocular hazards from *impact, nuclear flash, chemical warfare agents and lasers are* discussed and related to the advantages and disadvantages of protective equipment. A review of some of the devices currently available for visual enhancement and the problems associated with their use is included. M.A.C.

N84-26284# German Army, Bueckburg (West Germany). Aviation School.
DISORIENTATION IN HELICOPTER FLIGHT
F. FEHLER *In* AGARD Aeromed. Support in Mil. Helicopter Operations 15p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

The incapacity of the pilot to maintain a safe path of flight due *to inadequate, erroneous or disregarded visual cues is investigated.* The psychological process of visual perceptions is discussed espcially with regard to the differences between optical stimuli *from the surroundings and their subjective perception by the* individual. Emphasis is placed on the fact that the human brain is an active organ and not just a mirror reflecting the visual stimuli *from outside. To minimize disorientation the aviator should have* in mind the basic programs according to which the brain processes visual stimuli, visual configurations which are prone to elicit visual illusions, and means to prevent the onset of disorientation. M.A.C.

N84-26285# German Air Force, Fuerstenfeldbruk (West Germany). Inst. of Aerospace Medicine.
HEARING LOSS ASSOCIATED WITH HELICOPTER FLIGHT
W. NEYE *In* AGARD Aeromed. Support in Mil. Helicopter Operations 9p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

The occurrence and the influence of hearing damages caused by aircraft noise is investigated. In the audiometry tests conducted in the course of examinations for qualification, marked hearing losses in the high frequencies, especially in Army helicoper pilots *are occasionally found. Through a comparative examination an* attempt is made to determine whether higher hearing losses can be observed in helicopter pilots of the Army as compared to pilots of the other Services. Helicoper specific noise characteristics that cause significant hearing losses in pilots, which are more pronounced in Army pilots as compared to pilots of other aircraft types are examined. M.A.C.

N84-26286# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
THERMAL CONTROL PROBLEMS IN MILITARY HELICOPTERS
J. R. ALLAN *In* AGARD Aeromed. Support in Mil. Helicopter Operations 10p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

The origins of thermal problems in military helicopters are discussed and compared with those of fixed wing aircraft. Some

typical helicopter sortie temperature profiles are presented for hot and cold environments. The requirements for protection from chemical warfare agents are described in relation to helicopter operations and the additional thermal problems arising from chemical protective assemblies and drills are described. Potential adverse effects on aircrew performance and fatigue are considered. Thermal hazards in post crash survival situations are also considered particularly those related to ditching in cold water. Various approaches to the relief of thermal stress in helicopter aircrew are considered. The limitation of engine powered environmental control systems and the potential advantages of personal conditioning systems are described. The advantages of liquid conditioned systems are compared with air systems. Cold environment protection is described in terms of insulation and water exclusion and the role of electrically heated garments is described. M.A.C.

N84-26287# Army Safety Center, Fort Rucker, Ala.
MEDICAL ASPECTS OF HELICOPTER SAFETY AND CRASHWORTHINESS
D. F. SHANAHAN *In* AGARD Aeromed. Support in Mil. Helicopter Operations 13p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

A review of the past five years' accident experience reveals that 80 percent are attributed to human error. The relationship of errors to system eficiencies is established through human factors analysis. Once identified, appropriate measures can be instituted to correct these deficiencies. Principles of helicopter crashworthiness are reviewed, and the means for deriving these principles from crash injury analysis is discussed. M.A.C.

N84-26288# Army Safety Center, Fort Rucker, Ala.
BACK PAIN IN HELICOPTER FLIGHT OPERATIONS
D. F. SHANAHAN *In* AGARD Aeromed. Support in Mil. Helicopter Operations 9p (SEE N84-26279 16-52) Apr. 1984 refs
Avail: NTIS HC A05/MF A01

One of the major medical problems associated with military helicopter flight operations is the high prevalence of back pain reported by flightcrews. Epidemiological surveys indicate that up to 75 percent of helicopter flightcrews complain of this affliction and that it is having a significant effect on manpower availability. The two most widely implicated etiological factors in this problem are poor posture dictated by control and seat configurations in most operational helicopters and the chronic vibration to which helicopter flightcrews are subjected. The epidemioloy and etiology of back pain in helicopter aircrews are examined and potential means for treatment and prevention discussed. M.A.C.

N84-26289# Danish Defence Command, Vedbaek. Aeromedical Services.
AEROMEDICAL SUPPORT OF HELICOPTER MEDICAL EVACUATION AND RESCUE OPERATIONS
K. JESSEN *In* AGARD Aeromed. Support in Mil. Helicopter Operations 5p (SEE N84-26279 16-52) Apr. 1984
Avail: NTIS HC A05/MF A01

Factors effecting medical evacuation and rescue operations by helicopter are investigated. The importance of proper training of the flight and medical crews is emphasized. An evaluation of appropriate medical equipment is included along with a listing of most frequency encountered medical emergencies. Flight stress on the patient is also examined. M.A.C.

N84-33011# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
OCCUPATIONAL MEDICINE RELEVANT TO AVIATION MEDICINE
Loughton, England May 1984 74 p refs In ENGLISH and FRENCH Symp. held in London, 4 Oct. 1983
(AGARD-CP-341; ISBN-92-835-0354-6; AD-A146458) Avail: NTIS HC A05/MF A01

Laser effects, toxicology, and vision problems are addressed. Among the specific topics considered are: occupational medicine; the biological and pathological effects of hydrazine; the toxicity of combustion products; the relationship among ethyl alcohol consumption, nystagmus, and the balance mechanism of the inner ear; cathode ray tubes and visual perception; laser safety; and laser damage to the eye. For individual titles, see N84-33012 through N84-33019.

N84-33012# Philips Medical Service, Eindhoven (Netherlands).
REVIEW OF OCCUPATIONAL MEDICINE RELEVANT TO AVIATION MEDICINE
H. ZUIDEMA *In* AGARD Occupational Med. Relevant to Aviation Med. 6 p (SEE N84-33011 22-52) May 1984
Avail: NTIS HC A05/MF A01

The aim and scope of occupational medicine are reviewed. The conditions required to practice occupational medicine are also considered. The following specific topics are addressed: occupational health care of the individual worker, occupational hygiene, and ergonomics. The preventive character of occupational medicine is emphasized. Aviation medicine is a subcategory of occupational medicine. R.S.F.

N84-33013# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
HYDRAZINE TOXICOLOGY: IMPACT ON SAFETY AND HEALTH IN MILITARY AVIATION
G. C. MOHR *In* AGARD Occupational Med. Relevant to Aviation Med. 4 p (SEE N84-33011 22-52) May 1984 refs
Avail: NTIS HC A05/MF A01

Hydrazine is a chemical of considerable military interest widely used as a rocket fuel and as a propellant for gas turbine generators. Extensive studies of the acute and chronic toxicity of hydrazine were conducted previously. The protocol used for toxicological evaluation of potentially hazardous chemicals is described briefly; pertinent data on acute effects are summarized; and the results of a large scale oncogenic evaluation are reviewed. Currently accepted guidelines for occupational medical management in the workplace are presented. Author

N84-33014# Danish Defence Command, Copenhagen. Medical Services.
HANDLING OF HYDRAZINE IN THE ROYAL DANISH AIR FORCE
K. JESSEN and S. TRAUTNER *In* AGARD Occupational Med. Relevant to Aviation Med. 4 p (SEE N84-33011 22-52) May 1984
Avail: NTIS HC A05/MF A01

The introduction of the F-16 fighter aircraft into the Royal Danish Air Force included the introduction of hydrazine as a propellant for the emergency power unit (EPU). The EPU and hydrazine are discussed briefly. The pathological effects of hydrazine exposure are reviewed along with environmental safety regulations extant in the Danish Air Force. A health examination program designed to collect baseline medical data is outlined. Three case histories of hydrazine accidents are presented. R.S.F.

N84-33015# Laboratoire Central de Biologie Aerospatiale, Paris (France). Div. de Chimie-Toxicologie.
A COMPARATIVE STUDY IN THE ANIMAL OF THE TOXICITY OF THE COMBUSTION PRODUCTS OF DIVERSE MATERIALS [ETUDE COMPARATIVE CHEZ L'ANIMAL DE LA TOXICITE DES PRODUITS DE THERMOLYSE DE DIVERS MATERIAUX]
J. P. DELCROIX and M. GUERBET *In* AGARD Occupational Med. Relevant to Aviation Med. 14 p (SEE N84-33011 22-52) May 1984 refs In FRENCH
Avail: NTIS HC A05/MF A01

Materials with minimal toxicity must be chosen in case of fire in an enclosed space and, more particularly, onboard aircraft. An analytical study of atmospheric products is not sufficient for evaluating the risks encountered. There must be experimentation with animals. A methodology was created which associates an original model fire and a protocol for exposing animals to toxic gas products in order to study the response to aggression of the entire organism with its susceptabilities and reactions. Objective toxicological criteria are proposed with a view towards establishing a classification of materials according to chosen danger criteria. Transl. by A.R.H.

N84-33016# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
AN UNUSUAL TOXICOLOGICAL PROPERTY OF ALCOHOL: THE DENSITY EFFECT ON THE ORGAN OF BALANCE
K. E. MONEY and J. P. LANDOLT *In* AGARD Occupational Med. Relevant to Aviation Med. 8 p (SEE N84-33011 22-52) May 1984 refs
Avail: NTIS HC A05/MF A01

The relationship among ethyl alcohol consumption, nystagmus, and the balance mechanism of the inner ear was investigated with particular concern for pilot performance during positional alcohol nystagmus (PAN). The following questions were addressed experimentally: (1) does simultaneous ingestion of heavy water with alcohol prevent the occurrence of the first phase of PAN; (2) does the second phase of PAN appear if the first phase is prevented; (3) is the second phase prolonged if the blood alcohol level is held high for a long time; and (4) does glycerol, which is denser than water, cause positional nystagmus. Nystagmus was recorded using electronystagmography. Results show that it is possible for the second phase of PAN to persist beyond 11 hours after the cessation of drinking. The cause of the second phase of PAN appears to be the presence of alcohol in the semicircular canals of the inner ear. R.S.F.

N84-33017# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).
VISUAL PERCEPTION IN SYSTEMS MANAGEMENT IN AERONAUTICS [LA PERCEPTION VISUELLE DANS LES CONDUITES DE SYSTEME EN AERONAUTIQUE]
J. P. MENU, G. SANTUCCI, and R. AMALBERTI *In* AGARD Occupational Med. Relevant to Aviation Med. 7 p (SEE N84-33011 22-52) May 1984 refs In FRENCH
Avail: NTIS HC A05/MF A01

Informatics is present in all domains of activity and especially in aeronautics where the cathode ray tube is the preferred mechanism for presenting information. Visual perception thus attracted is analyzed under its diverse aspects. How the physical characteristics of the access stimuli are measured is described and mechanisms for information processing are then examined. A method is presented for evaluating the operator's capabilities for integrating preceeding information. Transl. by A.R.H.

N84-33018# Bundesministerium der Verteidigung, Bonn (West Germany).
EVALUATION AND CONTROL OF LASER HAZARDS
G. HOLTRUP *In* AGARD Occupational Med. Relevant to Aviation Med. 4 p (SEE N84-33011 22-52) May 1984
Avail: NTIS HC A05/MF A01

International agreements on laser safety are summarized and the laser safety regulations valid for the West German military forces are presented. Laser materials and their associated output wavelengths are enumerated. Problems which arise from airborne laser operations are discussed along with the development of eye-safe lasers. R.S.F.

N84-33019# Centre de Recherches du Service de Sante des Armees, Clamart (France).
VISUAL FUNCTION AND THE DEFINITION OF THRESHOLDS FOR EXPOSURE TO LASER RADIATION [LA FONCTION VISUELLE ET LA DEFINITION DES SEUILS D'EXPOSITION AU RAYONNEMENT LASER]
L. COURT, D. COURANT, G. SANTUCCI (CERMA), J. P. CHEVALERAUD, and G. PERDRIEL (Service de Sante des Armees) *In* AGARD Occupational Med. Relevant to Aviation Med. 17 p (SEE N84-33011 22-52) May 1984 refs In FRENCH
Avail: NTIS HC A05/MF A01

Dangers presented by the use of lasers and more particularly those related to laser radiation are essentially due to eye impairment. If determination of the maximum value of exposure requires precise knowledge of the physical parameters and associated biological effects, the influence of laser beams on visual function should be evaluated in the dynamic perspective of sensory physiology. The threshold must express the limit value of a relation existing between the energy and/or the power dissipated in the exposed biological structure and the appearance of the smallest functional impairment or a detectable lesion capable of involving damage. This definition introduces two concepts, the choice of criteria, reversible or irreversible impairment, and the measurement, of the associated energy exchange. It thus appears that biological and physical parameters constitute a whole of which the elements react on each other in a complex dynamic. Their descriptions, the definition and criteria, and experimental results illustrate the difficulties encountered in analyzing functional impairment and in determining the exposure limits as well as call to mind the uncertainty of actual norms. Transl. By A.R.H.

N85-20642# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
MOTION SICKNESS: MECHANISMS, PREDICTION, PREVENTION AND TREATMENT
Loughton, England Nov. 1984 174 p refs In ENGLISH and FRENCH Symp. held in Williamsburg, Va., 3-4 May 1984 (AGARD-CP-372; ISBN-92-835-0369-4; AD-A152548) Avail: NTIS HC A08/MF A01

Motion sickness continues to be a significant operational problem in the armed forces of the NATO countries. Space motion sickness has emerged as a major operational concern in the short duration space shuttle flights, with nearly 50% of all crew members experiencing some symptoms. Recent developments in understanding etiological factors contributing to air, sea, car, simulator and space sickness are reported. Neurological mechanisms mediating motion sickness are identified, predictive tests of susceptibility are discussed, and the prevention and treatment of motion sickness are addressed. Laboratory findings are identified which can be incorporated into programs for alleviating motion sickness under operational conditions. For individual titles see N85-20643 through N85-20660.

N85-20643# Rockefeller Univ., New York.
NEUROPHYSIOLOGICAL CORRELATES OF MOTION SICKNESS: ROLE OF VESTIBULOCEREBELLUM AND 'VOMITING CENTER' REANALYZED
A. D. MILLER and V. J. WILSON *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 5 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Unexpected findings were obtained regarding the role of the nodulus and uvula of the vestibulocerebellum in vestibular-induced vomiting and the existence of a readily identifiable, discretely localized vomiting center. Sinusoidal electrical stimulation of the vestibular labyrinths of decerebrate cats could produce vomiting and related activity similar to that observed during motion sickness. These symptoms occurred in animals with lesions of the posterior cerebellar vermis that included the nodulus and uvual, indicating, by analogy, that these structures are not essential for the development of many symptoms of motion sickness in intact animals. Electrical stimulation of the brainstem was used in an attempt to localize a vomiting center to a restricted anatomical region. Vomiting proved difficult to produce; a vomiting center, stimulation of which evoked readily reproducible results, could not be identified. R.S.F.

N85-20644# Brandeis Univ., Waltham, Mass. Spatial Orientation Lab.
INFLUENCE OF GRAVITOINERTIAL FORCE LEVEL ON APPARENT MAGNITUDE OF CORIOLIS CROSS-COUPLED ANGULAR ACCELERATIONS AND MOTION SICKNESS
J. R. LACKNER and A. GRAYBIEL *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 7 p (SEE N85-20642 11-52) Nov. 1984 refs Prepared in cooperation with Naval Air Station, Pensacola, Fla.
Avail: NTIS HC A08/MF A09

The Skylab astronauts showed a great decrease in susceptibility to motion sickness during exposure to Coriolis cross-coupled angular accelerations when tested in orbital flight. In order to determine whether this decreased susceptibility is related entirely to adaptation or in part to changes in vestibular and function, subjects were tested in the free fall and high force phases of parabolic flight maneuvers. Susceptibility to motion sickness during Coriolis stimulation as a function of force level and the perceived intensity of Coriolis cross-coupled angular accelerations as a function of force level were measured. Subjects exhibited fewer and less severe symptoms of motion sickness when tested in free fall than they did for the same Coriolis stimulation in 1G. They exhibited much earlier and more severe symptoms when

tested in 2G. They exhibited much earlier and more severe symptoms when tested in 2G. It is concluded that part of the Skylab astronauts' inflight decrease in susceptibility to Coriolis stimulation was related to alterations in vestibular and sensorimotor control that occur immediately during exposure to microgravity force levels. R.S.F.

N85-20645# University Hospital, Copenhagen (Denmark).
VESTIBULAR AND OCULOMOTOR FUNCTION DURING GZ VARIATIONS
S. VESTERHAUGE, A. MANSSON, and T. S. JOHANSEN *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 5 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Ten normal subjects were exposed to G-force variations during parabolic flights and turns in a SAAB Supporter aircraft. A vertical head drift accompanied by a vertical eye drift was recorded in all subjects. The eye drift was most prominent during the hyper-G phase of the parabolic manoeuvres. Compensatory eye movements were induced by horizontal head rotations. No statistical significant changes could be demonstrated in this reflex. Horizontal oculomotor saccades were induced with a visual distance of + or 10 deg. A significant increase of the latency time could be demonstrated during the weightless phase of the parabolas. It is concluded that spontaneous eye and head drift and disturbances in voluntary eye movements might contribute to the development of motion sickness during combat maneuvers and space flight. R.S.F.

N85-20646*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
PREDICTION OF THE SPACE ADAPTATION SYNDROME
M. F. RESCHKE, J. L. HOMICK, P. RYAN, and E. C. MOSELEY *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 19 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

The univariate and multivariate relationships of provocative measures used to produce motion sickness symptoms were described. Normative subjects were used to develop and cross-validate sets of linear equations that optimally predict motion sickness in parabolic flights. The possibility of reducing the number of measurements required for prediction was assessed. After describing the variables verbally and statistically for 159 subjects, a factor analysis of 27 variables was completed to improve understanding of the relationships between variables and to reduce the number of measures for prediction purposes. The results of this analysis show that none of variables are significantly related to the responses to parabolic flights. A set of variables was selected to predict responses to KC-135 flights. A series of discriminant analyses were completed. Results indicate that low, moderate, or severe susceptibility could be correctly predicted 64 percent and 53 percent of the time on original and cross-validation samples, respectively. Both the factor analysis and the discriminant analysis provided no basis for reducing the number of tests. R.S.F.

N85-20647# Institute for Perception RVO-TNO, Soesterberg (Netherlands).
PREDICTION OF SEASICKNESS SUSCEPTIBILITY
W. BLES, H. A. A. DEJONG (Academic Medical Centre, Amsterdam), and W. J. OOSTERVELD (Academic Medical Centre, Amsterdam) *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 6 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Thirty-nine subjects, suffering from chronic seasickness, and 21 controls were submitted to several tests in order to find parameters for the prediction of seasickness susceptibility. Routine electronystagmography examination revealed a labyrinthine predominance of more than 30% with caloric irrigation in about 15% of the seasickness susceptibles, suggesting a higher incidence of chronic motion sickness susceptibility in subjects with a labyrinthine imbalance than in normals. Cupulometry revealed identical slopes of the sensation cupulogram for both groups. No difference in slope was found for the nystagmus cupulogram either. The time constant of the 'velocity storage mechanism' also covered the same range for both groups. Stabilometry performed in a tilting room suggested that seasickness susceptibles are more visually oriented than the controls as revealed by the visually induced postural instability. R.S.F

N85-20648# Naval Aerospace Medical Research Lab., Pensacola, Fla.
LABORATORY TESTS OF MOTION SICKNESS SUSCEPTIBILITY
J. M. LENTZ *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 9 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Five laboratory tests of motion sickness susceptibility that were evaluated over the years at the Naval Aerospace Medical Research laboratory in Pensacola are reviewed. These tests, involving Coriolis stimuli, off-vertical rotation, visual/vestibular interactions, were developed with the objective of predicting individual susceptibility to airsickness and space sickness. Individual tests which are discussed include: brief vestibular disorientation test, coriolis sickness susceptibility test, sudden-stop vestibulovisual test, tilted-axis rotation test, and the visual/vestibular interaction test. B.G.

N85-20649# Naval Aerospace Medical Research Lab., Pensacola, Fla.
RESULTS OF A LONGITUDINAL STUDY OF AIRSICKNESS INCIDENCE DURING NAVAL FLIGHT OFFICER TRAINING
W. C. HIXSON, F. E. GUEDRY, JR., and J. M. LENTZ *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 13 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

The results of a longitudinal study of airsickness in a large sample population of Naval Flight Officers (NFOs) being trained to perform various nonpilot flighty duties prior to assignment to operational fleet squadrons are outlined. The acquisition of airsickness data on an individual student basis was stressed as training progressed from the basic/primary level through the advanced/secondary level to the fleet readiness squadron phase for each of the major NFO training pipelines. The primary objectives were to define the incidence of airsickness in each of the training squadrons and to identify differences in the motion stress exposure associated with the different pipelines that can affect decisions on the initial selection and assignment of NFO candidates. A secondary objective was to relate the inflight airsickness data to the results of several short tests of motion reactivity given to a segment of the study population prior to their beginning flight training. Author

N85-20650*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
SUSCEPTIBILITY OF CAT AND SQUIRREL MONKEY TO MOTION SICKNESS INDUCED BY VISUAL STIMULATION: CORRELATION WITH SUSCEPTIBILITY TO VESTIBULAR STIMULATION
N. G. DAUNTON, R. A. FOX (San Jose State Univ., Calif.), and G. H. CRAMPTON (Wright State Univ., Dayton, Ohio) *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 5 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Experiments in which the susceptibility of both cats and squirrel monkeys to motion sickness induced by visual stimulation are documented. In addition, it is shown that in both species those individual subjects most highly susceptible to sickness induced by passive motion are also those most likely to become motion sick from visual (optokinetic) stimulation alone. Author

N85-20651# Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge (France).
SUSCEPTABILITY TO KINETOSES AND THE AMPLITUDE PERCEIVED FROM SENSORY ILLUSIONS [SUSCEPTIBILITE AUX CINETOSES ET AMPLITUDE PERCUE DES ILLUSIONS SENSORIELLES]
A. LEGER *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 10 p (SEE N85-20642 11-52) Nov. 1984 refs In FRENCH
Avail: NTIS HC A08/MF A01

Coriolis accelerations provoked by the starting and stopping of a centrifuge entail a strong illusory sensation of angular displacement. The amplitude of these sensations was studied in

two groups of subjects who were either receptive or nonreceptive to motion sickness. The axes of application of the load factor was varied with respect to the head. Considerable differences of amplitude were noticed between the two groups for the series of protocols studied. The orientation of the load factor strongly influences the appearance of the kinetosis syndrome.
Transl. by A.R.H.

N85-20652# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).
PREFLIGHT AND POSTFLIGHT MOTION SICKNESS TESTING OF THE SPACELAB 1 CREW
K. E. MONEY, D. G. WATT (McGill Univ., Montreal, Quebec), and C. M. OMAN (Massachusetts Inst. of Tech., Cambridge) *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 8 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

The Four Spacelab 1 payload crew members, as experimental subjects, were exposed to a variety of motion sickness tests. Contrary to expectation, the crew member who was most susceptible to these tests was the least susceptible to space motion sickness, and the crew member who was most susceptible to space motion sickness was one of the least susceptible to these tests. On the third day after returning from the mission, one of the preflight tests (KC 135) was repeated, and all of the crew members were found to be non-susceptible. Statements of generalities will have to wait for the accumulation of more experimental subjects. Author

N85-20653# Essex Corp., Orlando, Fla.
SIMULATOR SICKNESS: REACTION TO A TRANSFORMED PERCEPTUAL WORLD. 6: PRELIMINARY SITE SURVEYS
R. S. KENNEDY, A. C. BITTNER, JR. (Naval Biodynamics Lab., New Orleans, La.), L. H. FRANK (Naval Training Equipment Center, Orlando, Fla), R. W. HOOT, M. E. MCCAULEY, and T. A. BINKS (Marine Corps Air Station, Jacksonville, N.C.) *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 11 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

There were numerous recent documented and anecdotal reports of aircrews experiencing psychophysiological disturbances, visual illusions and sickness following the use of flight simulators. Symptoms of simulator sickness occur not only during flight, but in some individuals, have lasted up to several hours post exposure. Furthermore, simulator aftereffects may be delayed; some aircrews report symptom onset as late as eight to ten hours post utilization. Incidents of simulator sickness were documented in fighter, attack, patrol and helicopter simulators. These occurrences were reported in both motion-base and fixed-base simulators, to pilots and other aircrewmen, as well as instructors. Simulator sickness represents a major obstacle to obtaining the full training potential from the vast inventory of flight simulators currently in use and under development. Data on pilot experience and exposure factors, symptomatology, scores on postural disequilibrium tests, video-game performance and engineering design aspects in two different Navy helicopter simulators are presented, along with a brief review of past simulator sickness studies. B.G.

N85-20654# Massachusetts Inst. of Tech., Cambridge. Dept of Aeronautics and Astronautics.
SPACE MOTION SICKNESS MONITORING EXPERIMENT: SPACELAB 1
C. M. OMAN, B. K. LICHTENBERG, and K. E. MONEY (Defence and Civil Inst. of Environmental Medicine, Downsview, Ontario) *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 21 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Symptoms and signs of space motion sickness and fluid shift were observed by 4 specially trained crewmembers on the physically demanding 10 day flight of Space Shuttle/Spacelab 1 launched on 11/28/83. Anonymous but detailed firsthand reports are presented. Three crewmen experienced persistent overall discomfort, and vomited repeatedly. Symptom pattern was generally similar to that seen in the individuals preflight, except that: prodromal nausea was brief or absent in some cases; facial pallor and cold sweating were usually absent; one subject experienced uncomfortable stomach elevation. However, symptoms were clearly modulated by head movement, were exacerbated by unfamiliar visual cues, and could be reduced by physical restraint providing contact cues around the body. Drugs known to be effective in preventing motion sickness were judged helpful in limiting symptoms, including vomiting. Results support the view that space sickness is a form of motion sickness. Author

N85-20655*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
SPACE ADAPTATION SYNDROME: INCIDENCE AND OPERATIONAL IMPLICATIONS FOR THE SPACE TRANSPORTATION SYSTEM PROGRAM
J. L. HOMICK, M. F. RESCHKE, and J. M. VANDERPLOEG *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 6 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Better methods for the prediction, prevention, and treatment of the space adaptation syndome (SAS) were developed. A systematic, long range program of operationally oriented data collection on all individuals flying space shuttle missions was initiated. Preflight activities include the use of a motion experience questionnaire, laboratory tests of susceptibility to motion sickness induced by Coriolis stimuli and determinations of antimotion sickness drug efficacy and side effects. During flight, each crewmember is required to provide a daily report of symptom status, use of medications, and other vestibular related sensations. Additional data are obtained postflight. During the first nine shuttle missions, the reported incidence of SAS has been48%. Self-induced head motions and unusual visual orientation attitudes appear to be the principal triggering stimuli. Antimotion sickness medication, was of limited therapeutic value. Complete recovery from symptoms occurred by mission day three or four. Also of relevance is the lack of a statistically significant correlation between the ground based Coriolis test and SAS. The episodes of SAS have resulted in no impact to shuttle mission objectives and, no significant impact to mission timelines. E.A.K.

N85-20656# Naval Biodynamics Lab., New Orleans, La.
ANALYSIS OF HEAD MOTION DURING SIMULATED, ROUGH WATER OPERATION OF A 2200 TON SURFACE EFFECT SHIP
W. R. ANDERSON, G. C. WILLEMS, and J. C. GUIGNARD *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 14 p (SEE N85-20642 11-52) Nov 1984 refs
Avail: NTIS HC A08/MF A01

Nineteen Navy volunteers were exposed, for periods up to 48 hours, to simulated motion environments predicted for a 2,000,000 Kg surface effect ship. Surface effect ships, which are supported by a cushion of air, operate at high speeds and produce motion strongly influenced by the dynamics of the air cushion. The motions of both the environment and the head of each volunteer were measured during scheduled 5 minute intervals and the relationship of head motion to impending emesis was investigated. The time series data and the frequency spectra were examined to identify variability in head response resulting from repetitions with the same subject, repetitions with different subjects, repetitions with a subject in different position, repetitions simulating different ship operating conditions, repetitions with and without pitch and roll motions, differences between well and sick subjects, fatigue, and progression to emesis. Heave, pitch and roll motions in the range of 0.05 to 1.5 Hz were simulated. It is indicated that a correlation between spontaneous head motion and motion sickness exist. The utility of studying the effects of motion in a controlled laboratory environment was demonstrated. E.A.K.

N85-20657# Institute of Aviation Medicine, Farnborough (England).
A DOUBLE BLIND COMPARATIVE TRIAL OF POWDERED GINGER ROOT, HYOSINE HYDROBROMIDE, AND CINNARIZINE IN THE PROPHYLAXIS OF MOTION SICKNESS INDUCED BY CROSS COUPLED STIMULATION
J. R. R. STOTT, M. P. HUBBLE, and M. B. SPENCER *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 6 p (SEE N85-20642 11-52) Nov 1984 refs
Avail: NTIS HC A08/MF A01

The relative effectiveness of powdered ginger root (1G), hyoscine (0.6 mg), cinnarizine (15 mg) and a placebo increase of the tolerance of subjects to the development of motion sickness symptoms induced by cross coupled stimulation. In order to assess the effect of each drug on performance, a range of tests was

carried out in the period between 90 minutes and 2 hours after taking the drug. The effectiveness of hyoscine in delaying the onset of motion sickness symptoms is confirmed and cinnarizine is shown to be similarly effective. The study failed to substantiate a previous report that powderd root ginger is of value in the prophylaxis of motion sickness. Significant differences in the results of performance tests were found only after the administration of hyoscine, which produced a small decrease in subjective alertness and a reduction in the velocity of saccadic eye movements.
E.A.K.

N85-20658# Institute of Aviation Medicine, Farnborough (England).
THE CURRENT STATUS OF THE RAF PROGRAMME OF DENSENSITISATION FOR MOTION SICK AIRCREW
J. R. R. STOTT and M. BAGSHAW *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 9 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

The desensitization to motion sickness program consists of a ground phase and a flying phase. Additional motion stimuli were incorporated into the ground phase of treatment and the flying phase is carried out in the high performance Hunter T7 aircraft. Comparison of the results of follow up for the period 1981 to 1983 with those for 1974 to 1980 indicates an improvement in overall success rate and shows a significant increse in the number of pilots who progress to fly in the demanding motion environment of fast jets.
E.A.K.

N85-20659# Institute of Aviation Medicine, Fuerstenfeldbruck (West Germany). Dept. 6 Aviation Psychology.
PSYCHOLOGICAL COMPONENTS IN THE DEVELOPMENT AND PREVENTION OF AIR SICKNESS
R. W. KEMMLER *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 8 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

The behavior of motion sick aircrew members was analyzed from 23 case studies. Situational context variables and their interaction with individual dispositions, behavior regulation patterns, coping mechanisms and self control techniques are discussed. It seems that sensitivity to motion is not the only criterion in the development of motion sickness. Countermeasures and their effects are described. Daily exercise of various of behavior regulation to build up successive adaptation to motion stress should enable persons to cope with motion sickness-producing situations in flight.
E.A.K.

N85-20660# Aerospace Medical Div., Brooks AFB, Tex.
BIOFEEDBACK TREATMENT OF AIRSICKNESS: A REVIEW
D. R. JONES and B. O. HARTMAN *In* AGARD Motion Sickness: Mechanisms, Prediction, Prevention and Treatment 4 p (SEE N85-20642 11-52) Nov. 1984 refs
Avail: NTIS HC A08/MF A01

Biofeedback as a treatment for air sickness is reviewed. Recognition of early symptoms of motion sickness and the use of relaxation techniques are outlined. The subjects are taught how to control the symptoms when they occur. It is found that the use of biofeedback modalities in the dynamic Coriolis chair environment is more effective in returning fliers to operational flying than relaxation training and desensitization alone.
E.A.K.

N85-21969# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THE CLINICAL AND BIOMEDICAL EVALUATION OF TRAUMA AND FATALITIES ASSOCIATED WITH AIRCREW EJECTION AND CRASH. A WORKING GROUP REPORT
D. J. ANTON, ed. (Royal Air Force, Farnborough, England) Loughton, England Dec. 1984 79 p refs
(AGARD-AR-194; ISBN-92-835-1483-1; AD-A152350) Avail: NTIS HC A05/MF A01

Topics covered include aerospace medicine, aircraft ejection and crash, head and neck injuries, radiological assessment of cervical injury; post mortem procedures; and clinical and biological evaluations of trauma and fatalities. For individual titles see N85-21970 through N85-21977

N85-21970# Royal Air Force, London (England).
INTRODUCTION: THE CLINICAL AND BIOMEDICAL EVALUATION FOR TRAUMA AND FATALITIES ASSOCIATED WITH AIRCREW EJECTION AND CRASH
In AGARD Rept. on the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 1-2 (SEE N85-21969 12-52) Dec. 1984 refs
Avail: NTIS HC A05/MF A01

Existing records suffer from major sources of error that make them unreliable for the generation of useful statistical ejection injury information. There is little reliable evidence to suggest that head and neck injury is a significant hazard of within envelope ejections on modern escape systems. Some evidence exists to suggest that failure to ensure adequate man/seat separation and optimal parachute alignment is responsible for a significant proportion of the severe and fatal injuries that have occurred. A prospective study on two areas was suggested: protocols on clinical and radiological information and post mortem procedures.
B.G.

N85-21971# *French Air Force, Paris.*
STATISTICS OF FRENCH ARMEE DE L'AIR EJECTIONS 1970 - 1980
In AGARD Rept. on the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 3-5 (SEE N85-21969 12-52) Dec. 1984 refs
Avail: NTIS HC A05/MF A01

A statistical analysis of aircraft ejections classified by airspeed and altitude is presented. Fatalities are listed by aircraft type, flight status, altitude, airspeed, helmet status, and sequence of ejection.
B.G.

N85-21972# German Air Force, Fuerstenfeldbruk (West Germany).
LIST OF HEAD/NECK INJURY ON EJECTION IN THE GERMAN ARMED FORCES FROM 1972-1981
In AGARD Rept. on the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 6-10 (SEE N85-21969 12-52) Dec. 1984 refs
Avail: NTIS HC A05/MF A01

Injuries and fatalities are listed according to date, aircraft type, ejection seat type, handle (upper/lower), head/neck injuries, other injuries, and injury cause. The two fatalities are discussed in detail to understand the mechanisms involved.
B.G.

N85-21973# Department of the Navy, Washington, D. C.
A REVIEW OF NECK INJURY AND IMPAIRED CONSCIOUSNESS ASSOCIATED WITH US NAVY EJECTIONS 1 JANUARY 1969 - 31 DECEMBER 1979
In AGARD Rept. on the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 11-16 (SEE N85-21969 12-52) Dec. 1984
Avail: NTIS HC A05/MF A01

Over the past decade major attention was focused on developing information concerning the casual mechanisms of injuries reported sustained by ejectees. Of particular interest was injury to the head, neck, and cervical spine. Injury to either of these parts and the resulting impairment of physical function and/or consciousness can sometimes result in death directly or contribute to a fatal outcome as result of the ejectee's inability to assist in his survival. In order to establish the scope of the problem, US Navy ejection data covering the period 1 January 1969 through 31 December 1979 were reviewed.
Author

N85-21974# Department of the Air Force, Washington, D.C.
A REVIEW OF FATALITY, IMPAIRMENT OF CONSCIOUSNESS, AND HEAD/NECK INJURY ON USAF EJECTIONS 1971 - JULY 1983
In AGARD Rept. of the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 17-21 (SEE N85-21969 12-52) Dec. 1984
Avail: NTIS HC A05/MF A01

With the increasing speed of USAF high performance aircraft (HPA) and the ever more complex maneuvering environment, a

great deal of attention is now being paid to the improvement of escape systems. Of special interest was injury to the head, neck and cervical spine. Nine hundred and fifty ejections from USAF aircraft that occurred during the period 1 January 1971 to mid-July 1983 are reviewed. The purpose is to present the USAF data in a form similar to that presented by the Royal Air Force (RAF) in AEG Report No. 476. Author

N85-21975# Royal Air Force, London (England).
A REVIEW OF FATALITY, IMPAIRMENT OF CONSCIOUSNESS AND HEAD AND NECK INJURY ON ROYAL AIR FORCE EJECTIONS 1968-1981
In AGARD Rept. on the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 22-33 (SEE N85-21969 12-52) Dec. 1984 refs
Avail: NTIS HC A05/MF A01

With the increasing refinement of escape systems, heightened attention was paid to the problems of incapacitation and head and neck injury on ejection. Two hundred and thirty seven peacetime, voluntarily initiated, ejections on Martin Baker escape systems, that occurred during the period 1 January 1968 to 31 December 1981 are reviewed. All ejections proceeded to full parachute deployment. Eight fatalities occurred; seven over water and one over land. Six cases of impairment of consciousness were reported and three cases of neck injury. Author

N85-21976# French Air Force, Paris.
THE CLINICAL AND RADIOLOGICAL ASSESSMENT OF CERVICAL INJURY, ANNEX A
In AGARD Rept. on the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 34-66 (SEE N85-21969 12-52) Dec. 1984 refs
Avail: NTIS HC A05/MF A01

The cervical spine is the most mobile portion of the spine. During trauma, this mobility is compounded by inertia forces at the skull and the presence of the spinal cord, which is less well protected here than in other portions of the spine. Injuries following ejection would seem to be unusual, but when they do occur may take a variety of forms: fracture dislocations, dislocations, severe strains. If these lesions are unstable, dramatic neurological complications may occur immediately or after some delay. The task of identifying factors of instability of a cervical lesion falls to the radiological examination. It should be recalled that radiological exploration of the whole spine, segment by segment, of any survivors is obligatory in the Armee de l'Air Francaise (French Air Force), following ejection or any accident involving the flight deck. The radiological examination of the cervical spine is difficult; it is based on the findings of the clinical examination of the subject and the plates are difficult to interpret. The initial radiological methods and incidences used (routine plates, tomograms and sometimes dynamic radiography) are considered. The more demanding secondary examinations, such as the scanner, myelogram or angiogram are not discussed. Author

N85-21977# German Air Force, Fuerstenfeldbruk (West Germany).
HEAD/NECK INJURY: POST MORTEM PROCEDURES, ANNEX B
In AGARD Rept. on the Working Group on the Clinical and Biomedical Evaluation of Trauma and Fatalities Associated with Aircrew Ejection and Crash p 67-68 (SEE N85-21969 12-52) Dec. 1984 refs
Avail: NTIS HC A05/MF A01

Post mortem procedures discussed include: (1) field investigation after fatal ejection; (2) autopsy; and (3) histological examination. B.G.

N85-31805# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
RESULTS OF SPACE EXPERIMENTS IN PHYSIOLOGY AND MEDICINE AND INFORMAL BRIEFINGS BY THE F-16 MEDICAL WORKING GROUP
Loughton, England Mar. 1985 162 p refs In ENGLISH and FRENCH Symp. held in Istanbul, 25-27 Sep. 1984 (AGARD-CP-377; ISBN-92-835-0376-7; AD-A157096) Avail: NTIS HC A08/MF A01

The French-Soviet Salyut 7, Shuttle and NASA/ESA Spacelab-1 missions and the results of space experiments in physiology and medicine are discussed. The following topics were discussed: the experience of a science astronaut on the Spacelab-1 mission; vestibular and sensorimotor responses to microgravity; cardiovascular responses, and sleep; immunological and radiobiological responses. Selection procedures, centrifuge operations and training physical training and G tolerance; and several aeromedical problems associated with F-16 fighter aircraft operations are also discussed. For individual titles see N85-31806 through N85-31826

N85-31806# Deutsche Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Flugmedizin
EVALUATION OF RESULTS OF SPACE EXPERIMENTS IN PHYSIOLOGY AND MEDICINE AND INFORMAL BRIEFINGS BY THE F-16 MEDICAL WORKING GROUP Technical Evaluation Report
K. E. KLEIN *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 2 p (SEE N85-31805 20-52) Mar. 1985
Avail: NTIS HC A08/MF A01

The exploration of space exposes man to a unique environment since it contains features which do not exist naturally and can hardly be simulated on Earth. Prominent in this respect is the relative absence of gravity which initiates changes in the human organism mainly through three modes of action: the specific effects of gravity sensing organs; the lack of hydrostatic pressure affecting fluid compartments; and the reduction of deformation forces on load bearing tissues. Data collected during previous space flights demonstrated that almost all physiological systems are affected by the space environment. Some of the most significant changes which have become known so far involve the vestibular, the cardiovascular and the musculo-skeletal system as well as blood and metabolism. Conclusions drawn from symposium proceedings are given. Since pitch and roll in microgravity do not result in otolith displacement, a sensory rearrangement becomes necessary in which the CNS reinterprets all otolith outputs as linear motion (otolith tilt translation reinterpretation hypothesis). The inability of otoliths to provide information on spatial orientation of head and body is compensated mainly by the increased utilization of visual cues. Spaceflight related redistribution of EMG activities in muscles responsible for posture control occurs in agreement with changes in otolith function. Space motion sickness is most likely provoked by sensory conflicts, in particular during pitch and roll motions. Individual susceptibility still can not be predicted, however, the easiness of adaptation to head movements while wearing reversing prisms may be indicative in this respect. For the time being, the mechanisms behind the unexpected finding of a caloric nystagmus in the absence of thermal convection during orbital flight remains inexplicable R.J.F.

N85-31807# Deutsche Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).
EXPERIENCE OF SCIENCE ASTRONAUT ON THE SPACELAB-1 MISSION
U. MERBOLD *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 7 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

The experience of a science astronaut on the Spacelab-1 mission is reported. The flight performance, crew training, experiment control, and human physiology and immune system experiments are discussed. R.J.F.

N85-31808# Mainz Univ. (West Germany). Dept. of Physiology.
THE EUROPEAN VESTIBULAR EXPERIMENTS OF THE SPACELAB-1 MISSION
R. VONBAUMGARTEN, A. BENSON (Royal Air Force Inst. of Aviation Medicine), A. BERTHOZ (CNRS, Paris), T. BRANDT (Alfried-Krupp-Krankenhaus), U. BRANDT, W. BRUZEK (Tuebingen Univ.), J. DICHGANS (Tuebingen Univ.), J. KASS, T. PROBST (Alfried-Krupp-Krankenhaus), H. SCHERER (Klinikum Grosshadern) et al. *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 2 p (SEE N85-31805 20-52) Mar. 1985
Avail: NTIS HC A08/MF A01

The European vestibular experiments on Spacelab 1 were designed to explore vestibular adaptation to the space environment and readaptation to the ground by conducting a series of vestibular tests which were repeated several times at different stages before, during, and after the mission. The tests included the threshold for linear oscillation, eye movements triggered by angular acceleration, optokinetic and caloric stimulation, and measurements of posture. Slow phase velocity of caloric nystagmus was increasing in the course of the mission. The results of most tests could be interpreted as indicating a decreasing gain of CNS processing of otolithic information during vestibular adaptation to the space environment. A series of vestibular tests were performed 120, 90, 60, 30 and 11 days before the Spacelab-1 mission and again during the first 6 days after recovery of the space craft. Similar experiments were performed during the mission on board Spacelab by the red shift of the Spacelab scientific crew. After our linear acceleration device Space Sled was descoped for the SL-1 mission and postponed to the D 1-mission a body restraint system (BRS) was constructed which allowed linear oscillation of the experimental subject in three different axes by hand operation of the operator. The test subject wore a vestibular helmet, which contained the electroculography amplifiers and a device for insurflation of heated on cooled air into the ears during the caloric test. An infrared sensitive camera (EMIR) ordered the movements of the right eye including eye rotation. The EMIR system was computing the XY displacements of the eye for display on a stripchart recorder in the payload operation center. In front of the left eye was a TV monitor mounted in a visor of the helmet for optokinetic stimulation, calibration and target cross resetting. R.J.F.

N85-31809# Royal Air Force Inst. of Aviation Medicine, Farnborough (England)
SOME RESULTS OF THE EUROPEAN VESTIBULAR EXPERIMENTS IN THE SPACELAB-1 MISSION
A. BENSON, R. VONBAUMGARTEN (Mainz Univ.), A. BERTHOZ (CNRS, Paris), T. BRANDT (Alfried-Krupp-Krankenhaus), U. BRAND, W. BRUZEK (Tuebingen Univ.), J. DICHGANS (Mainz Univ.), J. KASS (Alfried-Krupp-Krankenhaus), T. PROBST (Klinikum Grosshadern), H. SCHERER (CNRS, Paris) et al. *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 10 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

A series of experiments was performed during the flight of Spacelab 1 to explore changes in vestibular function and visual vestibular interactions associated with adaptation to microgravity. Tests were also conducted on the ground during the four months before flight and over the six days post flight. Measurements were made of the threshold for detection of linear oscillation and of vestibulo-ocular elicited by angular and linear accelerations and by optokinetic and caloric stimuli. These revealed changes associated with the modified otolithic afference in microgravity, though the most unexpected finding was that caloric stimulation in orbital flight evoked nystagmus comparable to that obtained on Earth. R.J.F.

N85-31810*# National Aeronautics and Space Administration Lyndon B. Johnson Space Center, Houston, Tex.
THRESHOLDS FOR DETECTION OF LINEAR OSCILLATION FOLLOWING PROLONGED WEIGHTLESSNESS
D. E. PARKER (Miami Univ., Oxford, Ohio), M. F. RESCHKE, A. P. ARROTT (Payload Systems, Inc.), J. L. HOMICK, and B. K. LICHTENBERG (Payload Systems, Inc.) *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 4 p (SEE N85-31805 20-52) Mar. 1985
Avail: NTIS HC A08/MF A01 CSCL 06S

Linear self motion detection thresholds, which were recorded as part of the European vestibular Experiments, varied across subjects. This variability is consistent with observations following the STS-8 and STS-11 Shuttle missions. Three astronauts who participated in the STS-8 and STS-11 (41-B) missions served as subjects in this experiment. Nominal amplituudes of parallel swing motion were determined by recording the displacement of a pointer attached to the swing bed relative to a scale taped to the floor. These nominal amplitudes were compared with those determined with a three axis accelerometer and strip chart recorder. The subject indicated his perception of self motion (yes or no) by manipulations of a joystick that was connected to one channel of the strip chart recorder. A small signal lamp was mounted on an ear pad support and was controlled by the experimenter's hand held microswitch. Prolonged weightlessness appeared to produce elevated self motion detection thresholds in one astronaut. However, a similar threshold elevation was not obtained from the other two astronauts. The basis for this discrepancy is unknown but it may be related to altered detection threshold criteria on the part of the astronaut who exhibited the threshold change. Failure to record threshold changes following prolonged weightlessness is consistent with the researcher's otolith tilt translation reinterpretation hypothesis. This hypothesis suggests that the sensitivity of the otolith receptors is not altered by weightlessness; rather the way in which the brain interprets otolith information is changed. R.J.F.

N85-31811# Massachusetts Inst. of Tech., Cambridge. Man-Vehicle Lab.
SPATIAL ORIENTATION IN WEIGHTLESSNESS AND READAPTATION TO EARTH'S GRAVITY
L. R. YOUNG, WATT D. G. (McGill Univ.), C. M. OMAN, K. E. MONEY (Defence and Civil Inst. of Environmental Medicine), and B. K. LICHTENBERG *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 6 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

Unusual vestibular responses to head movements in weightlessness may produce spatial orientation illusions and symptoms of space motion sickness. An integrated set of experiments was performed during Spacelab 1, as well as pre and postflight, to evaluate otolith organ and semicircular canal mediated responses by a variety of measurements, including eye movements, postural control, perception of orientation and motion sickness susceptibility. Author

N85-31812*# National Aeronautics and Space Administration Lyndon B. Johnson Space Center, Houston, Tex.
REINTERPRETATION OF OTOLITH INPUT AS A PRIMARY FACTOR IN SPACE MOTION SICKNESS
M. F. RESCHKE, D. E. PARKER (Miami Univ., Oxford, Ohio), J. L. HOMICK, D. J. ANDERSON (Michigan Univ., Ann Arbor), A. P. ARROTT (Payload Systems, Inc.), and B. K. LICHTENBERG (Payload Systems, Inc.) *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 18 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01 CSCL 06S

It is hypothesized that exposure to prolonged free fall is a form of sensory/motor rearrangement rather than a direct change in otolith sensitivity or sensory compensation for a reduced otolith input. The rearrangement of stimuli will force a new interpretation by the CNS of otolith input. This reinterpretation is necessary for a structured and meaningful interaction with the new environment. Data from two flight experiments are presented which support an otolith reinterpretation hypothesis. The first experiment measured vestibulo-spinal reflex changes as a function of sustained free fall. Findings indicate that when a monosynaptic reflex (H-reflex), measured from the major postural muscles (soleus), is used

adaptation to space flight includes a change in how the CNS interprets a fall. In a normal gravity environment a sudden unexpected fall will produce a potentiated H reflex. After seven days in flight an equivalent fall does not potentiate the reflex. During postflight a greatly increased reflex is observed in those crewmen most susceptible to space motion sickness. In the second experiment self motion perception and torsional eyemovements were modified as a function of exposure to sustained free fall. Preflight roll motion (about the X axis) was perceived as pure roll, and the eye movements recorded were countertorsional. Postflight, roll stimulation was perceived as linear translation (side to side movement) with a small angular motion component. Eye movement measurements confirmed significantly more horizontal motion.
G.L.C.

N85-31813# Centre National de la Recherche Scientifique, Paris (France). Lab. de Physiologie Neurosensorielle.
POSTURAL ADJUSTMENTS ASSOCIATED WITH ARM MOVEMENTS IN WEIGHTLESSNESS [AJUSTEMENTS POSTURAUX ASSOCIES AU MOUVEMENT DU BRAS EN APESANTEUR]
F. LESTIENNE and G. CLEMENT *In* AGARD Results of Space Expt. in Physiol and Med. and Informal Briefings by the F-16 Med. Working Group 8 p (SEE N85-31805 20-52) Mar. 1985 refs In FRENCH
Avail: NTIS HC A08/MF A01

Postural adaptation associated with voluntary arm movement was studied in two subjects in the course of one seven day flight. In weightlessness, a redistribution of electromyographic activity among flexor and extensor muscles was observed at the ankle. The analysis of cinemagraphic data indicates a definite inclination of the body to lean forward at the beginning of flight, followed by a gradual return to a position identical to the one observed in a terrestrial gravity situation. These results are interpreted utilizing biodynamic diagrams.
M.G.

N85-31814# Stirling Univ. (Scotland). Dept. of Psychology.
MASS-DISCRIMINATION DURING PROLONGED WEIGHTLESSNESS
H. E. ROSS, E. E. BRODIE, and A. BENSON (Royal Air Force Inst. of Aviation Medicine) *In* AGARD Results of Space Expt. in Physiol. and Med and Informal Briefings by the F-16 Med. Working Group 3 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

An experiment to compare weight and mass discrimination was conducted using 5 of the crew of STS-9 (Spacelab 1) as subjects. Thresholds for mass discrimination under microgravity in flight were found to be higher by a factor of about 1.8 than for weight discrimination before the flight, and there was no consistent improvement throughout the 10 day mission. This suggests that inertial cues to mass (gained through accelerating objects) are not as effective as weight cues. The crew showed an aftereffect for two or three days on return to Earth, when their bodies felt heavy and their weight discrimination was impaired. This suggests that some adaptation to weightlessness occurred during the flight, probably early in the mission before the majority of the mass discrimination tests were conducted.
G.L.C.

N85-31815*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
CHANGES IN CARDIOVASCULAR FUNCTION: WEIGHTLESSNESS AND GROUND-BASED STUDIES
H. SANDLER, D. J. GOLDWATER, M. W. BUNGO (NASA, Lyndon B. Johnson Space Center), and R. L. POPP (Stanford Univ.) *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 9 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01 CSCL 06S

Echocardiographic measurements were taken on members of four Space Shuttle missions before (F-10 to F-12) and twice after (L+0 and L+7 to 14 days) 7- to 9-day space flight missions. Such recordings allowed for determination of left ventricular chamber dimensions and subsequent calculations of left ventricular volume and stroke volume. Resting ventricular volume could be shown to significantly decrease 23% on L+) and to be associated with a significant 28% decrease in stroke volume. Studies 7 to 14 days layer showed amelioration of effects, but persistence of end diastolic volume change. Such findings occurred despite ability to fully ambulate and exercise during the postflight period. Comparison of findings with bed rested subjects (athletic and nonathletic) showed similar changes, but changes after bed rest were of smaller magnitude compared to the flight crews. It is concluded that space flight induces significant changes in heart volume even after short duration (7-9 days) missions. Heavy athletic conditioning preflight may contribute to the severity of the observed changes in the flight crews and to the apparent slow postflight process of recovery.
G.L.C.

N85-31816# Tours Univ. (France). Lab. de Biophysique Medicale.
STUDY OF THE CARDIOVASCULAR SYSTEM IN MICROGRAVITY: RESULTS AND PERSPECTIVES [ETUDE DU SYSTEME CARDIOVASCULAIRE EN MICROGRAVITE: RESULTATS ET PERSPECTIVES]
L. POURCELOT, J. M. POTTIER, F. PATAT, and P. ARBEILLE *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 9 p (SEE N85-31805 20-52) Mar. 1985 refs In FRENCH Previously announced in IAA as A85-13112
Avail: NTIS HC A08/MF A01

The cardiovascular system during weightlessness was studied during the Franco-Soviet Solyut 7 flight in June 1982. An ultrasonic system was developed which functions with Doppler effect, rapid imagery and time measurement. The changes of volume and cardiac functions and the veneral circulation were studied before, during, and after the flight. The dynamic cardiovascular system during flight was compared with simulation tests.
Transl. by E.A.K.

N85-31817# Freie Univ., Berlin (West Germany). Dept. of Physiology.
CARDIOVASCULAR RESEARCH IN SPACE: PROBLEMS AND RESULTS
K. A. KIRSCH, L. ROECKER, R. KRAUSE, O. H. GAUER, H. J. WICKE, R. F. LANDRY, and B. BUENSCH *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 10 p (SEE N85-31805 20-52) Mar. 1985 refs Sponsored by Bundesministerium fuer Forschung und Technologie
Avail: NTIS HC A08/MF A01

In order to see whether the headward fluid shift during spaceflight is followed by increased venous pressures in the upper half of the body in astronauts during the Spacelab 1 Mission pressures in an antecubital vein (PVP) was measured together with the hematocrit (Hct) and the ADH concentration pre-, in- and post-flight. Central venous pressure was followed pre- and post-flight, together with the dy weight (BW). 22 hours after launch PVP was lowered as compared to pre-flight values and remained so during the whole mission, whereas Hct and the ADH were elevated. Apparently the space adaptation of the low pressure system is a highly dynamic process being over within 24 hours. The readaptation to ground conditions follows a similar time course.
Author

N85-31818# Rome Univ. (Italy). Postgraduate School of Aerospace Medicine.
THREE-DIMENSIONAL BALLISTOCARDIOGRAPHY IN MICROGRAVITY
A. SCANO, E. RISPOLI, F. STROLLO (INRCA), and G. CAMA (ISEF) *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 13 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

Some triaxial ballistocardiograms (BCG) and one electrocardiogram lead have been repeatedly recorded on 4 crew-members of the Columbia Shuttle (STS-9) before, during and after a microgravity period of 9 days. In view of this project a miniaturized 'accelerometric equipment was designed and manufactured so as to pick-up the BCG signal from the dorsal region and to record it on a magnetic 4-track tape recorder. A special sequence was devised and implemented in the various flight and round states. The measurements carried out on numerous and long tracing samples, previously decoded and transcribed on paper, proved the reliability of this technique.
B.W.

N85-31819# Antwerp Univ. (Belgium).
SLEEP AND WAKE PHYSIOLOGY IN WEIGHTLESSNESS
O. QUADENS, H. L. GREEN (Clinical Research Center, Harrow), and P. DEQUAE *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 6 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

Among the electrophysiological parameters which are used to define the sleep and waking states, the muscle activity (EMG) and the eye-movements (EOG) were recorded during sleep in the Spacelab 1 mission, allowing detection of Rem-sleep but precluding evaluation of slow wave sleep. The EOG evidenced an important increase in the number of eye-movements during night zero as compared to the pre- and postflight baseline data. The waking electroencephalogram (EEG) was recorded during parabolic flights and showed a significant increase in the theta frequency band during the acrophase of the parabolas. Author

N85-31820# Eidgenoessische Technische Hochschule, Zurich (Switzerland). Lab. fuer Biochemie.
SENSITIVITY OF HUMAN LYMPHOCYTES TO MICROGRAVITY IN-VITRO
A. COGOLI *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 8 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

Studies were conducted on the effect of gravity on lymphocytes, the cells responsible for the immune response. A decrease of lymphocyte reactivity has been observed since 1973 in Soviet and U.S. astronauts after space flight. Ground-based studies performed in hypergravity and in simulated low-gravity conditions suggest the hypothesis that low-g depresses, whereas high-g increases lymphocyte activation. Cultures of human lymphocytes were flown in an incubator on the 1st Spacelab mission and exposed to the mitogen concanavalin A, a substance capable of activating lymphocytes in-vitro. The stimulation of the flight samples was less than 3 percent of that of the ground controls. Although the results are very clear, it is premature now to draw conclusions from this experiment on the effect of space flight on the immune system of the astronauts. B.W.

N85-31821# Deutsche Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. for Aerospace Medicine.
BIOSTACK EXPERIMENTS ON STS-FLIGHTS AND THE IMPACT FOR MAN IN SPACE
H. BUECKER *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 8 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

The radiobiological properties of the heavy ions of cosmic radiation were investigated on Spacelab 1 by use of biostacks, monolayers of biological test organisms sandwiched between thin foils of different types of nuclear track detectors. Biostacks were exposed to cosmic radiation at several locations with different shielding environments in the module and on the pallet. Evaluations of the physical and biological components of the experiment to data indicate that in general they survived the spaceflight in good condition. Dosimetric data are presented for the different shielding environments. Author

N85-31822# Belgian Air Force, Brussels. Centre Medical.
SELECTION PROCEDURES FOR F-16 PILOTS IN THE BELGIAN AIR FORCE
P. VANDENBOSCH *In* AGARD Results of Space Expt. in Physiology and Med. and Informal Briefings by the F-16 Med. Working Group 8 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

By the introduction of the high sustained G F-16 aircraft, the problem of the physical standards was raised. These physical standards for flying must ensure that individuals selected for aviation duties are free from medical conditions or defects which could adversely affect flying safety, mission completion, or their own health. The standards should ensure that an individual selected for flying training is qualified for world wide duty. That means that he should not only be capable of enduring the various stresses involved in flying, but also be capable of withstanding the considerable stresses involved in ejection or egress from the aircraft, and in escape and survival in a hostile environment. There exist a number of mild or subclinical medical conditions which could be aggravated by high sustained G or potentially result in sudden pilot incapacitation. The pathology of these conditions influenced by high G effects are examined. Author

N85-31823# United States Air Forces in Europe, APO New York 09012.
G-INDUCED LOSS OF CONSCIOUSNESS (GLC)
R. F. LANDRY *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 3 p (SEE N85-31805 20-52) Mar. 1985
Avail: NTIS HC A08/MF A01

Although not a new phenomenon, GLC has recently been implicated more frequently as the primary cause for aircraft mishaps. New generation aircraft with the ability of rapid onset and sustainability of high accelerative forces is certainly the major reason for this. Pilot surveys have revealed GLC is more common than previously thought. Prevention of GLC is totally dependent on education of the aircrews: education on the timely performance of a proper anti-G straining maneuver, the physiology of GLC, and the need to maintain the body in optimal condition for flying. Author

N85-31824# Danish Defence Command, Vedbaek. Aeromedical Services.
PHYSICAL TRAINING AND G TOLERANCE
K. JESSEN *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 8 p (SEE N85-31805 20-52) Mar. 1985 refs
Avail: NTIS HC A08/MF A01

High performance aircraft impose extreme physiological stress to the pilots. In particular is the G tolerance of the pilots crucial as exposure to sustained and repeated acceleration forces acting in the head-to-foot direction induces increased demands on cardiovascular and pulmonary functions. The use of backward tilting of the seat and of anti-G-suits will in combination with straining maneuvers help tolerance of high G forces. The effect of the straining on G tolerance will depend on the capacity of the cardiovascular system and of the oxidative metabolic capacity of the exercising muscles (in particular abdominal and leg muscles). Physical training could consequently be one possibel way to improve G tolerance. The effects of training on the body and how it can be achieved are considered. Author

N85-31825# Royal Netherlands Air Force, Soesterberg. Aviation Medicine Div.
CENTRIFUGE OPERATIONS AND TRAINING IN THE ROYAL NETHERLANDS AIR FORCE
H. VANDENBIGGELAAR and G. HOEKSTRA *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 4 p (SEE N85-31805 20-52) Mar. 1985
Avail: NTIS HC A08/MF A01

With the introduction of a new generation fighter aircraft many nations are confronted with the High Sustained G (HSG) phenomenon. This phenomenon may result in a sudden unexpected loss of consciousness (GLC) which has proven to cause fatalities. Three requirements must be met by the pilot of a HSG fighter in order to be able to master his man machine system, without losing his consciousness: (1) good understanding of the anti-G straining techniques; (2) excellent physical condition; and (3) well fitting anti-G suit. The Royal Netherlands Airforce uses a Human Centrifuge as training aid for the G-training of the F-16 pilot population. How this centrifuge affects pilot training is considered. Author

N85-31826# United States Air Forces in Europe, APO New York 09012.
HYDRAZINE AND THE F-16
R. F. LANDRY *In* AGARD Results of Space Expt. in Physiol. and Med. and Informal Briefings by the F-16 Med. Working Group 2 p (SEE N85-31805 20-52) Mar. 1985
Avail: NTIS HC A08/MF A01

The introduction of the F-16 into many of the world's air forces has also introduced a rocket fuel to many areas previously unfamiliar with the propellant. In the event of the single engine failure or any interruption of hydraulic or electrical power, a high energy, quick response (three seconds) source of emergency power

is available in the Emergency Power Unit (E.P.U.) which is fueled by hydrazine. The hydrazine is in the form of H70 (70% N2H4 and 30% H2O) and 6.8 US gallons make a full tank. The toxicity of hydrazine is considered along with ways to safely handle it.
Author

N86-26802# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.
VISUAL PROTECTION AND ENHANCEMENT
Loughton, England Dec. 1985 230 p refs In ENGLISH and FRENCH Conference held in Athens, Greece, 22-24 Apr. 1985 (AGARD-CP-379; ISBN-92-835-0384-8) Avail: NTIS HC A11/MF A01

Vision is the preeminent sensory channel through which the aviator obtains information necessary for the control of his aircraft and the execution of his operational role. Recognizing this to be important, all reasonable and practical means of enhancing and protecting vision should be adopted. The papers presented considers not only systems for visual protection and enhancement but also addressed the basic physiological and pathological mechanisms underlying existing and future solutions. For individual titles see N86-26803 through N86-26825.

N86-26803# Army Electronics Research and Development Command, Fort Belvoir, Va. Night Vision and Electro-Optics Lab.
IMAGE INTENSIFIERS: PAST AND PRESENT
R. W. VERONA *In* AGARD Visual Protection and Enhancement 5 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

The evolution of the image intensifier is presented from the first through the third generation. Technological advancements during the past two decades, such as the microchannel plate and the gallium arsenide photocathodes, have significantly improved the image intensifier's projected life time and performance capabilities. Improved manufacturing techniques have contributed to the intensifier's extended life and expanded performance capabilities. This continued progress attests that the image intensifier continues to be a viable sensory extension helping man achieve his goal, the conquest of darkness. Author

N86-26804# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
FLIR, NVG AND HMS/D SYSTEMS FOR HELICOPTER OPERATION: REVIEW
H. D. V. BOEHM *In* AGARD Visual Protection and Enhancement 27 p (SEE N86-26802 17-52) Dec. 1985 refs
Avail: NTIS HC A11/MF A01

In the last decade, electro-optical systems have been used successfully in military and civil applications. They extend the scope of operation of ground vehicles, helicopters and fixed wing aircraft from daytime into nighttime, with a 24 hour readiness covering even bad weather conditions. The visual aids fall into two physical categories: the image intensifiers, which amplify reflected residual light in the near infrared and the thermal imager, which detect the thermal radiation of all bodies mainly in the 8 to 12 micrometer atmospheric window for bodies with T approx. 20 C. During the last five years, the investigator has carried out helicopter flight trials at night using examples of all these visionic aids (FLIR, LLLTV, NVG, HMS/D and Direct View Optics) for piloting and observation tasks. The detection, recognition and identification range of nine different FLIR were tested in ground and laboratory tests. The evaluation of an optical sensor platform location in the helicopter nose-, roof- and mast-mounted versions, the comparison of thermal and intensifier images and the NVG compatible cockpit were topics of the tests. The optical sensors are described with their limitations and some results of the trials are given, with regard to the pilot's stress situation and eye safety. Author

N86-26805# German Army Aviation School, Bueckeburg (West Germany).
OPERATIONAL EXPERIENCES WITH NIGHT VISION GOGGLES IN HELICOPTER LOW-LEVEL FLIGHT AT NIGHT
H. HAIDN *In* AGARD Visual Protection and Enhancement 8p (SEE N86-26802 17-52) Dec. 1985 refs
Avail: NTIS HC A11/MF A01

The operational marginal conditions are described with regard to the threat analysis in the Central European theater. This is supplemented by a presentation of the technological and physical aspects of the available visual sensors, such as helmet mounted night vision goggles, low light level television, and forward looking infrared and their employment as pilotage aids within the helicopter cockpit. Also, a description is given of the work capabilities and limitations inherent with the employment of electro-optical vision aids. This involves a comparison of the visual capabilities of the unaided eye during low level flight with Moon illumination at night, conditions during reduced light levels, and viewing the same scene with electro-optical sensors. The requirement for glare protection within the cockpit is discussed and different solutions are represented. An exceptional and difficult problem to solve is currently presented by positive position fixing under the given circumstances. Aids and procedures to improve navigation were devised and are now successfully in use. Finally, the results of interviews with helicopter pilots, who have long term experience with the use of helmet mounted night vision goggles are discussed. Author

N86-26806# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).
EVALUATION OF HELICOPTER HELMET-MOUNTED DISPLAY MOCK-UP
G. SANTUCCI and C. VALOT *In* AGARD Visual Protection and Enhancement 14 p (SEE N86-26802 17-52) Dec. 1985 refs
Avail: NTIS HC A11/MF A01

A psychophysiological investigation was conducted on a mockup to evaluate a helmet mounted FLIR display. This experiment included laboratory and inflight testing. Laboratory testing included angular visual acuity, contour perception and stereoscopic acuity. Electrooculography was used to test binocular behavior under monocular stimulation (interocular synergy, binocular rivalry, optokinetic nystagmus). Results showed decreased angular and stereoscopic acuity, and provided a better understanding of eye activity components in this situation. Inflight testing: stressful perception was evidenced during low level helicopter flight, which can be either an overestimation of distances and altitude by active pilots, or an underestimation of these parameters by passive pilots. An illusory sensation was observed under certain binocular uses of helmet mounted displays. It concerns contour vision. Hypotheses are formulated for these various sensory changes. Author

N86-26807# Naval Air Development Center, Warminster, Pa.
VISUAL AND SPECTRORADIOMETRIC PERFORMANCE CRITERIA FOR NIGHT VISION GOGGLES (NVG) COMPATIBLE AIRCRAFT INTERIOR LIGHTING
W. A. BREITMAIER and F. REETZ, III *In* AGARD Visual Protection and Enhancement 11 p (SEE N86-26802 17-52) Dec. 1985 refs
Avail: NTIS HC A11/MF A01

A draft military specification for NVG-compatible aircraft interior lighting was developed. The specification is based on the utilization of a specific type of NVG, the AN/AVS-6 Aviators Night Vision Imaging System (ANVIS). The performance requirements and testing methodology established in the specification and the rationale for developing these requirements are described. The performance requirements are affected by three factors: luminance, chromaticity, and ANVIS compatibility. Luminance requirements do not change drastically from the requirements that presently exist for interior lighting. However, the chromaticity requirements of green for primary and secondary lighting, and yellow for both master caution and warning indicators are different from those that presently exist. The reason for this change is that any lighting with a significant amount of red energy cannot be used in a cockpit that is required to be ANVIS compatible. The implications for this new color design for cockpit lighting are discussed together with the rationale for the chromaticity coordinates and limits chosen. ANVIS compatibility is defined in terms of the spectral sensitivity of the ANVIS and the combination of spectral radiance of the cockpit lighting and the outside world night radiance. Quantitative testing methodology for determining ANVIS compatibility of cockpit lighting is also discussed. A thorough description of all analytic and laboratory studies performed in support of this specification development is presented. Author

N86-26808# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.
NIGHT VISION SUPPORT DEVICES: HUMAN ENGINEERING INTEGRATION
L. V. GENCO *In* AGARD Visual Protection and Enhancement 8 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Although NVGs extend the luminance range over which vision can be used, current AN/PVS systems require special cockpit lighting to be fully effective, reduce visual depth of field and diminish the field of view. All three of these factors are extremely important to pilots performing night operations. The results of several operationally oriented efforts conducted by the U.S. Air Force to improve visual performance, cockpit lighting, and flight information transfer in conjunction with the use of NVGs are described. The efforts include an operational definition of NVG compatible lighting, a recommended approach to improving depth of focus, an attempt to expand field of view, and a description of a NVG HUD using optically injected flight data. All efforts center around using or modifying current AN/PVS NVGs used by US forces. Author

N86-26809# Army Aeromedical Research Lab., Fort Rucker, Ala.
MICRO-HEADS-UP DISPLAY FOR ENHANCEMENT OF NIGHT VISION GOGGLE OPERATIONS
R. SIMMONS, K. KIMBALL, and B. HAMILTON *In* AGARD Visual Protection and Enhancement 9 p (SEE N86-26802 17-52) Dec. 1985 refs
Avail: NTIS HC A11/MF A01

A series of investigations which were initiated in 1976 and completed in March 1984 by the US Army addressed the utility of providing a subminiature heads-up flight instrument display for the NVG system. The research first attempted to identify critical flight information that should be provided to supplement the degraded environmental cues during NVG operations. Subsequent research explored methods of presentation (digital vs. dynamic information), in-line mounting of the display to NVG, and in-flight human factor considerations of the total system. Author

N86-26810# Army Aeromedical Research Lab., Fort Rucker, Ala.
AEROMEDICAL LESSONS LEARNED WITH NIGHT VISION DEVICES
D. R. PRICE and W. E. MCLEAN *In* AGARD Visual Protection and Enhancement 10 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

A review of night vision devices used in the military helicopter flight environment is presented, along with aeromedical lessons learned. Discussion revolves around experience with three U.S. Army aviation systems: the currently used second-generation night vision goggle (NVG), or AN/PVS-5; the soon-to-be-fielded AN/AVS-6 third-generation NVG; and the AH-64 Apache thermal sensor and imaging system. Performance characteristics are presented, and primary emphasis is on aeromedical research related to pilot interface with the systems to include visual acuity, contrast sensitivity, depth discrimination, dark adaptation, crew fatigue, and adaptational problems. Author

N86-26811# Marconi Avionics Ltd., Rochester (England). Airborne Display Div.
NIGHT VISION BY NVG WITH FLIR
G. C. BULL *In* AGARD Visual Protection and Enhancement 7 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Night Vision Goggles and fixed forward looking infrared equipment both have particular operational shortcomings when used in a fixed wing aircraft for close air support at night. However, when operated together, they compensate for each others deficiencies forming a highly capable system at far less cost and complexity compared with other night vision systems. Author

N86-26812# Hamburg Univ. (West Germany). Dept. of Ophthalmology.
PARTICULAR PROBLEMS OF AIRWORTHINESS FROM AN OPHTHALMOLOGICAL VIEW
J. DRAEGER, K. HANKE, and H. WIRT *In* AGARD Visual Protection and Enhancement 3 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Navigation of aircrafts depends on visual acuity and optical perception in the main. Therefore ophthalmological evaluation is of major importance in aviation medicine. Each country uses its own national medical standards for the three different pilot classes. But there still remain applicants not exactly meeting these standards. In West Germany, a special expert board is competent for these borderline cases in civil aviation. Some examples are given from the practice of this board showing the particular problems of appropriate decisions. Also the major differences of national regulations between West Germany and the USA are discussed, comparing civil and Air Force standards. Author

N86-26813# Letterman Army Inst. of Research, San Francisco, Calif.
COMPUTER VISUAL SIMULATION OF CONTRAST SENSITIVITY DEFICITS INDUCED BY LASER AND CHEMICAL ANTIDOTE EXPOSURE
H. ZWICK, D. MONROE, and L. SHERMAN *In* AGARD Visual Protection and Enhancement 4 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Training in some complex combat related tasks may produce a degree of transient visual impairment which may simulate what could be expected in combat. A method is presented for simulating visual impairment produced by potential combat conditions. The use of a computer to both digitize and store as well as produce the simulated image has provided an ideal tool for research. The degree of realism provided by such simulation offers suggestions for development of more realistic training techniques Author

N86-26814# Hamburg Univ. (West Germany). Dept. of Ophthalmology.
NEW GLASSES FOR PRESBYOPIC PILOTS
J. DRAEGER, H. WIRT, and K. HANKE *In* AGARD Visual Protection and Enhancement 3 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Presbyopia is a physiological condition starting by an age of about 40 and increasing steadily with age until accommodation ceases around 55. This means that the naked eye is not able to read instruments and charts in near distance. In a fighter cockpit the information of the head-up display is projected on to the windscreen. Therefore, the pilot has to share his attention between infinity and the projected image of the head-up display, focussing and defocussing very quickly between both distances, always looking straight. This reaction slows down with age. In an experimental study an attempt was made to investigate this complex problem and to test certain solutions. A group of untrained presbyopic subjects were asked to perform specifically designed tasks of assembling small parts and were fitted with different multifocal glasses. In three different ranges and different levels, approximately according to the distance in a cockpit, they had to differentiate and to grasp small electronic elements and to fix them on an electronic plate. The time needed and the mistakes were noted and compared. The evaluation showed much better results for those subjects which had with their glasses the greatest visual field for each specific range and level. E.R.

N86-26815# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
CONTACT LENSES FOR PILOTS AND AIRCREW IN THE SERVICES
J. K. CLOHERTY *In its* Visual Protection and Enhancement 12 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

After working for five years in the contact lens department of Moorsfields Eye Hospital in London and after fitting and monitoring forty volunteers in the RAF Aircrew Soft Contact Lens Trial, it is the opinion of the author that high water content soft contact lenses, or silicone lenses, used as extended wear lenses, are the

only contact lenses which are suitable in an aircrew service environment. The fitting and monitoring of such lenses must be carried out by experts in the field of contact lenses. Author

N86-26816# National Aerospace Medical Centre, Soesterberg (Netherlands).
DYNAMIC BEHAVIOUR OF SPHERICAL AND ASPHERICAL CONTACT LENSES EXPOSED TO +GZ-ACCELERATION FORCES
H. PUNT, A. C. H. VANDENHEUVEL, H. H. VANDENBIGGELAAR (*Royal Netherlands Air Force, The Hague.*), G. J. HOEKSTRA, and A. J. P. ROUWEN (Militair Hospitaal Dr. A. Mathijsen, Utrecht (Netherlands).) *In* AGARD Visual Protection and Enhancement 5 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

A study was made of the behavior of two types of hard contact lenses fitted to a young myopic pilot and exposed to +Gz-acceleration forces. The degree of dislocation of the hard lenses was studied as was the pathological phenomena of the cornea under increasing +Gz-forces. The two types of the evaluated contact lenses are a conventional spherical polymethylmethacrylate (PMMA) lens and an aspherical gas-permeable lens. In a human centrifuge a test person was exposed to +Gz-forces increasing from +1 to +9 Gz. In the gondola a videotelecamara was focussed at the head of the test person during the total test session. It could be concluded that the aspherical gas-permeable contact lenses maintained an optimal concentration under all circumstances. The conventional hard contact lenses with a spherical base curve and a smaller diameter showed downward decentration under increasing +Gz-loads from +6 Gz to a peak value of 8.6 Gz. However, the dislocation never caused the contact lens to leave the cornea. The results are discussed in relation to practical consequences for pilot flying high performance aircraft. Author

N86-26817# Letterman Army Inst. of Research, San Francisco, Calif.
EFFECTS OF BROAD-BANDED EYE PROTECTION ON DARK ADAPTATION
H. ZWICK, T. A. GARCIA, E. S. BEATRICE, and K. R. BLOOM *In* AGARD Visual Protection and Enhancement 8 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Modern combat scenarios require soldiers to perform military tasks under night time conditions. While image enhancement devices are vital to such military performance, unimpaired human night vision retinal mechanisms are essential for performance success. Protection of the human biological sensor is of utmost importance. In this investigation, earlier findings indicating that sunglasses could prevent deleterious effects of bright light on dark adaptation are reexamined. It was found that the use of broad band attenuating spectacles could improve absolute visual thresholds but they had minimal effect on central retinal mechanisms. Dark adaptation functions measured with long wavelength light showed no significant sunglass effect; whereas, such functions measured with intermediate spectral light decreased in final visual thresholds. These differential effects were obtained under environmental light conditions insufficient to produce an evaluation in final visual thresholds for control group subjects not provided with sunglasses. The results strongly support previous arguments for providing standard visible and near ultraviolet protection to personnel required to perform military tasks under extremely bright environmental light. Author

N86-26818# School of Aerospace Medicine, Brooks AFB, Tex.
EYE PROTECTION AGAINST INTENSE LIGHT SOURCES
D. N. FARRER *In* AGARD Visual Protection and Enhancement 3 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

The assessment of modern techniques for the protection of the eyes against laser radiation must begin with the careful evaluation of these stimuli within the context of impairment of useful work. Occupational safety and health standards were designed to define exposure limits of laser systems to prevent damage. However, an eye hazard may not exist within some exposure conditions (e.g., glare, dazzle, or reversible scotoma) in which functional vision impairment could result in job performance failures. Additionally, eye protection devices should not induce impairment properties. It is within this context that this research program was designed. The identification of laser threats, effects on functional vision and eye protective device properties are important considerations for successful aircrew performance. The vast array of intense light sources which represent threats to functional vision, introduces significant challenges for this research area. Author

N86-26819# WWDBw ABC-Schutz, Munster (West Germany).
CALCULATIONS ON TECHNICAL REQUIREMENTS FOR PROTECTION DEVICES AGAINST A NUCLEAR LIGHT FLASH
W. REHMANN and H. SESTERHENN *In* AGARD Visual Protection and Enhancement 11 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Preliminary calculations on the requirements for protective devices against permanent retinal burns caused by nuclear detonations were based on a simplified model which was also used for this study. Computations concerning the reversible flash blindness of flight crews caused by a nuclear explosion is studied as well as the resultant technical requirements to be met by antiflash eye protection systems. In the low yield nuclear range the computations led to shutter times which are technically unfeasible at the present time. Therefore, additional computations were made to determine the periods of blindness occurring when technically feasible antiflash eye protection systems are used. They were then compared with the periods of blindness to be expected under identical conditions but without antiflash eye protection systems. Author

N86-26820# WWDBw ABC-Schutz, Munster (West Germany).
GERMAN DEVELOPMENT OF A LC-FLASHBLINDNESS DEVICE
W. REHMANN and H. SESTERHENN *In* AGARD Visual Protection and Enhancement 6 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

A research program was conducted on the feasibility of flash blindness protection by liquid crystal techniques. The result was the development of a reversible fast optical shutter basically consisting of a liquid crystal cell enclosed in 2 crossed polarizers, which provided promising data for an application for flash blindness protection. Shutter times were in the range of 50 to 80 microseconds, an open state transmittance of 0.25 to 0.30 is state of the art. The closed state transmittance amounts to .0001 to .00001. Author

N86-26821# *Naval Air Development Center, Warminster, Pa.* Life Sciences Research Group.
THE APPLICATION OF DIFFRACTION OPTICS TECHNIQUES TO LASER EYE PROTECTION
G. T. CHISUM *In* AGARD Visual Protection and Enhancement 4 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

Development of a method of protecting the eyes of military personnel from laser radiation has been pursued for a number of years. The devices developed have marginal acceptability, particularly for aircrew personnel. Efforts underway to develop a holographic diffraction grating protection device indicate that such a device is feasible and that the requirements of high transmittance, multiple wavelength rejection and configuration suitable for aircrew use can be met. Author

N86-26822# Letterman Army Inst. of Research, San Francisco, Calif.
FOVEAL FLASHES AND HUMAN PERFORMANCE
D. I. RANDOLPH, E. T. SCHMEISSER, and E. S. BEATRICE *In* AGARD Visual Protection and Enhancement 6 p (SEE N86-26802 17-52) Dec. 1985
Avail: NTIS HC A11/MF A01

The role of several variables in the production of a flash which would reduce the ability of humans to detect and discriminate targets, functions which are required of both air and ground troops is determined. Four volunteers were exposed to xenon gas discharge tubes with different retinal spot sizes and flash durations. The task consisted of a reaction time experiment in which the subjects detected both the presence and orientation of a striped grating which subtended 0.57 deg at the retina. Three grating contrasts at three pattern-background contrasts were presented in a pseudo random order. Three flash conditions were used. The

results showed that the larger image size and longer flash durations produced significantly poorer performance on both the detection and discrimination tasks. For the smallest retinal spot size, and the shortest flash condition, the detection but not the discrimination times were faster than the nonflash trials. This indicated that while the flash may have acted as a preparatory signal, more complex pattern processing remained sensitive to the flash. Author

N86-26823# Letterman Army Inst. of Research, San Francisco, Calif.

PERMANENT VISUAL CHANGE ASSOCIATED WITH PUNCTATE FOVEAL LESIONS

H. ZWICK, K. R. BLOOM, and E. S. BEATRICE *In* AGARD Visual Protection and Enhancement 8 p (SEE N86-26802 17-52) Dec. 1985

Avail: NTIS HC A11/MF A01

In order to understand battlefield hazards of laser exposure under field conditions, it has been necessary to evaluate effects of small punctate foveal lesions on visual function of nonhuman primates. Previous experiments have found a correlation between functional loss and foveal damage. The present investigation showed that detecting the effects of small foveal lesions is not an easy task. From the results, the possibility that considerable foveal damage could occur before a measurable change in visual function could be detected with presently available visual function testing procedures is apparent. It is recommended that more sensitive visual function test procedures, such as clinical tests that measure both spectral and spatial resolution under threshold contrast conditions. Author

N86-26824# British Aerospace Public Ltd. Co., Kingston-upon-Thames (England). Systems Engineering Dept.

VISUAL DIFFICULTIES ASSOCIATED WITH FUTURE WINDSCREEN AND HUD INTEGRATION

A. J. HULME and K. F. SHRUBB *In* AGARD Visual Protection and Enhancement 9 p (SEE N86-26802 17-52) Dec. 1985

Avail: NTIS HC A11/MF A01

The integration of a binocular HUD and the windscreen requires the consideration of a number of optical parameters if the HUD symbology is to be superimposed on the real world scene without giving rise to unacceptable visual difficulties. These parameters are described as are the causes of these difficulties, and a number of experiments carried out during these investigations are reported. The significance of these results for future aircraft and their operations is discussed. Author

N86-26825# British Aerospace Public Ltd. Co., Lancashire (England). Cockpit Specialist Group.

HUMAN FACTORS: THE CINDERELLA DISCIPLINE IN COCKPIT INTERFACE DESIGN

K. W. MARTIN and J. LAYCOCK (Royal Aircraft Establishment, Farnborough, England) *In* AGARD Visual Protection and Enhancement 10 p (SEE N86-26802 17-52) Dec. 1985

Avail: NTIS HC A11/MF A01

The present trend in military aircraft design towards compact cockpits, multifunction controls and displays, and integrated systems within more agile and smaller airframes, has resulted in a greater need for human factors involvement in the design of the man machine interface. The cockpit of the modern military aircraft is inevitably a compromise of conflicting design disciplines, and one in which human factors fails to achieve any long term influence because the discipline lacks the absolute argument necessary for survival in the industrial environment. If human factors are to establish the degree of influence the current levels of research justify, then a new approach is necessary. This approach must recognize the practical problems associated with the design and manufacture of the integrated weapons delivery system that future aircraft represent. One possible approach may be the generation of human factors design tools, for use by engineers, which incorporate human sensory emulations and provide outputs that can be integrated into the engineering discipline. Author

N86-30309# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Aerospace Medical Panel.

MEDICAL SELECTION AND PHYSIOLOGICAL TRAINING OF FUTURE FIGHTER AIRCREW

Loughton, England Dec. 1985 146 p refs In ENGLISH and FRENCH Conference held in Athens, Greece, 25-26 Apr. 1985 (AGARD-CP-396; ISBN-92-835-0385-6) Avail: NTIS H A07/MF A01

The conference proceedings reviewed and made recommendations with respect to the medical selection and physiological and physical training of pilots who are to operate future fighter aircraft. The relevant characteristics of a proposed USAF fighter and the European Fighter Aircraft were discussed and used as the basis for selection and training considerations. Contributors drew upon the experience of the medical selection of pilots for present fighter aircraft. The cardiovascular, vision, and vertebral column aspects of medical selection and monitoring are considered in depth and recommendations made as to the methods which should be employed in the future. The influence of physical fitness upon pilot performance is addressed. The philosophy and practice of physiological training of aircrews is reviewed with emphasis on the value of the human centrifuge in teaching G protective maneuvers. For individual titles see N86-30310 through N86-30327.

N86-30310# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.

AIRCREW ASPECTS OF UNITED STATED FUTURE FIGHTER AIRCRAFT

R. D. KROBUSEK *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 5 p (SEE N86-30309 21-52) Dec. 1985

Avail: NTIS HC A07/MF A01

The cockpit environment of fighter aircraft for the year 2000 and beyond will undoubtedly need aircraft technologies and protective devices to meet the ever growing enemy challenge. Recent advances in aircraft structures, flight controls, sensors, multipurpose and touch-sensitive displays, voice recognition and synthesis, enemy defenses, and chemical/biological warfare (CBW) technologies will combine to create a cockpit environment for future fighter aircraft vastly different and potentially more complex than any previously encountered by aircrews. This integration of equipment and crewmembers will interact such that new stresses will be created and existing ones aggravated. Special maneuver capability through the use of direct side force may provide significant tactical advantage at the expense of stress due to lateral acceleration forces. A few of these current technolores and some of the driving forces which will affect the cockpit environment of tomorrow's aircraft will be identified and discussed briefly. These technologies, as well as others, should receive further study for their effects on the aircrew prior to application in future aircraft. Proper application of the results of these studies will prevent the unbridled growth of cockpit complexity. Author

N86-30311# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).

CANADIAN FORCES APPROACH TO AIRCREW MEDICAL SELECTION

G. GRAY *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 6 p (SEE N86-30309 21-52) Dec. 1985

Avail: NTIS HC A07/MF A01

With advances in aircraft performance capabilities and in medical screening technology, major changes in Canadian Forces aircrew medical screening procedures were proposed and are being introduced. In addition to the standard battery of tests, additional screening procedures being introduced or evaluated include drug screening for cannabinoids, contrast sensitivity function visual assessment, echocardiograms, cardiovascular risk assessment, pulmonary function testing, an aeromedical history questionnaire, and a psychosocial and clinical review by a flight surgeon. Screening electroencephalograms are being continued. This data is used to reject candidates who fail to meet slection standards, and to provide a Medical Suitability Rating for acceptable candidates. Of candidates screened 2.8% had positive tests for urinary cannabinoids. Contrast sensitivity norms for the aircrew candidate population are higher than for other populations studied.

Contrast sensitivity may be helpful in assessing candidates whose vision is close to standards. This approach to initial medical screening should reduce attrition of experienced aircrew for medical reasons, and will enhance flight safety over the years to come.
Author

N86-30312# Tactical Air Command, Langley AFB, Va.
MEDICAL SELECTION AND PHYSIOLOGICAL TRAINING OF FIGHTER PILOTS: A 1985 PERSPECTIVE AND OVERVIEW
R. M. DEHART *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 5 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

From an aeromedical perspective, there are two major goals for the Tactical Air Force. The first is to reduce the aircraft mishap rate due to human factor variables. The second is to enchance pilot capability to perform in the modern fighter environment. Fighter pilots can perform in the 9G (sub z) environment effectively and safely if they are properly selected, educated, and trained. In addition to being good aviators, smart, and aggressive, fighter pilots must be physically healthy and in excellent physical condition. A thorough understanding of high-G physiology and the personal physiological flight envelope is needed. Accomplishing the variety of initiatives required to realize these goals is an exciting challenge for the aerospace medical community. Author

N86-30313# School of Aerospace Medicine, Brooks AFB, Tex.
CARDIOVASCULAR STANDARDS FOR SELECTION AND RETENTION OF HIGH PERFORMANCE PILOTS IN THE USAF: PERSPECTIVES FOR THE NEXT DECADE
J. R. HICKMAN, JR., G. M. MCGRANAHAN, JR., R. M. PAULL, and R. M. DEHART (Tactical Air Command, Langley AFB, Va.) *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 7 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

Cardiovascular selection and retention standard must be based upon a number of considerations which are primarily epidemiological in nature. In young applicants, there is little rationale in the performance of expensive, labor intensive studies which yield nonspecific results, most of which are normal variants. Stress tests and Holter monitors fall into this category. Since the significance of nonspecific findings is determined by the presence or absence of underlying organic structural defects, it is recommended that testing in a young population be directed toward the detection of anatomical defects. It is also recommended that abnormal findings of a structural nature then be assessed with functional tests to determine whether the applicant may enter some form of aviation training or be disqualified from all training. B.G.

N86-30314# Centre Principal d'Expertises Medicales du Personnel Navigant de l'Aeronautique, Paris (France).
SELECTION AND MEDICAL TESTING OF MIRAGE 2000 PILOTS: REPORT OF ECHOCARDIOGRAPHY [SELECTION ET SURVEILLANCE MEDICALES DES PILOTES DE MIRAGE 2000: APPORT DE L'ECHOCARDIOGRAPHIE]
H. ILLE, A. DIDIER, N. ALLEGRINI, and C. MAUREL *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 13 p (SEE N86-30309 21-52) Dec. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

The use of echocardiological examinations in the selection of prospective combat aircraft crews is discussed. Included is a comparative study of two homogeneous pilot cohorts; one consists of 34 transport aircraft pilots, and the other consists of 32 combat pilots. It is shown that the two cohorts present the same anomalies of the right cardiac region (mitral valvular prolapsus). However, it is shown that the anomalies of the right cardiac region form a right ventricular dilation only in combat pilots. Two hypotheses were developed: that the anomalies are an adaptation of the right cardiac region to accelerations, or that they are a stage preceeding secondary myocardial shock due to aeronautical constraints.
B.G.

N86-30315# Hopital d'Instruction des Armees, Versailles (France).
CONTINUOUS ECG MONITORING OF MIRAGE 2000 PILOTS (COMPARISON WITH MIRAGE 3 AND F1 PILOTS) [ENRIGISTREMENT CONTINU DE L'E.C.G. CHEZ LES PILOTES DE MIRAGE 2000 (COMPARAISON AVEC LES PILOTES DE MIRAGE 3 ET F1)]
A. SEIGNEURIC, G. LEGUAY, J. P. BURLATON, G. POYOT, and M. SYLVESTRE *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 3 p (SEE N86-30309 21-52) Dec. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

Continuous Electrocardiographic monitoring for a duration of 24 hours allows a comparison of a sample of 24 conventional combat aircraft pilots (Mirage III and F1), with 7 Mirage 2000 pilots. A comparison of problems due to excitability during flight does not show signification differences among the two groups. Problems due to solar repolarization were recorded only for high-performance aircraft pilots. Differences primarily included cardiac frequencies in flight; they were clearly lower for the Mirage 2000 pilots as observed acceleration was increased. This corresponds with the differences in characteristics of the two populations, pertaining to the different missions. It is shown that modern combat aircraft, characterized by intense and prolonged acceleration, are capable of causing a certain excitability factor for the pilots. It is important to determine the influence of this acceleration on the cardiovascular system. B.G.

N86-30316# Centre d'Essais en Vol, Bretigny-sur-Orge (France).
THE USE OF ECG CHANGES CAUSED BY ACCELERATION AS TOLERANCE PREDICITION FACTORS [LES MODIFICATIONS ELECTROCARDIOGRAPHIQUES INDUITES PAR LES ACCELERATIONS, FACTEUR PREDICTIF DE LA TOLERANCE]
J. H. CLERE, H. VIELLEFORD, and J. L. POIRIER *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 7 p (SEE N86-30309 21-52) Dec. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

High-G accelerations experienced by combat aircraft pilots are arythmogenic. Of 328 electrocardiographic (EKG) tests done on 146 subjects submitting to accelerations of 4 to 11 G at a duration of 20 to 60 seconds, 215 supraventricular anomalies were observed on 181 tests, and 37 ventricular anomalies were observed on 31 tests. The frequency of these anomalies are a function of the intensity of the acceleration. However, there appeared to be no correlation between the EKG anomalies and the hemodynamic phenomena caused by problems of visual function or psychomotor problems. Thus it is stated that EKG monitoring may be of interest for use as a prediction factor for acceleration tolerance. It is stated that the anomalies of rhythm are probably based on vagus reflexes caused by attempts by the heart to protect against the acceleration, as well as by the venous responses to the centrifuge. B.G.

N86-30317# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
ENTRY VISUAL STANDARDS AND OCULAR EXAMINATION TECHNIQUES FOR FUTURE FIGHTER AIRCREW
D. H. BRENNAN *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 6 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

The visual tasks of future fighter aircrew are likely to increase both in magnitude and complexity. The increasing adoption of devices for visual enhancement and protection, even now, poses problems for integration with spectacles. The visual standards required for initial selection for training as a pilot or navigator should, if numbers permit, be such that trained aircrew are unlikely to require a visual aid until presbyopia physiologically demands correction in the latter half of the fourth decade. The visual standards considered appropriate for future fighter aircrew and the related ocular examination techniques both conventional and those designed to test such specialized ocular functions as stereopsis, glare resistance, dark adaptation, hue discrimination, and modulation transfer function are discussed. Author

N86-30318# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).
SENSITIVITY TO COLOR CONTRASTS AND THE SELECTION OF NAVIGATOR PERSONNEL [SENSIBILITE AU CONTRASTE EN COULEURS ET SELECTION DU PERSONNEL NAVIGANT]
J. P. MENU, G. SANTUCCI, and C. CORBE *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 8 p (SEE N86-30309 21-52) Dec. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

Using a specific psychophysical method, the sensitivity to color contrasts (FSC) was systematically tested for subjects undergoing ophthalmological examinations. Following FSC examinations, several subjects with ametrophic conditions were studied. The FSC examinations were modified to obtain the exact nature of the ophthalmological I problem. It is shown that there is a change in the spatial frequencies of the blue section for subjects with myopic disorders, and a change in the red section for far-sighted subjects. This change is shown to be proportional to the degree of ametrophic disorder. Thus, FSC tests are proposed as a basis for tests for the selection of navigators. B.G.

N86-30319# School of Aerospace Medicine, Brooks AFB, Tex. Neurosciences Function.
COMPUTER ANALYSIS OF VISUAL AND VESTIBULAR OCULOMOTOR FUNCTION IN THE MEDICAL SELECTION OF FIGHTER AIRCREW MEMBERS
J. W. WOLFE, E. J. ENGELKEN, and K. STEVENS, W. *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 6 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

Methods for evaluating visual and vestibular-oculomotor function in aircrew members are reviewed. Three specific tests are described: pursuit tracking, harmonic angular acceleration, and saccadic tracking. In all of these tests, on-line computer analysis is used to quantify and describe the input/output relationships. An example of clinical data from pursuit tracking and harmonic angular acceleration tests for a patient with known pathology are used to demonstrate changes in test results. The major point is that it is now practical to evaluate oculomotor function in pilots and aircrew members selected for fighter aircraft duty. Author

N86-30320# Naval Aerospace Medical Research Lab., Pensacola, Fla.
VISUAL CAPABILITIES RELATED TO FIGHTER AIRCREW PERFORMANCE IN THE F-14 AND ADVERSARY AIRCRAFT
W. A. MONACO and P. V. HAMILTON *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 9 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

Standards for aviation personnel should be based on capacities for performing critical tasks. The use of scores on task-relevant visual tests to predict air-to-air target detection performance of pilots involved in air combat maneuver (ACM) training was determined. A series of automated vision tests was determined in a mobile field laboratory located at a Tactical Air Combat Training System (TACTS) range. A computerized telemetry network provides extensive real time data on observer and target aircraft flight dynamics, and environmental parameters. A pilot's performance on each ACM engagement was measured by the slant range at the instant he sighted a target aircraft. Priminary analyses show that about 30% of the variance in the slant range is accounted for by flight dynamics, and environmental parameter, and vision data. Author

N86-30321# Naval Aerospace Medical Research Lab., Pensacola, Fla.
VISION TEST BATTERY THRESHOLD AND RESPONSE TIME AS PREDICTORS OF AIR-TO-AIR VISUAL TARGET ACQUISITION IN F-14 AND ADVERSARY AIRCRAFT
A. MORRIS, P. V. HAMILTON, W. A. MOREY, and R. P. BRIGGS (University of Southern California, Los Angeles.) *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 8 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

The Naval Aerospace Medical Research Laboratory (NAMRL) Vision Test Battery provides assessment of various visual functions, including spot detection, acuity at high and low contrast, glare sensitivity, and accommodative flexibility. Within these tests are measures of threshol, threshold-stressed response time (for near-threshold stimuli), and unconfounded response time (for supra-threshold stimuli). The contribution of response time variables to predicting flight performance was evaluated for 73 fighter pilots. Vision test data were compared to performance in air combat maneuver training. The distance (slant range) between the observer and target aircraft at time of initial visual detection was used as the performance variable. Availability of response time variables enhanced the ability to predict the air-to-air visual target detection performance of these pilots. Four vision variables accounted for about 32% of the variance in performance of those pilots who detected target aircraft at slant ranges greater than the group average. Prediction of performance is improved by incorporating other vision data and additional refinement of the performance measure. Author

N86-30322# Hopital d'Instruction des Armees, Paris (France).
THE VERTEBRAL COLUMN: SELECTION AND APTITUDE OF COMBAT AIRCRAFT PILOTS OF THE FUTURE [COLONNE VERTEBRALE: SELECTION ET APTITUDE DES PILOTES D'AVION DE COMBAT DU FUTUR]
P. J. METGES, J. FLAGEAT, R. AUFRET, R. P. DELAHAYE, and H. VIEILLEFOND *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 3 p (SEE N86-30309 21-52) Dec. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

The new generation of combat aircraft is characterized by the possibility of negative effects on the vertebral column due to extended or peak acceleration forces. In order to provide the pilot with optimal capacity for visual information assimilation, the cervical rachis must remain mobile and is therfore vulnerable under certain circumstances. Lesions may occur in this area during flight. Prevention of this condition is based on three elements: extensive radiological examination of the rachis for pilot applicants; technical improvements in helmet alignment; and physical adaptation training. B.G.

N86-30323# Militair Hospitaal Dr. A. Mathijsen, Utrecht (Netherlands).
SYSTEMATIC RADIOGRAPHIC EXAMINATION OF THE SPINE FOR SELECTION OF F-16 PILOTS: A PRELIMINARY REPORT
A. VANDALEN and H. H. M. VANDENBIGGELAAR (Royal Netherlands Air Force, Soesterberg.) *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 4 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

With the introduction of the high performance aircraft F-16 in the Royal Netherlands Air Force an increase in spinal column disorders was anticipated. Therefore, a systematic whole spine radiography of candidate student pilots (CSPs) and qualified pilots (QPs) designated to fly F-16 were performed since December 1982. To reduce radiation exposure radiographs were made using a modern 14 inch intensifier. So far, 225 CSPs and 196 QPs were examined. Strict application of the medical criteria leads to a rejection of 20% of the CSPs because of spinal disorders visualized on X-ray. For F-16 pilots, the major region of interest seems to be the cervical spine. The rejection rate could be reduced by readjustment of the medical criteria and separate selection of helicopter and fighter pilots. Systematic examination of QPs who had no or incomplete previous examinations uncovers a high rate of spinal disorders. In the series QPs without any symptoms were only rejected because of cervical discopathy with osteophyte formation on the backside of the vertebrae and resulting narrowing of the spinal canal. Author

N86-30324# CEAM, Mont-de-Marsan (France).
PHYSICAL TRAINING OF MIRAGE 2000 PILOTS [ENTRAINEMENT PHYSIQUE DES PILOTES DE MIRAGE 2000]
G. POYOT, J. M. CLERE, J. LEMOT, and J. P. DELATTRE *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 5 p (SEE N86-30309 21-52) Dec. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

Nine combat aircraft pilots underwent physical training specifically designed to increase their tolerance to acceleration forces. The suitability of the training was studied using centrifuge tests. The increase in tolerance could be attributed to the effects of the physical training or to an adaptation to the centrifuge. It is

shown that together with an excellent original physical condition, specific physical training may increase the tolerance of acceleration forces. Further testing of this is expected. B.G.

N86-30325# Belgian Air Force, Brussels.
TREADMILL SPIROERGOMETRY IN THE SELECTION AND SCREENING OF HIGH-PERFORMANCE COMBAT AIRCRAFT PILOTS IN THE BELGIAN AIR FORCE [SPIROERGOMETRIE SUR TAPIS ROULANT DANS LA SELECTION ET LA SURVEILLANCE DES PILOTES D'AVIONS A HAUTES PERFORMANCES DE LA FORCE AERIENNE BELGE]
G. PIROUIN, J. VASTESAEGER, and P. VANDENBOSCH *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 5 p (SEE N86-30309 21-52) Dec. 1985 In FRENCH
Avail: NTIS HC A07/MF A01

All pilots of the Belgian Air Force who were designated for conversion to the F-16 aircraft underwent cardiovascular and respiratory examinations. One of the tests was a test for maximum treadmill effort. In the first study, the results of the screening were combined with the results of tests conducted on a group of young candidate student pilots. The aerobic capacity of this population was then evaluated. The test sample included 156 persons of various ages and in different stages of physical conditioning. In the second study, the positive effects of physical training on the treadmill spiroergometric examination of a group of F-16 pilots were examined. B.G.

N86-30326# Naval Aerospace Medical Research Lab., Pensacola, Fla.
RELATIONSHIP OF CARDIOPULMONARY FITNESS TO FLIGHT PERFORMANCE IN TACTICAL AVIATION
G. R. BANTA and J. D. GRISSETT *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 11 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

Current endeavors to identify whether cardiopulmonary fitness can positively influence flight performance in a tactical fighter community are discussed. Population analyses of experienced and student Naval aviators present evidence that the U. S. Navy aviation pilot community is in an above the average state of physical fitness with less than average coronary heart disease potential. Correlations found between cardiopulmonary fitness and psychophysiological responses that occur during simulated and/or actual flight operations present strong ecidence that flight performance could be favorably affected. Author

N86-30327# Naval Aerospace Medical Inst., Pensacola, Fla. Aviation Physiology Dept.
HYPOBARIC TRAINING OF FLIGHT PERSONNEL WITHOUT COMPROMISING QUALITY OF LIFE
D. M. HERRON *In* AGARD Medical Selection and Physiological Training of Future Fighter Aircrew 7 p (SEE N86-30309 21-52) Dec. 1985
Avail: NTIS HC A07/MF A01

The increased incidence in decompression sickness during physiology training among U. S. Navy aircrew personnel and medical attendants requires a search for alternative means of permitting recognition and corrective action of hypoxia. The requirement for individual hypoxia training is considered valid not just by Navy regulations but by aeromedical practioners throughout the world. A proposal is made to utilize a gas mixture consisting of 7.4% oxygen and 92.6% nitrogen to induce hypoxia at ground level. This would permit ground level hypoxia training with similar symptoms of hypoxia as presently demonstrated at 25,000 feet in a decompresion chamber but would alleviate the primary cause of decompression sickness. All other U. S. Navy training objectives for the chamber exposure would be safely met and more efficiently demonstrated. The initial financial burden in modifying the existing decompression training chamber would be moderate when considering development and manufacturing of a new training device. The ultimate gain exists in decreased human suffering and the necessary return of credibility to the aeromedial training community. This is a must if we are to profess to do no harm. Author

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MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT

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

N85-19653# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
HUMAN FACTORS CONSIDERATIONS IN HIGH PERFORMANCE AIRCRAFT
Loughton, England Nov. 1984 197 p *refs* In ENGLISH and FRENCH Symp. held in Williamsburg, Va., 30 Apr. - 2 May 1984 (AGARD-CP-371; ISBN-92-835-0368-6; AD-A152468) Avail: NTIS HC A09/MF A01

The physical and mental demands placed on the crews of combat aircraft are severe now and are projected to increase in severity in the next five to fifteen years. Human factors needs, promises and practices to design future aircraft systems to ameliorate the physical stressors and mental workload of the crew are addressed. Future mission requirements, emerging technologies, and findings from research on physiological and cognitive processes and methodology are discussed. For individual titles see N85-19654 through N85-19672.

N85-19654# Smiths Industries Ltd., Bishops Cleeve (England).
AIRCREW AND AVIONICS: FRIENDS OR FOES?
R. A. CHORLEY *In* AGARD Human Factors Considerations in High Performance Aircraft 9 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01

The Proliferation of display devices has led to a situation where the complexities of the visual task of acquiring essential information from large numbers of displays, and of providing inputs to the system through large numbers of controllers, are only marginally acceptable. Means are now becoming available to ease this situation. Efforts to design aircrew-friendly avionics systems in an attempt to reduce pilot workload are discussed. Multifunction displays and controllers and facilities, such as direct voice input and speech output are all potentially capable of making avionics systems more efficient. B.W.

N85-19655# Army Research Inst. Field Unit, Fort Benning, Ga.
MILITARY PILOT ERGONOMICS
I. C. STATLER *In* AGARD Human Factors Considerations in High Performance Aircraft 13 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01

The problem facing virtually all modern military command and control systems is processing and selection among increasingly large amounts of information. Poor system design or excessive mission demands result in high operator workload. A crew workload problem exists in today's tactical military aircraft that can contribute to mission failure or loss of pilot and aircraft. Examples of current designs in which it appears that design engineers have not understood or have ignored fundamental requirements of human sensory and cognitive characteristics and limitations are discussed. Background information to the current problem of the man-machine interface in the tactical military aircraft is provided and current approaches to achieving increased mission performance are discussed. B.W.

N85-19656# Department of the Air Force, Wright-Patterson AFB, Ohio. F-16 System Program Office.
IMPLICATIONS OF GUIDANCE AND CONTROL TECHNOLOGY ON HUMAN FACTORS CONSIDERATIONS
R. C. ETTINGER *In* AGARD Human Factors Considerations in High Performance Aircraft 13 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01

Emerging technologies in guidance and control which are candidates for future aircraft are discussed. An advanced development program which successfully demonstrated Integrated Fire/Flight Control (IFFC) technology to automatically deliver air-to-air and air-to-surface weapons while maneuvering is

described. The advanced cockpit design of the new F-16 C/D aircraft is also described. Brief descriptions of normal acceleration of G induced loss of consciousness, anti-G hardware and pilot G tolerance in the F-16 are also covered. Lastly, the angle of attack and load factor limiting features of the F-16 and how they affect the maneuvering of this relaxed static stability, fly-by-wire, high performance aircraft are described in detail. B.W.

N85-19657# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Human Engineering Dept.

OBSERVATIONS OF PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS OF TERRAIN FOLLOWING FLIGHT BASED ON IN-FLIGHT TEST EXPERIENCE

F. KOEHL and D. SEECK (Messerschmitt-Boelkow-Blohm G.m.b.H., Manching, West Germany) *In* AGARD Human Factors Considerations in High Performance Aircraft 8 p (SEE N85-19653 10-54) Nov. 1984 refs

Avail: NTIS HC A09/MF A01

A short description of the PANAVIA 200 TORNADO TF-System, Displays and Controls is given. The physiological and psychological effects including monitoring and workload aspects during the current TORNADO TF test flying described are a result of interviewing aircrews with a wide variety of individual operational experience. Crew interviews revealed this task to be a high load on the aircrew. Load is a combination of physical and psychic parts, depending on environmental factors and flight conditions. Crew system confidence is acquired through step by step progression to lowest height and from visual meteorological conditions (VMC) to instrument meteorological conditions (IMC)-Terrain Following and will be the base for later services operational pretraining. No pathogenic influences have been observed up to now. B.W.

N85-19658# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.

PERSONNEL PROTECTION CONCEPTS FOR ADVANCE ESCAPE SYSTEM DESIGN

J. W. BRINKLEY *In* AGARD Human Factors Considerations in High Performance Aircraft 12 p (SEE N85-19653 10-54) Nov. 1984 refs

Avail: NTIS HC A09/MF A01

The severe emergency escape conditions associated with low-altitude and high-speed environments are often beyond the performance capabilities of contemporary ejection seats. A new escape system design approach is needed to extend the performance envelope without increasing the stresses imposed on the ejecting crewmembers. A new approach was developed and specific ejection-seat subsystem design technologies are being explored by the United States Air Force. The central concept of the approach is the automatic selection of the performance characteristics of the escape system based on the conditions that exist at the time of ejection, and the adaptive control of the escape-system performance throughout the escape episode. Ejection-seat subsystem design concepts being developed to implement this approach are summarized. Several crew-protection concepts are reviewed, including a method to control the risk of injury to be proportional to the life threat of specific escape conditions and a windblast protection device called the flow-stagnation fence. A means to provide real-time assessment and control of the accelerations imposed on an ejection seat's occupant is vital to the new escape system design approach. A six-degree-of-freedom acceleration exposure-limit method currently being developed to meet this requirement is presented. Author

N85-19659# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.

TOLERANCE, FATIGUE, PHYSIOLOGICAL AND PERFORMANCE EFFECTS OF SUSTAINED AND OSCILLATING LATERAL ACCELERATIONS

R. E. VANPATTEN *In* AGARD Human Factors Considerations in High Performance Aircraft 6 p (SEE N85-19653 10-54) Nov. 1984 refs

Avail: NTIS HC A09/MF A01

The advent of six degree of freedom aircraft such as the AFTI/F-16 prompted performance oriented research on the effects of sustained and oscillating lateral acceleration (+ or - Gy). The literature of classical tolerance research in lateral acceleration is reviewed as a basis for the recent centrifuge research performed at the Air Force Aerospace Medical Research Laboratory. Issues of pilot restraint, biodynamic control cross-coupling, fatigue, body positioning, and pilot performance sensitivity to lateral acceleration are discussed. Results are presented in the context of operational cockpit requirements with implications for the design and performance of future six degree of freedom fighter aircraft. Author

N85-19660# Naval Air Development Center, Warminster, Pa. Aircraft and Crew Systems Technology Directorate.

ANALYSIS OF THE TRANSIENT RESPONSE OF TEMPORAL ARTERY BLOOD FLOW DATA RELATIVE TO VARIOUS ANTI-G SUIT PRESSURE SCHEDULES

R. J. CROSBIE *In* AGARD Human Factors Considerations in High Performance Aircraft 11 p (SEE N85-19653 10-54) Nov. 1984 refs

Avail: NTIS HC A09/MF A01

A method is presented for objectively measuring the relative effectiveness of various G protective equipment or techniques by comparing the quantitative response of a subject's mean Doppler flow velocity signal to a series of modest G profiles when using each protective system in turn. The method is applied to evaluate two configurations of the Navy's new servo controlled anti-G valve in comparison with the standard ALAR valve during exposure to G profiles having various rates of G onset. Author

N85-19661# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Unternehmensgruppe Hubschrauber und Flugzeuge.

IMPACT OF FUTURE AIRCOMBAT CHARACTERISTICS ON PILOT PERFORMANCE AND COCKPIT DESIGN

K. D. RICHTER *In* AGARD Human Factors Considerations in High Performance Aircraft 15 p (SEE N85-19653 10-54) Nov. 1984 refs

Avail: NTIS HC A09/MF A01

Future medium - and short-range weapons are expected to change aircombat characteristics significantly. Medium-range (MR) weapon technology and performance will force a supersonic maneuvering type aircombat with sustained energy as well as highly dynamic character in terms of climb/descent rates and spatial position changes. All-respect capabilities of new short-range (SR) weapons will establish their employment from head-on, at least frontal hemisphere positions. The SR-aircombat is characterized by instantaneous maneuvering and is drifting to lower speeds and lower loadfactor levels. A high acceleration/reclined seat cockpit seems not necessary, if fighter design requirements are observed. The MR head-down aircombat is expected to influence pilot performance to a large degree and pose problems concerning spatial disorientation; manual versus automatic maneuvering, degree of automation; and aircraft performance monitoring and mental processing of tactical situation information. Solution requirements are postulated to divide human and system tasks. System automation and integration is discussed to reduce pilot workload and create a time margin for qualified decision-making. A tactical Information & Command System is discussed and a tactical display layout proposed. Author

N85-19662# Centre d'Etudes et de Recherches de Medecine Aerospatiale, Paris (France).

GRASP OF INFORMATION BY THE PILOT IN FUTURE COMBAT AIRCRAFT [PRISE D'INFORMATION PAR LE PILOTE DANS LES AVIONS DE COMBAT FUTURE]

G. SANTUCCI, C. VALOT, R. AMALBERTI, and J. P. MENU *In* AGARD Human Factors Considerations in High Performance Aircraft 7 p (SEE N85-19653 10-54) Nov. 1984 refs In FRENCH

Avail: NTIS HC A09/MF A01

Future combat aircraft will be complex systems. The management of such a system imposes a much more important workload which should be carried out under intense psychological constraints. There is risk of surpassing the pilot's capacities. To alleviate this, a computer would be added to the pilot's equipment. The division of tasks between these two partners, and the dialog between them, posses problems that must be defined before their solution can be found. The first of these problems must be psychological and physiological simultaneously, and of an intricate type. This approach is developed. Transl. by A.R.H.

N85-19663# *Defence Centre for* Leadership, *Copenhagen* (Denmark). Aviation Psychology Branch.
CONCEPTUAL MODEL OF CRITICAL REQUIREMENTS FOR EFFECTIVE PILOT PERFORMANCE IN HIGH PERFORMANCE AIRCRAFT
J. TERMOHLEN *In* AGARD Human Factors Considerations in High Performance Aircraft 8 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01

The conceptual model of critical job requirements of the operational Air Force pilot was updated through an interview study. Participants were pilots of varying flying experience and ranking *from colonel to lieutenant. In addition, crew members and air traffic* controllers were interviewed. The critical incident technique was used. Participants were asked to relate actual incidents demonstrating effective or ineffective pilot behavior. A total of 153 persons were interviewed; they contributed 444 incidents. Data analysis resulted in the formulation of the following action or trait categories and subcategories: (1) action power and competence (capacity, alertness, independence and will power, decisiveness, coolness); (2) knowing one's limitations and attempting not to exceed them; (3) dependability (admitting mistakes, responsibility, honesty); (4) leadership; (5) self-discipline; (6) social function and team work. The results are to be utilized in policy making by *various command and management levels and training of flight* instructors, students, and officer candidates. R.S.F.

N85-19664# *Virginia Polytechnic Inst. and State Univ., Blacksburg.* Dept. of Industrial Engineering and Operations Research
ELECTRONIC DISPLAYS: THEIR STRENGTHS AND WEAKNESSES FOR ADVANCED HIGH PERFORMANCE AIRCRAFT
H. L. SNYDER and R. H. BOGLE *In* AGARD Human Factors Considerations in High Performance Aircraft 11 p (SEE N85-19653 10-54) *Nov. 1984 refs*
Avail: NTIS HC A09/MF A01

Various aircraft cockpit display technologies are compared on the basis of maximum size, maximum spatial resolution, available colors, luminance, and luminance range. The specific technologies considered are CRT, plasma discharge, *electroluminescent, liquid* crystal, electrochromic, and light emitting diode. The technological parameters of the cockpit displays are discussed with respect to visual task compatibility and flight crew needs and performance.
R.S.F.

N85-19665# Royal Aircraft Establishment, Farnborough (England). Flight Systems Dept.
CHANGING SYSTEM AND DISPLAY CONCEPTS AND THEIR IMPACT ON AIRCREW PERFORMANCE
V. P. SCHMIT *In* AGARD Human Factors Considerations in High Performance Aircraft 11 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01

Future aircraft equipment fits and flight profiles are threatening to overload the operator's ability to accept and process the information presented to him, as direct results of an increase in *information volume and a reduction in time available. It is assumed* that, for the foreseeable future, the primary modality for information display in the cockpit should remain visual, while control inputs to the system will be mutable in modality. A number of topics relating to visually displayed information are considered: (1) visual search and system location cueing; (2) design of spatial location cueing symbology; (3) selective attention and display coding conventions; (4) design procedures for new tactical symbology; (5) information integration in flight information displays; and (6) the costs of attention switching in the flying task. Some new tactical information display concepts are discussed, and areas of research necessary to support future aircraft displays and systems are highlighted.
R.S.F.

N85-19666# Royal Air Force Inst. of Aviation Medicine, Farnborough (England).
SOME EFFECTS OF DISPLAY FORMAT VARIABLES ON THE PERCEPTION OF AIRCRAFT SPATIAL ORIENTATION
R. M. TAYLOR *In* AGARD Human Factors Considerations in High Performance Aircraft 14 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01

Aircraft head-up display (HUD) standardization should be guided by empirical evidence from studies of operator performance. The effects of HUD pitch scale design variables on pitch and roll recovery tasks were evaluated in four experiments. Design variables are identified that have significant effects on decision making performance. Recommendations are made for HUD pitch scale standardization. The findings are discussed in terms of cognitive processes involved in the perception of complex multidimensional visual stimuli. R.S.F.

N85-19667# Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
THE COCKPIT OF THE YEAR 2000: HOW BIG A STEP?
J. M. REISING and T. J. EMERSON *In* AGARD Human Factors Considerations in High Performance Aircraft 4 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01

The cockpit of the year 2000 is envisioned to be dramatically different from those of current fighter aircraft. The upcoming hardware and software available in the mid 1990s are discussed together with the impact on the pilot of having them available for use. Among the advanced technologies considered are electro-optic displays, voice control, touch sensitive overlays, programmable switches, helmet mounted displays, and artificial intelligence software. R.S.F.

N85-19668*# *National Aeronautics and Space Administration* Ames Research Center, Moffett Field, Calif.
INFLUENCE OF A PERSPECTIVE COCKPIT TRAFFIC DISPLAY FORMAT ON PILOT AVOIDANCE MANEUVERS
S. R. ELLIS, M. W. MCGREEVY, and R. J. HITCHCOCK (San Jose State Univ.) *In* AGARD Human Factors Considerations in High Performance Aircraft 9 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01 CSCL 05H

Perspective projections of cockpit displays of traffic information (CDTI) on CRTs to present vertical separation information to airline pilots were examined. The perspective projection was compared *with plan view projections of the same air traffic situations.* Comparison of the pilots' avoidance maneuvers made when using the perspective display with those made while using more the conventional plan view display showed that pilots maneuvered somewhat earlier with perspective displays. With the perspective display, they maneuvered more frequently in the vertical dimension. The bias to maneuver horizontally probably reflected the poorer presentation of vertical separation on previously used plan view traffic displays. The avoidance decisions made by pilots using both perspective and plan view displays shows fewer unsuccessful maneuvers and fewer maneuvers producing spacing violations with the perspective format. E.A.K.

N85-19669# Illinois Univ., Urbana-Champaign. Inst. of Aviation.
THE MULTIPLE RESOURCES MODEL OF HUMAN PERFORMANCE: IMPLICATIONS FOR DISPLAY DESIGN
C. D. WICKENS *In* AGARD Human Factors Considerations in High Performance Aircraft 6 p (SEE N85-19653 10-54) Nov. 1984
Avail: NTIS HC A09/MF A01

Three cognitive principles of display design proposed within the framework of the multiple resources model of human performance are described. These principles are: (1) stimulus central processing compatibility describing the optimum association *of display format to the working memory code used in performance* of a task, (2) resource competition, describing how the optimum configuration for displaying two or more sources of task information is to employ separate resources; and (3) task integration, a principle that constrains the application of the resource competition when separate stimulus elements must be integrated into a single mental model for the task. Five experiments are described that investigate *these principles in isolation and in different combinations in aviation*

related tasks. The data generally support all three principles, and indicate that compatibility is a dominant concept when placed in opposition with resource competition. E.A.K.

N85-19670*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
PILOT WORKLOAD, PERFORMANCE AND AIRCRAFT CONTROL AUTOMATION
S. G. HART and T. B. SHERIDAN (MIT, Cambridge, Mass.) *In* AGARD Human Factors Considerations in High Performance Aircraft 12 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01 CSCL 05H

Conceptual and practical issues associated with the design, operation, and performance of advanced systems and the impact of such systems on the human operators are reviewed. The development of highly automated systems is driven by the availability of new technology and the requirement that operators safely and economically perform more and more activities in increasingly difficult and hostile environments. It is noted that the operators workload may become a major area of concern in future design considerations. Little research was done to determine how automation and workload relate to each other, although it is assumed that the abstract, supervisory, or management roles that are performed by operators of highly automated systems will impose increased mental workload. The relationship between performance and workload is discussed in relation to highly complex and automated environments. E.A.K.

N85-19671# Naval Air Development Center, Warminster, Pa.
THE F-18: A NEW ERA FOR HUMAN FACTORS
S. C. MERRIMAN and J. P. MOORE (McDonnell Douglas Corp., St. Louis) *In* AGARD Human Factors Considerations in High Performance Aircraft 5 p (SEE N85-19653 10-54) Nov. 1984
Avail: NTIS HC A09/MF A01

The crew station of the Navy/Marine Corps' newest high performance tactical jet aircraft - the F/A-18 HORNET and the human factors effort involved in its development and testing are described. The F/A-18 represents the first of a new generation of military aircraft. Its development posed a host of novel man machine interface, crew station design and human factors engineering problems in need of creative solutions. Compared to other tactical jet aircraft currently serving the military, the F/A-18 is, by design, the most mission flexible and growth accommodating aircraft in the inventory. To develop the HORNET major changes in the human factors engineering approach were required. Involved are: thorough mission analyses, technology risk assessment and a step-by-step process of proof or concept in realistic mission simulators. E.A.K.

N85-19672# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
AIRCREW-AIRCRAFT INTEGRATION ISSUES IN FUTURE US ARMY HELICOPTERS
E. J. HARTZELL, E. W. AIKEN, and J. W. VOORHEES *In* AGARD Human Factors Considerations in High Performance Aircraft 16 p (SEE N85-19653 10-54) Nov. 1984 refs
Avail: NTIS HC A09/MF A01 CSCL 05H

Some human factors research issues, the resolution of which will be vital to the successful operation of future military helicopters are reviewed. Understanding and reducing the helicopter pilot's workload is examined by a diverse program directed at answering some of the more fundamental questions relating to the transfer displays and interactions between pilot and automated systems. The results of three experimental studies which address the issues of display control compatibility, characteristics of integrated controllers, and voice systems are presented. E.A.K.

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COMPUTER OPERATIONS AND HARDWARE

Includes computer graphics and data processing.

N84-34177# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
REPORT OF THE WORKING GROUP ON LARGE-SCALE COMPUTING IN AERONAUTICS
Jun. 1984 110 p
(AGARD-AR-209; ISBN-92-835-1474-2; AD-A146085) Avail: NTIS HC A06/MF A01

The economics that computational fluid dynamics have brought to aerodynamic design, in reducing the cost of wind tunnel testing and reduction in development time, are considerable. Emphasis will be placed on modelling flows of increasing complexity. There are inviscid and thin layer calculations, Reynolds averaged Navier-Stokes solutions and large eddy simulation. Three aspects of rocket technology are currently inhibited by inadequate computing resources: modelling of combustion instability; holographic diagnosis of exhaust emissions; and modelling of kinetics from flame front to exhaust nozzle. Large scale computers would allow such modelling. The use of computers in aeronautics is dependent upon the power and storage capacity of the computers, ability to generate coordinate systems for complex configurations, algorithms for the solution of flow field equations, and the capability to model turbulent flows. Transonic small perturbation methods are used to calculate transonic flows. Nonlinear field methods are used for flows over complex shapes. The finite element method is also used. For future requirements, the major task of computing facilities will come from applications in the design of aircraft, helicopters, and missiles. S.B.

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SYSTEMS ANALYSIS

Includes mathematical modeling; network analysis; and operations research.

N85-20751# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
SPACE SYSTEM APPLICATIONS TO TACTICAL OPERATIONS
Loughton, England Oct. 1984 181 p refs In ENGLISH and FRENCH Symp. held in Hampton, Va., 17-21 Oct. 1984
(AGARD-CP-344; ISBN-92-835-0357-0; AD-A151864) Avail: NTIS HC A09/MF A01

The attribute of space communication, navigation, and remote sensing systems which contribute to the effectiveness of tactical military operations are characterized and assessed. The interaction of space assets with ground and mobile resources are investigated as well as consequence operational issues. Future trends in space technology and their relationship to evolving combat needs are examined. For individual titles see N85-20752 through N85-20779.

N85-20752# Tactical Air Command, Langley AFB, Va.
TACTICAL OPERATIONS AND SPACE APPLICATIONS
T. L. CRAIG *In* AGARD Space System Applications to Tactical Operations 3 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

There are obvious benefits to be gained by tactical air forces from the use of the space frontier (not necessarily manned space forces). Increases in capabilities to communicate; observe global weather; support search and rescue; maintain surveillance, navigate precisely; and develop other technology is impressive. These space-related capabilities must be integrated with air, ground, and sea capabilities so that armed forces can interoperate effectively. Efforts to address the Soviet space-based threat using the ASAT missile, and the contributions of the NAVSATR GPS, VHSIC, on-board computers, and satellite communications are reviewed. A.R.H.

N85-20753# Air Force Space Div., Los Angeles, Calif.
US MILSATCOM: PRESENT AND FUTURE
R. H. GIBSON *In* AGARD Space System Applications to Tactical Operations 8 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The communications requirements of tactical users of U.S. Military Satellite Communications (MILSATCOM) systems are discussed, and present MILSATCOM sytstems are described. In recognition of known threats to satellite communications systems, the deficiencies in tactical military satellite communications are outlined. Then developing and planned MILSATCOM systems and the benefits of increased survivability expected to be achieved by interoperability and internetting are disucssed. Evolving technologies, especially in the new communications band extremely high frequency (EHF), and their potential payoffs are also considered. A.R.H.

N85-20754# Defense Communications Agency, Washington, D.C.
INTEGRATED SUPPORT OF TACTICAL OPERATIONS BY SATELLITE COMMUNICATIONS
W. P. MCKEE, JR. *In* AGARD Space System Applications to Tactical Operations 6 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

One of 14 key features of the architecture of worldwide digital system architecture (WWDSA) for the U.S. Department of Defense is the expanded and integrated use of satellite communications in the support of both strategic and tactical defense missions. Under the WWDSA concept, satellite connectivity will be available on an as needed and near instantaneous basis through the use of demand assignment multiple access without overtaxing satellite capacity. Satellite communications will complement the other means of connectivity; and, in some cases be used only when no other means of suitable connectivity are available as for restoral of damaged terrestrial links or for provision of temporary video circuits. A large number of small satellite Earth terminals, with an effective integrated satellite/terrestrial transmission control system, would allow satellite communications to be truly integrated with other communications media to provide increased survivability and more effective support of tactical, strategic and defense-wide operations. How WWDSA Feature L may provide integrated satellite communications support of tactical operation is considered. A.R.H.

N85-20755# Massachusetts Inst. of Tech., Cambridge.
EHF MILSATCOM SYSTEMS FOR TACTICAL USERS Abstract Only
D. R. MCELROY *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984 Sponsored by AF
Avail: NTIS HC A09/MF A01

Certain types of satellite communications (SATCOM) systems can provide features required for tactical operations. One approach involves the use of the wide bandwidth allocations in the EHF band (i.e., 30-to-50 GHz) to provide systems with larger capacities and to permit the use of robust spread spectrum modulation techniques. Evolution into these higher frequencies also offers the opportunity to incorporate signaling structures which are functionally common across multiple user communities. Such techniques provide interoperability possibilities while allowing more efficient use of spacecraft assets and minimizing the number of unique terminal developments. Furthermore, the concept departs from traditional SATCOM designs by incorporating increased satellite sophistication for reduced terminal size and complexity requirements. The associated spacecraft would employ advanced technologies such as uplink antenna discrimination, on-board signal processing, and downlink beamhopping. Several system configurations for providing EHF service to tactical users are presented, the advantage of the advanced technologies incorporated are discussed, and some spacecraft implementation possibilities are indicated. A.R.H.

N85-20756# National Defence Headquarters, Ottawa (Ontario).
TACTICAL MILITARY COMMUNICATIONS BY SATELLITE RELAY AT HIGH LATITUDES
J. COLLINS, E. DESLAURIERS, I. MATHESON, and J. OHRT *In* AGARD Space System Applications to Tactical Operations 15 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

The trend in military satellite communication for tactical purposes is towards the EHF spectrum. For currently practical power aperture levels geostationary EHF satellite communications are not considered likely to be militarily reliable for a country such as Canada. This is due to high path losses at latitudes common to Canadian operations. The use of inclined orbits to solve this problem is examined. Elliptic synchronous and semi-synchronous and low circular orbits are examined in terms of operating and tracking requirements, including rages and Doppler effects at the user terminal. It is concluded that a highly elliptic inclined semi-synchronous orbit possesses significant advantages for EHF tactical communications at latitudes common to military operations in Canada. A.R.H.

N85-20757# Signals Research and Development Establishment, Christchurch (England). Satellite Communications Centre.
UK SKYNET 4 COMMUNICATIONS SATELLITES Abstract Only
T. C. TOZER and P. H. MASTERMAN *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The UK Skynet 4 Satellites, which will provide enhanced tactical and strategic communications facilities for the British forces, is based upon the proven ECS vehicle and employs 3-axis stabilization in geostationary orbit. The total power consumption of about 1.2 kw is derived from solar panels and the on-station mass is about 660 kg. At a position of 1 w, the first satellite will be visible from Europe, the East coast of America and the Middle East. Satellite contains four wideband transparent transponders designed to handle a large number and variety of users. A number of reconfigurable antenna options may be selected, including Earth, NATO, European, and Central European cover. Another notable feature is the adaptive nulling antenna; this may be controlled by telecommand to mitigate the effect of uplink jamming. The processing channel employs a spread-spectrum uplink which is despread on the satellite to give both secure broadcast and telecommand. This self-contained receiver represents a significant achievement in on-board processing. An experimental 44 GHz receiver is incorporated with a downlink at SHF to be used for R&D purposes and to asses the potential of EHF. Some of the satellite features with their rationale are highlighted, and some likely future directions are indicated. A.R.H.

N85-20758# Admiralty Surface Weapons Establishment, Portsdown (England).
MINIMIZATION OF SYSTEM VULNERABILITY IN NAVAL SATELLITE COMMUNICATION NETWORKS Abstract Only
C. J. MADAMS *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The advent of the microprocessor readily enabled the modern implementation of complex modulations and simplified the control of communication networks and encouraged a fresh examination o the architecture employed in the United Kingdom's Naval SHF satellite communications. The principle of the present SATCOM organization, including threat scenarios are discussed. Models are developed that are both compatible with current operational practice and future requirements. The concept of system distribution is then applied, the path of a signal being traced from operational origin to destination. The vulnerability of each path node is discussed and countermeasures which include alternate modes that minimize weakness are described. Such a treatment leads to an enhanced traffic capacity and realizes a system which is readily expanded to meet changing/increased requirements. It also impinges on build standard criteria and can lead to a more economic solution than currently practiced. Author

N85-20759# Ferranti Electronics Ltd., Poynton (England).
THE FERRANTI TACTICAL SHF SATCOM STATION (MANSAT) Abstract Only
I. L. WESTALL and A. S. MCKANDERSON *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The Communications Group of the Royal Signals and Radar Establishment (RSRE) Malvern, England, pioneered development of small tactical SHF (7 GHz to 8 GHz) satellite ground terminals. The concept of an SHF terminal small enough to be carried on a man's back was further developed. Field trials models weighing 17 Kg including antenna, power supply and carrying frame were manufactured and extensively trailed in field conditions. As currently configured, the equipment provides either 50 bit/sec. telegraph or analogue speech (both duplex). A digital secure speech facility is currently being developed. Depending on the satellite antenna system in use the terminal can either be worked to a main satellite ground station or another small station. The equipment characteristics allow it to operate freely with the SKYNET, DSCS and NATO satellites. The performance of the station and its principal components are outlined, together with current developments. Author

N85-20760# Marconi Space and Defence Systems Ltd., Bushey (England).
TACTICAL SATELLITE TERMINALS FOR LAND AND AIRBORNE C3 APPLICATIONS Abstract Only
P. A. LAW and D. CUMMINGS *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The increasing RF power that has become available from the growth in size of satellites over the years was used by the owners of satellite systems in a number of different ways. Civil authorities such as PTTs and Commercial Carriers have used the extra power for increased channels and for higher data rate services, third world nations have benefited from simpler and cheaper earth stations and the military have developed a whole range of small terminals for tactical use. The operational need for long distance, continuously available, error-free communication and the melding of Communications with Command and Control is discussed. Ground satellite terminals in use and in development are described and their technical characteristics discussed. Current work on a satellite terminal for the Nimrod long range maritime patrol aircraft are described. Techniques employed such as spread-spectrum modulation and frequency hopping for terminals operating in the military SHF satellite band are considered. B.W.

N85-20761# Air Force Space Div., Los Angeles, Calif.
THE GLOBAL POSITIONING SYSTEM (GPS): PROGRAM STATUS UPDATE Abstract Only
W. H. JONES *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The Global Positioning System (GPS) has the capability to passively provide position location to within a 15 meter SEP on a worldwide, day or night, all weather basis. It can also provide better than 100 nanosecond timing accuracy and 0.1 meter per second velocity accuracy. The system's capabilities offer a wide range of military applications and will enable users to operate with enhanced performance. The system consists of a space segment, control segment, and user segment. The GPS program proceeded into full-scale development in 1979 after a highly successful concept validation phase. Field testing of the user equipment began in January 1983, and the DSARC 3 production decision is scheduled for May 1984. A status update of each of the three segments is presented, including system capabilities, test results, schedule, and future plans. Some special system features and logistics and operational considerations are addressed. User equipment development and testing are given primary emphasis. B.W.

N85-20762# Aerospace Corp., Los Angeles, Calif.
GPS SYSTEM FIELD TESTING
J. M. CLIFFORD *In* AGARD Space System Applications to Tactical Operations 17 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The test program for Global Positioning System GPS Phase User Equipment (UE) is extensive. It includes seven different kinds of tests ranging from in-plant tests to initial operational test and evaluation. They differ by time, purpose, and test agency. Field development, tests, and evaluation (DT&E) tests are described. B.W.

N85-20763# Air Force Space Div., Los Angeles, Calif.
POTENTIAL IMPACT OF NAVSTAR GPS ON NATO TACTICAL OPERATIONS
E. M. PRICE and B. SPROSEN *In* AGARD Space System Applications to Tactical Operations 5 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The NAVSTAR Global Positioning System was created when the United States Deputy Secretary of Defense directed that separate efforts by the U.S. Navy and the U.S. Air Force to develop a satellite-based navigation system be combined into a single program and placed under the executive control of the USAF. In 1978, at the invitation of the United States, nine NATO nations joined the project by establishing a NATO team at the NAVSTAR Joint Program Office. NATO involvement in the program is discussed and some of the unique, operationally significant features of the system are presented. A few representative operational scenarios where the benefits of NAVSTAR would be particularly useful are presented. B.W.

N85-20764# Aerospace Corp., Los Angeles, Calif.
COVERAGE AND BUILDUP OF THE NAVSTAR CONSTELLATION
P. KRUH *In* AGARD Space System Applications to Tactical Operations 10 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

NAVSTAR is now in Phase 2, the full-scale engineering phase. During this phase, a constellation is being maintained with four to five vehicles to support testing. A buildup of the constellation of 18 space vehicles and three active spares will begin in 1986 and will take approximately 2 years to complete. The coverage with the operational constellation is discussed and the factors that determine a strategy for the buildup are detailed. Information on the navigation capabilities that will be available during the transition from the test to the operational constellation is provided. The test configuration provides several hours of navigation coverage over selected regions of the Earth. As the constellation is built up, availability to users will increase in both duration and in the areas of coverage on Earth. About midway through the buildup, complete worldwide, two-dimensional navigation coverage will be achieved. The performance measures, the constraints, and the objectives used in determining the buildup strategy are all discussed. The performance achieved during the buildup using a candidate strategy is presented. B.W.

N85-20765# Tactical Air Command, Langley AFB, Va.
TACTICAL APPLICATIONS OF GPS USER EQUIPMENT Abstract Only
G. M. BARBEE *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The Global Positioning System GPS user equipment is described with emphasis on system strengths and weaknesses which affect its tactical applications. GPS operation is discussed as well as signal outages, selective availability, jamming scenarios, and vulnerability. Previous test results, expected future testing and demonstrated capabilities such as passive rendezvous, precision runway approach and blind bombing are described. Integration and aircraft installation programs are also addressed along with rationale for TAF GPS aircraft priorities, concepts of operations for search and rescue, special operations, reconnaissance and master navigation plan impacts. B.W.

N85-20766# Air Force Space Div., Los Angeles, Calif.
DEFENSE METEOROLOGICAL SATELLITE PROGRAM (DMSP)
J. A. CURTIS and C. P. ARNOLD, JR. *In* AGARD Space System Applications to Tactical Operations 4 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The Defense Meteorological Satellite Program (DMSP) is a total satellite system composed of spacecraft with meteorological sensors, an Earth-based command and control network, fixed and mobile user stations, and a communication network linking the various segments together. The mission of DMSP is to provide global meteoroloical data to Tri-Service Commanders in support of worldwide military operations, both strategic and tactical, and to advance spaceborne meteorological sensing technology to meet changing Department of Defense requirements. B.G.

N85-20767# Air Weather Service, Scott AFB, Ill.
MILITARY APPLICATIONS OF METEOROLOGICAL SATELLITE (METSAT) DATA
N. P. RAUSCHER In AGARD Space System Applications to Tactical Operations 3 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The military applications of METSAT data and, in particular, Air Weather Service's (AWS) processing and use of data from the US Department of Defense METSAT, the polar-orbiting Defense Meteorological Satellite Progam (DMSP) are addressed. The primary mission of AWS is to support US Air Force and US Army operations. In modern warfare, the presence or absence of clouds directly impacts the ability to successfully and economically perform the military missions, and with the recent development of extremely expensive cloud-sensitive weapon systems, the accuracy of cloud information assumes an even greater role. AWS processes and uses all available data to satisfy mission requirements. Peacetime cloud data sources include the DMSP, NOAA polar orbiting and geostationary satellites, worldwide surface and upper air weather data, and foreign geostationary METSATs. In wartime, the Defense Meteorological Satellite Program may be the only consistent source of meteorological data. DMSP provides data to AWS in two modes - direct readout and recorded. Direct readout data are received through transportable terminals on land and sea and provide direct cloud imagery support to Army and Air Force field commanders and Navy operations afloat. Recorded DMSP data received at the Air Force Global Center (AFGWC) and the Fleet Numerical Oceanography Center (FNOC) are processed and used to support worldwide operations such as joint military exercises, aerial refueling missions and many more. Author

N85-20768# National Oceanic and Atmospheric Administration, Washington, D. C.
CIVIL WEATHER SATELLITE SYSTEMS
D. B. MILLER *In* AGARD Space System Applications to Tactical Operations 10 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

An overview of the presently operating U.S. civil weather satellites, their space and ground systems and their data distribution systems is provided. Examples of the data products available from the satellites are provided with emphasis on their potential application to the support of tactical operations. The products from the civil weather satellites include multi-spectral imagery on several time and space scales and quantitative products that are of use in providing weather support to tactical planners. The present DoD-Civil weather satellite cooperative arrangements are reviewed with a discussion of the shared processing arrangements currently being implemented. A brief overview of international weather satellite coordination is also provided. An outlook of future trends in the development of future civil weather satellite systems is also provided. B.G.

N85-20769# Meteorological Office, Bracknell (England).
METEOROLOGICAL AND OCEANOGRAPHIC SUPPORT DURING THE FALKLANDS CONFLICT
I. J. W. POTHECARY and J. MARSH *In* AGARD Space System Applications to Tactical Operations 7 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

During Operation Corporate the United Kingdom faced the task of making opposed landings on South Georgia and the Falkland Islands 8,000 miles from the home base in the advancing southern winter. Meteorological and oceanographic support of a high standard was provided throughout the conflict because of the availability of data from orbiting (NOAA-6 and NOAA-7) and geostationary (GOES-E and METEOSAT) weather satellites. The Meteorological Office 15-level global atmosphere numerical model was brought into routine use to cover the South Atlantic, four months ahead of schedule. Satellite temperature soundings (SATEMs) from the Tiros Operational Vertical Sounders (TOVS) on NOAA-6 and NOAA-7 provided essential data for the numerical model. Under a special arrangement with the United States at a later stage in the conflict successive NOAA-6 and NOAA-7 Advanced High Resolution Infra-Red (AVHRR IR) passes over the South Atlantic and South America were combined into composite pictures and the data was transmitted to the United Kindgom. The composites were used to select areas of special interest which were then examined at up to full resolution. Processed data included multi-spectral color images and sea surface temperature profiles which were invaluable in positioning units of the Task Force to take maximum advantage of oceanographic, sea fog or cloud conditions. Author

N85-20770# Royal Aircraft Establishment, Farnborough (England) Space and New Concepts Dept.
DEVELOPMENT OF SATELLITE DATA PRESENTATION FOR ENVIRONMENTAL FORECASTING
D. W. S. LODGE and M. R. ROSWELL *In* AGARD Space System Applications to Tactical Operations 13 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

The techniques developed during and since the operation to recover the Falkland Islands using image processing to enhance the value of meteorological satellite images for environmental forecasting are discussed. Data were used from METEOSAT, GOES-E and NOAA 7 AVHRR. Among the methods adopted were the production of time-lapse sequences of images and multi-temporal color composites for the analysis of weather system dynamics, multi-spectral color composites for cloud type identification and radiance temperature measurements used for sea surface temperature measurement, ice detection and fog discrimination. Some of the problems encountered are described and how they were overcome. The image processing system used was prototype for a Satellite Environmental Data Acquisition System about to enter service with CINCFLEET Weather and Oceanographic Center. Author

N85-20771# Naval Air Station, Norfolk, Va. Eastern Oceanography Center.
PRACTICAL APPLICATIONS OF SATELLITE-DERIVED METEOROLOGICAL AND OCEANOGRAPHIC DATA IN NAVAL OPERATIONS
C. A. WEIGAND *In* AGARD Space System Applications to Tactical Operations 8 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

Environmental data derived from satellites give the military commander critical information upon which to base decisions. Since the air-ocean environment can significantly alter the performance of today's technologically-advanced weapons and sensors, the military commander must have access to all factors affecting them. The Satellite-data Processing and Display System (SPADS) at the Naval Eastern Oceanography Center in Norfolk, Virginia is a computer-based system which produces high quality, real time satellite imagery and data with which to assess meteorological and oceanographic conditions. SPADS allows the tactical analyst to receive imagery in real time, process and display it and interact with the image to maximize extraction of relevant data. The system is described and case examples are discussed which demonstrate the capabilities of such a system and show how satellite imagery can be applied to various operational situations. Author

N85-20772*# National Aeronautics and Space Administration, Washington, D.C.
STATUS OF THE NATIONAL SPACE TRANSPORTATION SYSTEM Abstract Only
J. A. ABRAHAMSON *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01 CSCL 22B

The National Space Transportation System is a national resources serving the government, Department of Defense and

commercial needs of the USA and others. Four orbital flight tests were completed July 4, 1982, and the first Operational Flight (STS-5) which placed two commercial communications into orbit was conducted November 11, 1982. February 1983 marked the first flight of the newest orbiter, Challenger. Planned firsts in 1983 include: use of higher performance main engines and solid rocket boosters, around-the-clock crew operations, a night landing, extra-vehicular activity, a dedicated DOD mission, and the first flight of a woman crew member. By the end of 1983, five commercial payloads and two tracking and data relay satellites should be deployed and thirty-seven crew members should have made flights aboard the space shuttle. Author

N85-20773*# National Aeronautics and Space Administration, Washington, D.C.
SHUTTLE/CENTAUR UPPER STAGE CAPABILITY
H. J. CLARK *In* AGARD Space System Applications to Tactical Operations 5 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01 CSCL 22B

A joint project to design, develop, procure, and produce Centaur upper stages for use with the Space Shuttle is discussed. A common Centaur G stage 6 meters (19.5 feet) in length is being jointly developed. A longer version designated Centaur G Prime is being developed by NASA to accomplish the Galileo and International Solar-Polar Mission flights in 1986. The Centaur G and G Prime will have the capability to place, respectively, approximately 4540 kilograms (10,000 pounds) and 5910 kilograms (13,000 pounds) into geosynchronous orbit from a standard Shuttle parking orbit of 278 kilometers (150 nautical miles) and Shuttle performance (lift) capability 29,500 kilograms (65,000 pounds). The advent of high energy upper stage capability in 1986 will permit space users and spacecraft developers to utilize spacecraft growth, stage combination concepts with storage modules, teleoperator systems, and other mission peculiar devices to satisfy complex mission demands. These capabilities should greatly enhance the usefulness of the space environment and stimulate mission planners toward conception of innovative means to meet ever increasing mission requirements. R.J.F.

N85-20774# Centre National d'Etudes Spatiales, Paris (France)
THE ARIANE FAMILY [LA FAMILLE ARIANE]
R. VIGNELLES *In* AGARD Space System Applications to Tactical Operations 6 p (SEE N85-20751 11-66) Oct. 1984 In FRENCH; ENGLISH summary
Avail: NTIS HC A09/MF A01

The development of the ARIANE launch vehicle was completed with the success of two qualification launches. This program led to an operational vehicle able to launch payloads of about 1800 kg on transfer to geostationary orbit. Two complementary development phases were decided in order to optimize the launch vehicle with respect to the evolution of payloads and thus to increase competitivity. The ARIANE 3 model is able to launch 2600 kg in transfer and is scheduled to begin operations in 1983. The ARIANE 4 has six different models for payloads ranging from 2000 kg to 4300 kg and will be available at the end of 1985. In parallel, the commercial credibility of ARIANE launch vehicles is being increased by the completion of the second launch pad in Kourou (French Guyana) that will start operations at the beginning of 1985. R.F.J.

N85-20775# Ford Aerospace and Communications Corp., Sunnyvale, Calif.
COMBAT CAPABLE SPACE SYSTEMS FOR TACTICAL SUPPORT
J. O. COCHRAN *In* AGARD Space System Applications to Tactical Operations 7 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

An overall strategy for providing a dispersed, survivable space system in response to projected Soviet threat capabilities is described. The physical and electro-optical threats are briefly outlined and countermeasures proposed. Strategies designed to deploy an interconnected space/ground complex so large that attack becomes impractical in terms of resources required for effective neutralization are emphasized. Recognizing that space systems exist only to support ground functions dictates that ground networks must also operate in crisis periods. Though a few large ground facilities may be justified as cost-effective in peacetime, these same facilities become critical choke points in wartime. These vulnerable nodes must be augmented by a dispersed network of interoperable mobile ground terminals such as the Transportable/Mobile Ground Station (T/MGS) capable of supporting a wide range of satellites, and the Single Channel Objective Tactical Terminal (SCOTT) which can bring survivable space support directly to troops in the field. R.J.F.

N85-20776# Centre National d'Etudes Spatiales, Paris (France). Applications Program Division
THE SPOT OPERATIONAL REMOTE SENSING SATELLITE SYSTEM: CURRENT STATUS AND PERSPECTIVES
G. BRACHET *In* AGARD Space System Applications to Tactical Operations 13 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The SPOT program, comprising Earth observation satellites and ground receiving stations is discussed. The first satellite, due for launch in 1985, will carry a payload of two identical high resolution visible instruments using CCD linear arrays technology. These will make images of the Earth with sampling step of 20 meters in three color bands in the visible range and in the near infrared, and with a sampling step of 10 meters in a broad, panchromatic band i.e., in black and white. This configuration is suitable for observing the small agricultural plots found in many countries. It also satisfies some conventional cartographic requirements. Sidelooking capability will allow the satellite to observe any region of the Earth at intervals of one to several days, thus allowing relatively fast changing phenomena to be monitored. It will also be possible to provide for stereoscopic vision by associating views taken from different angles. R.J.F.

N85-20777# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany)
THE ESA REMOTE SENSING SATELLITE SYSTEM (ERS-1)
E. H. VELTON *In* AGARD Space System Applications to Tactical Operations 11 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

The ERS-1 remote sensing system is presently in the definition phase. The system development will start in early 1984, launch of the first satellite is planned for mid 1988 from Guyana Space Centre by the European launcher ARIANE. The ERS-1 system development will be performed jointly by the member states of the European Space Agency together with Norway and Canada. Mission objectives, system elements, instruments, data processing, and ground support are discussed. R.J.F.

N85-20778# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
A MODERN APPROACH OF A SYNTHETIC APERTURE RADAR PROCESSOR AND ITS TECHNOLOGICAL ASPECTS
H. FROEHLICH and R. SCHOTTER *In* AGARD Space System Applications to Tactical Operations 7 p (SEE N85-20751 11-66) Oct. 1984 refs
Avail: NTIS HC A09/MF A01

A flexible hardware concept is presented which allows the handling of high speed image processing tasks. The concept is applied to a realtime synthetic aperature radar (SAR) processor covering C-band ERS-1 as well as X-band radar data. SAR principles, the SPECAN-algorithm which is made use of in the processor breadboard, some of the basic hardware processing modules, and performance data are described. The performance data show that high speed image processing can be implemented at low power consumption and small volume. Due to the universal concept, cost can also be kept down for this class of processing tasks. R.J.F.

N85-20779# National Aeronautics and Space Administration, Washington, D.C.
EARTH RESOURCES RESEARCH USING THE SHUTTLE IMAGING RADAR SYSTEM Abstract Only
R. MONSON and C. ELACHI (JPL) *In* AGARD Space System Applications to Tactical Operations 1 p (SEE N85-20751 11-66) Oct. 1984
Avail: NTIS HC A09/MF A01

The Shuttle Imaging Radar (SIR) is an L-band synthetic radar that transmits and receives horizontally polarized microwave radiation. It was originally launched on the second Shuttle test flight (STS-2) in November 1981 with the antenna depression angle fixed at 43 deg. In this configuration, the radar system was referred

to as SIR-A, and it collected more than then a million square kilometers of Earth imagery in a variety of areas situated between 38 deg north and south latitude. SIR-A data was optically recorded onboard the Shuttle, and it was subsequently correlated on the ground to produce imagery with a 50 kilometer swath width and a surface resolution of approximately 40 meters. The SIR is presently being upgraded into a new configuration termed SIR-B, in which the radar's antenna can be mechanically rotated in the Shuttle's payload bay during an orbital mission. SIR-B is currently scheduled for flight on the seventeenth Shuttle mission (STS-17) that is tentatively planned for August 1984. In its new configuration, the SIR-B can be used to image selected regions at different angles of incidence ranging from 15 deg to 60 deg (as measured from the local vertical). In principle, multiple incidence angle radar imagery of selected areas can be coregistered and used to differentiate surficial materials on the basis of their roughness characteristics. This procedure is conceptually similar to the use of multispectral imagery acquired at shorter wavelengths to discriminate surficial materials on the basis of their pigmentation.
R.J.F.

N85-29686*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
EXTRACTION OF AERODYNAMIC PARAMETERS FOR AIRCRAFT AT EXTREME FLIGHT CONDITIONS
K. W. ILIFF May 1985 24 p refs Presented at the AGARD Symp. on Unsteady Aerodyn. Fundamentals and Appl. to Aircraft Dyn., Goettingen, West Germany, 6-9 May 1985
(NASA-TM-86730; H-1290; NAS 1.15:86730; AGARD-PAPER-24) Avail: NTIS HC A02/MF A01 CSCL 12B

The maximum likelihood estimator has been used to extract stability and control derivatives from flight data for many years. Most of the literature on aircraft estimation concentrates on new developments and applications, assuming familiarity with basic concepts. This paper briefly discusses the maximum likelihood estimator and the aircraft equations of motion that the estimator uses. The current strength and limitations associated with obtaining flight-determined aerodynamic coefficients in extreme flight conditions is assessed. The importance of the careful combining of wind tunnel results (or calculations) and flight results and the thorough evaluation of the mathematical model is emphasized. The basic concepts of minimization and estimation are examined for a simple computed aircraft example, and the cost functions that are to be minimized during estimation are defined and discussed. Graphic representations of the cost functions are given to help illustrate the minimization process. Finally, the basic concepts are generalized, and estimation of stability and control derivatives from flight data is discussed. Author

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OPTICS

Includes light phenomena.

N85-26367# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
TECHNICAL EVALUATION REPORT ON AVIONICS PANEL SPECIALISTS' MEETING ON DIGITAL OPTICAL CIRCUIT TECHNOLOGY
H. M. GIBBS (Arizona Univ., Tucson) Loughton, England Feb. 1985 12 p refs
(AGARD-AR-202; ISBN-92-835-1484-X; AD-A156037) Avail: NTIS HC A02/MF A01

The research and development status of optical circuit technology is presented and its relevance in the broad context of digital processing, communication, radar, avionics, and flight control implementation is examined. Materials for devices are considered as well as etalons, waveguides, and optics in computers. Recommendations for future efforts are offered. A.R.H.

N85-29757# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Avionics Panel.
DIGITAL OPTICAL CIRCUIT TECHNOLOGY
B. L. DOVE, ed. (NASA. Langley Research Center) Loughton, England Mar. 1985 222 p refs Symp. held in Schliersee, West Germany, 11-12 Sep. 1984
(AGARD-CP-362; ISBN-92-835-1485-8; AD-A156906) Avail: NTIS HC A10/MF A01

The Proceedings for the 48th Meeting of the AGARD Avionics Panel contain the 18 papers presented a Technical Evaluation Report, and discussions that followed the presentations of papers. Seven papers were presented in the session devoted to optical bistability. Optical logic was addressed by three papers. The session on sources, modulators and demodulators presented three papers. Five papers were given in the final session on all optical systems. The purpose of this Specialists' Meeting was to present the research and development status of digital optical circuit technology and to examine its relevance in the broad context of digital processing, communication, radar, avionics and flight control systems implementation. For individual titles see N85-29758 through N85-29775.

N85-29758# Heriot-Watt Univ., Edinburgh (Scotland). Dept. of Physics.
OPTICALLY BISTABLE DEVICES USING INSB
S. D. SMITH, F. A. P. TOOLEY, A. K. WALKER, J. G. H. KAR, and B. S. WHERRETT *In* AGARD Digital Opt. Circuit Technol. 9 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

InSb etalons operated at 77 K and illuminated by CO lasers (5.5 micrometers) exhibit CW optical bistability. A wide range of experiments were performed to permit the basic characterization of these devices and to demonstrate their various potential applications. The latter include signal amplification, modulation and, with external switching, the construction of logic gates. Two devices on a single etalon have now been coupled to form a simple all-optical circuit. New results were also obtained with InSb at room temperature using pulsed CO2 lasers (10.6 micrometers). Author

N85-29759# Johann-Wolfgang-Goethe-Univ., Frankfurt am Main (West Germany). Physikalisches Inst.
OPTICALLY NONLINEAR AND BISTABLE BEHAVIOUR OF DIRECT GAP SEMICONDUCTORS
C. KLINGSHIRN, K. BOHNERT, H. KALT, and K. KEMPF (LITEF) *In* AGARD Digital Opt. Circuit Technol. 14 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

The optical properties of semiconductors, i.e., the spectra of absorption and refraction are determined in the vicinity of the absorption edge by exciton states. At low light intensities, the optical properties of a sample are independent of the incident light power. This is the regime of linear optics. Under illumination with strong light fields, generally from lasers, the optical properties become intensity dependent. These so called nonlinear optical phenomena can be detected by various experimental techniques like laser induced grating spectroscopy or excite and probe beam techniques. From the experimental data, the physical origin of the nonlinearities may be deduced. The most important contributions are with increasing excitation a broadening of the exciton resonances, transitions to the biexciton and finally the phase transition to an electron-hole plasma. Some of these excitation induced variations of the optical properties can be used to achieve optical bistability. Various types of absorptive and dispersive bistability were found. These optically bistable devices promise interesting possibilities for application as digital memories or as elements for logical operations. Author

N85-29760# Royal Signals and Radar Establishment, Malvern (England).
OPTICAL BISTABILITY IN CD(X)HG(1-X)TE
A. MILLER, D. CRAIG, G. PARRY (Univ. College, London), J. G. H. MATHEW, and A. K. KAR *In* AGARD Digital Opt. Circuit Technol. 11 p (SEE N85-29757 18-74) Mar. 1985 refs Prepared in cooperation with Heriot-Watt Univ., Edinburgh
Avail: NTIS HC A10/MF A01

The origin and characteristics of nonlinear effects in CdHgTe Fabry-Perot etalons at 10.6 micrometers which arise from large

intensity dependent refractive index changes are discussed. Optical switching and bistability were observed in room temperature samples by two photon excitation. The band gap dependencies of these phenomena are analyzed. Author

N85-29761# Heriot-Watt Univ., Edinburgh (Scotland). Dept. of Physics.
OPTICAL MODULATORS AND BISTABLE DEVICES USING MOLECULAR GASES
R. G. HARRISON, W. J. FIRTH, I. A. AL-SAIDI, and E. CUMMINS *In* AGARD *Digital Opt. Circuit Technol. 8 p* (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

That so-called bistable nonlinear Fabry-Perot resonators can actually exhibit a rich variety of instabilities is predicted; in particular the resonator can convert a steady input field into an oscillatory or even chaotic output field. Oscillation itself leads to a passive all optical laser modulator device tunable in frequency in the range of approximately 1 GHz with anticipated applications in optoelectronics and telecommunications. The unique advantages of molecular gases as nonlinear media in these systems was utilized in successfully demonstrating these effects using pulsed CO2 laser radiation, the results of which are in excellent accord with theory, analysis also showing that prospects for CW operation are promising. Author

N85-29762# Plessey Research (Caswell) Ltd., Towcester (England). Allen Clark Research Centre.
AN EXPERIMENTAL NONLINEAR OPTICAL WAVEGUIDE DEVICE
I. BENNION, M. J. GOODWIN, D. J. ROBBINS, and J. STEWART *In* AGARD Digital Opt. Circuit Technol. 9 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

An experimental nonlinear optical waveguide device is described which comprises a glass optical waveguide surmounted by CS2. Intensity-dependent hysteresis in the power guided by the structure was observed which is related to the intensity-dependent refractive index of the overlayer. The surface of a planar optical waveguide is contacted to a nonlinear medium to produce a nonlinear interface in a simple waveguide format. It is anticipated that a waveguide configuration, being compact and capable of achieving the high optical intensities required for nonlinear optics from a source of relatively modest power output, might form the basis for a device employing this effect. The waveguide nonlinear interface using a plane wave approach similar to that employed by Kaplan for the bulk case was analyzed. The analysis shows that for the TE modes of the waveguide a straightforward generalization of linear slab waveguide theory leads to modes parameterized by the power flow in the waveguide in the nonlinear case. The plane wave theory of the waveguide device is summarized, and the experimental results are described. E.R.

N85-29763# *Army Missile Lab., Redstone Arsenal, Ala.*
STATIONARY PROPERTIES AND SWITCHING CHARACTERISTICS OF DISPERSIVE OPTICAL BISTABILITY IN CUCL
C. M. BOWDEN, J. W. HAUS (National Research Council), and C. C. SUNG *In* AGARD Digital Opt. Circuit Technol. 10 p (SEE N85-29757 18-74) Mar. 1985 refs Prepared in cooperation with Alabama Univ., Huntsville
Avail: NTIS HC A10/MF A01

The stationary properties are presented for optical bistability (OBO from a semiclassical exciton-biexciton model for CuCL in the limit of large Fresnel number. Numerical solutions using the second-order Maxwell's equation (EX) are compared with corresponding solutions where the slowly varying envelope approximation (SVEA) has been made. In addition, the Ex and SVEA results are compared with the corresponding mean-field results (MFA). It is found that results obtained using the SVEA are in close quantitative agreement with those using the second-order Maxwell's equation (EX results), whereas the MFA results are in qualitative agreement only. On the basis of the close quantitative agreement between the SVEA and EX results, we use the SVEA hierarchy of equations to numerically compute dynamics of switching as the input field is varied. The calculation is done without adiabatic elimination, which is not valid for OB in CuCL. Our main conclusions are that the OB in CuCL in steady state can be characterized very closely as a Kerr type nonlinearity and that the switch-down time is approximately equal to the switch-up time which is close to 80 psec at the laser photon energy 3177 mev. The switching time correlates with the polariton lifetime in the material and this has significant consequences for the switching characteristics in dispersive media. Author

N85-29764# Army Missile Lab., Redstone Arsenal, Ala.
CAVITYLESS OPTICAL BISTABILITY IN SYSTEMS OF TWO-LEVEL ATOMS
C. M. BOWDEN and F. A. HOPF *In* AGARD Digital Opt. Circuit Technol. 8 p (SEE N85-29757 18-74) Mar. 1985 refs Prepared in cooperation with Arizona Univ., Tucson
Avail: NTIS HC A10/MF A01

The local field correction (LFC) is used to eliminate the local field in the macroscopic semiclassical density matrix for a collection of homogeneously broadened, two level atoms interacting with the radiation field, which is described by Maxwell's equation. The system of equations is solved in steady state with the boundary conditions for a plane wave normally incident on the dense absorbing medium of propagation length much less than a resonance wavelength. Optical bistability (OB) is predicted, based upon adiabatic or steady state conditions. As a test of the validity of the predictions, results are reported using a semiclassical heuristic microscopic model with fluctuations for a collection of a finite number of electric field driven, two level atoms. In this case no LFC is needed and none is made; however, OB is observed consistent with the predictions from the steady state macroscopic model. Author

N85-29765# Arizona Univ., Tucson. Optical Sciences Center.
PROSPECTS FOR PARALLEL NONLINEAR OPTICAL SIGNAL PROCESSING USING GAAS ETALONS AND ZNS INTERFERENCE FILTERS
H. M. GIBBS, J. L. JEWELL (Bell Telephone Labs., Inc., Holmdel, N.J.), Y. H. LEE, A. MACLEOD, G. OLBRIGHT, S. OVADIA, N. PEYGHAMBARIAN, M. C. RUSHFORD, M. WARREN, D. A. WEINBERGER et al. *In* AGARD Digital Opt. Circuit Technol. 5 p (SEE N85-29757 18-74) Mar. 1985 refs Prepared in cooperation with Bell Telephone Labs., Inc., Murray Hill, N.J.
Avail: NTIS HC A10/MF A01

Micron thick semiconductor etalons perform logic operations using input beams of a few mW. Problems associated with the parallel operation of thousands of etalons are discussed. GaAs and ZnS appear to be the most attractive materials for low power room temperature operation. GaAs etalons and ZnS interference filters are both attractive for multiple beam nonlinear optical signal processing. Clearly it is highly desirable to reduce the switching power and heat generated in each pixel. Meanwhile the present values are low enough to pursue the other problems of generating multiple beams and developing useful architectures. Author

N85-29766# Heriot-Watt Univ., Edinburgh (Scotland).
ALL-OPTICAL LOGIC GATES WITH EXTERNAL SWITCHING BY LASER AND INCOHERENT RADIATION
S. D. SMITH, F. A. P. TOOLEY, A. C. WALKER, J. G. H. MATHEW, M. TAGHIZADEH, and B. S. WHERRETT *In* AGARD Digital Opt. Circuit Technol. 8 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

Nonlinear Fabry-Perot etalons, with bistable or stepped characteristic, were shown to act as logic gates and hence provide a basis for all-optical digital computing. Experimental studies have demonstrated coupling of these gates, a range of external switching possibilities and both infrared and visible wavelength operation. These successfully show at the simplest level, the feasibility of this concept. The infrared carrier wavelength and processing system could readily utilize an array of 1,000 elements in 1 sq. cm of InSb which, switching in approximately 100 ns, implies a data rate of 10 to the 11th power bits/sec. A total input power of the order 1 W would not all be dissipated in the device. In practice other operating wavelengths, and hence materials, will be necessary to ensure full exploitation of these techniques. With the rapidly expanding data communication rates permitted by fiber-optic networks the advantages of using wide band all-optical processing techniques in the link interfaces could be considerable. Similarly, all-optical processing of visual information could prove extremely efficient in, for example, robotics applications. Author

N85-29767# Thomson-CSF, Orsay (France). Lab. Central de Recherches.
INTEGRATED ELECTROOPTICAL COMPONENTS USING DIELECTRIC SUBSTRATES
M. PAPUCHON, Y. BOURBIN, S. VATOUX, and C. PUECH *In* AGARD Digital Opt. Circuit Technol. 8 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

After a brief review on the different configurations which have been used to obtain modulators and switches, recent progress is discussed. In addition, the use of these electrooptical devices in optoelectronic feed back loops is described. In particular experiments using interferometric modulators showed the interesting properties of such configurations for optical comparison, linearization of the response of the modulator and different amplification. Remote control of an electrooptical directional coupler is also described. Then the use of an optical comparator in a channel of an A/D electrooptical converter is presented.
R.J.F.

N85-29768# British Telecom International (England). Research Labs.
THE POTENTIAL OF SEMICONDUCTORS FOR OPTICAL INTEGRATED CIRCUITS
S. RITCHIE and A. G. STEVENTON *In* AGARD Digital Opt. Circuit Technol. 20 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

Optical circuits made with semiconductors should eventually have considerable performance, reliability and cost benefits over similar components made with many alternative materials, because of the ability to integrate waveguide devices with optical sources, detectors and electronic circuitry. Although, at present, the performance of semiconductor waveguide devices is inferior to that of devices made with lithium niobate, progress is rapid and there seem no fundamental reasons why semiconductor devices should not eventually give performance comparable with many non-semiconductor devices. A wide range of semiconductor optical and electronic devices will be available for integration in semiconductor optical integrated circuits, but considerable technological developments are needed - especially in epitaxial growth.
Author

N85-29769# Cambridge Univ. (England). Engineering Dept.
MULTIPORT OPTICAL DETECTORS
N. G. WALKER and J. E. CARROLL *In* AGARD Digital Opt. Circuit Technol. 13 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

At microwave frequencies the application of multiport junctions to making phase and amplitude measurements is well established. In this technique unknown signals are combined in a multiport to give a number of output signals. Monitoring the power at each output port then enables the required signal information to be deduced. Here the equivalent optical measurements made when a number of light beams are mixed in a lossless junction and then detected using photoemissive devices is investigated. This is called optical multiport detection by analogy with the microwave theory. Applications of some optical multiports to various phase and amplitude measurement problems are discussed. The quantum theory multiport detection is introduced, and the quantum operator corresponding to the complex amplitude measurement made by a particular multiport is presented. It is not known how to realize practically a measurement of the quantum maximum likelihood phase estimator, however the performance of the multiport operator in measuring phase comes within seventy percent of this limit.
R.J.F.

N85-29770# Standard Elektrik Lorenz A.G., Stuttgart (West Germany). Research Center.
PICOSECOND PHOTOCONDUCTIVE DEVICES FOR 10 GBIT/S OPTOELECTRONIC SWITCHING
G. VEITH *In* AGARD Digital Opt. Circuit Technol. 14 p (SEE N85-29757 18-74) Mar. 1985 refs Sponsored by Max-Planck-Gesellschaft, Deutsche Forschungsgemeinschaft, and Technische Univ. Wien
Avail: NTIS HC A10/MF A01

Semiconductor materials with a high density of recombination and trapping centers exhibit extremely short carrier lifetimes in the order of 1 to 100 ps and have been the base for the development of high speed optoelectronic switches. These devices are activated by picosecond laser pulses and can be driven nearly free of jitter with respect to the optical excitation pulses. They show some unique properties as picosecond risetimes and response times and can be operated within a relatively high dynamical range (10-5 to 10 sub 4 V) (0.00001 to 0.0001 V). A review is given on the wide field of possible applications of the ultrafast photoconductive switches. They can be used as photodetectors for picosecond light pulses as well as sampling gates for the characterization of high speed electronic and optoelectronic devices. In some experiments which are discussed more in detail the author demonstrates the capability of this type of photoconductive switches for the generation of picosecond infrared pulse trains in laser diodes and for the generation of high-bit rate electrical codes for use in Gbit/s optical communication and sensing systems, for logical switching and for testing purposes of high speed electronic instrumentations.
R.J.F.

N85-29771# Erlangen-Nuremberg Univ. (West Germany). Physikalisches Inst.
THE PROSPECTS OF THE DIGITAL OPTICAL COMPUTER
H. BARTELT, A. W. LOHMANN, and J. WEIGELT *In* AGARD Digital Opt. Circuit Technol. 5 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

The suitability of electrons and photons for the purpose of computing is assessed. Based on these fundamental features it is pointed out why photons are in some ways better suited for parallel processors. Parallel processors are needed to satisfy the ever-increasing demand for speed of computation. The status of digital optical computing experiments is surveyed. It is concluded that electrons are well suited for switching operations as they occur in a logic processor. But electrons are not so easy to guide from one point to another point. On that score, photons are more suitable. Recently, photons became amenable also for logic processing. Hence, the stage is set for the development of an all-optical digital computer. A digital optical computer has as its assests: parallel processing; global interconnections, that are favorable for architecture and algorithms. But the digital optical computer is a late-comer. Nevertheless, the optical computer has a chance to supplement the electronic computer as a special purpose parallel processor.
R.J.F.

N85-29772# Texas Instruments, Inc., Dallas. Central Research Lab.
DEFORMABLE MIRROR NEAREST NEIGHBOR OPTICAL COMPUTER
A. D. MCAULAY *In* AGARD Digital Opt. Circuit Technol. 9 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

A relatively simple optical computer is described which is capable of performing one billion operations per second with 32 bit data for nearest neighbor computations. It assumes the availability of deformable mirror devices having 1000 by 1000 elements which can be set in 8 mseconds. A simple system with two deformable mirror devices, one charge coupled device, and some simple electronics, operates at 15.6 million operations per second. Higher performance is achieved by duplicating this equipment because the nearest neighbor and residue number concepts permit perfect parallel efficiencies. The matrix operations dominate the computation because overlapping of other operations is possible by algorithm modification.
R.J.F.

N85-29773# University Coll., London (England). Microwave Research Unit.
OPTICAL TECHNIQUES FOR SIGNAL DISTRIBUTION AND CONTROL IN ADVANCED RADAR AND COMMUNICATION SYSTEMS
J. R. FORREST *In* AGARD Digital Opt. Circuit Technol. 14 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

It is concluded that optical techniques offer some advantages for signal distribution and control in advanced radar and communication systems. They are clearly ideal for transporting microwave signals over considerable distances, as in remote positioning of radar receivers, provided high dynamic range is not required and an enclosed transmission path is essential. They are an elegant means of distributing low level r.f. or i.f. signals around

an active phased array where these signals are of relatively constant amplitude (as in mixer local oscillator applications). However, there is currently a rather restrictive limit on the size of distribution network possible. Optical techniques are obviously suitable for distributing digital control signals to phased array modules and confer considerable immunity to interference. They are less suitable for high dynamic range signals, such as the received radar returns, either at r.f. or when downcovered to i.f. Future developments in coherent optics or in fast optical A/D technology could, however, influence this conclusion. Currently, the optimum applications for optical techniques appear to be i.f. beamformers for multibeam communication satellite systems and in calibration/monitoring systems for phased arrays. R.J.F.

N85-29774# Defense Advanced Research Projects Agency, Arlington, Va. Electronic Sciences Div.
ELECTRO-OPTIC TECHNIQUES FOR VLSI INTERCONNECT
J. A. NEFF *In* AGARD Digital Opt. Circuit Technol. 7 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

A major limitation to achieving significant speed increases in very large scale integration (VLSI) lies in the metallic interconnects. They are costly not only from the charge transport standpoint but also from capacitive loading effects. The Defense Advanced Research Projects Agency, in pursuit of the fifth generation supercomputer, is investigating alternatives to the VLSI metallic interconnects, especially the use of optical techniques to transport the information either inter or intrachip. As the on chip performance of VLSI continues to improve via the scale down of the logic elements, the problems associated with transferring data off and onto the chip become more severe. The use of optical carriers to transfer the information within the computer is very appealing from several viewpoints. Besides the potential for gigabit propagation rates, the conversion from electronics to optics conveniently provides a decoupling of the various circuits from one another. Significant gains will also be realized in reducing cross talk between the metallic routings, and the interconnects need no longer be constrained to the plane of a thin film on the VLSI chip. In addition, optics can offer an increased programming flexibility for restructuring the interconnect network. Author

N85-29775# Ohio State Univ., Columbus. ElectroScience Lab.
NUMERICAL OPTICAL COMPUTING AT THE OHIO STATE UNIVERSITY
S. A. COLLINS, JR., S. F. HABIBY, and A. F. ZWILLING *In* AGARD Digital Opt. Circuit Technol. 19 p (SEE N85-29757 18-74) Mar. 1985 refs
Avail: NTIS HC A10/MF A01

Designs for various devices intended to perform numerical operations using a Hughes liquid crystal light valve and the residue arithmetic representation are considered. A numerical optical temporal integrator, intended to take as input a string of numbers and keep a running sum is presented, as is an optical clock designed to generate optical timing pulses using a liquid crystal light valve. A comparison of binary and residue arithmetic in one application is given. A discussion of a numerical optical matrix multiplier is given. A sketch of the design is shown and the information layout on the light valve and input planes is described. R.J.F.

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DOCUMENTATION AND INFORMATION SCIENCE

Includes information storage and retrieval technology; micrography; and library science.

N83-31531# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
USE OF SCIENTIFIC AND TECHNICAL INFORMATION IN THE NATO COUNTRIES
Mar. 1983 131 p refs In ENGLISH; partly in FRENCH Meeting held at Rome, 29-30 Sep. 1982
(AGARD-CP-337; ISBN-92-835-0325-2; AD-A130687) Avail: NTIS HC A07/MF A01

Organizational structure and operation of defense/aerospace information centers, typical services, and a coordinated information structure are discussed. For individual titles, see N83-31532 through N83-31543.

N83-31532# Dokumentationszentrum der Bundeswehr, Bonn (West Germany).
ORGANIZATIONAL STRUCTURE AND OPERATION OF DEFENCE AND AEROSPACE INFORMATION CENTERS IN THE FEDERAL REPUBLIC OF GERMANY
H. BRAUN and G. TITTLEBACH (Fachinformationszentrum Energie Physik Mathematik G.m.b.H., Eggenstein-Leopoldshafen, West Germany) *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 9 p (SEE N83-31531 19-82) Mar. 1983
Avail: NTIS HC A02/MF A01

The objectives, tasks, users and services of both information centers are described in detail. The spectrum of information services covers the production of machine-readable databases, magnetic tape services, the publication of printed information services, online services, individual information services, like retrospective search and SDIs, and literature supply. Present development, efficiency, operational methods and techniques are discussed as well as the organizational structures, budgets, future trends and matters of cooperation. Author

N83-31533# Technisch Documentatie en Informatie Centrum voor de Krijgsmacht, The Hague (Netherlands).
ROYAL NETHERLANDS ARMED FORCES SCIENTIFIC AND TECHNICAL DOCUMENTATION- AND INFORMATION-CENTER (TDCK)
E. GRUETZMACHER *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 17 p (SEE N83-31531 19-82) Mar. 1983 refs
Avail: NTIS HC A02/MF A01

The history; organization, tasks and authorizations; service rendering; user's circle and informations-sources; and recent internal developments of the Netherlands Armed Forces Scientific and Technical Documentation and Information Center (TDCK) are summarized. Author

N83-31534# Centro di Dokumentazione Tecnico-scientifica della Difesa, Rome (Italy).
THE ITALIAN DEFENCE SCIENTIFIC AND TECHNICAL DOCUMENTATION CENTRE
G. MORELLI *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 4 p (SEE N83-31531 19-82) Mar. 1983
Avail: NTIS HC A02/MF A01

The history of the Italian Defence Technical Scientific Documentation Center, its structure, sectorial organization, staff consistency and qualification, administration; its dependence, authority and tasks; structural and operational inconveniences; and present services. Author

N83-31535*# *National Aeronautics and Space Administration,* Washington, D.C.
ORGANIZATIONAL STRUCTURE AND OPERATION OF DEFENSE/AEROSPACE INFORMATION CENTERS IN THE UNITED STATES OF AMERICA
H. E. SAUTER (Defense Technical Information Center, Alexandria, Va.) and L. N. LUSHINA *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 23 p (SEE N83-31531 19-82) Mar. 1983 refs
Avail: NTIS HC A02/MF A01 CSCL 05B

U.S. Government aerospace and defense information centers are addressed. DTIC and NASA are described in terms of their history, operational authority, information services provided, user community, sources of information collected, efforts under way to improve services, and external agreements regarding the exchange of documents and/or data bases. Contents show how DTIC and NASA provide aerospace/defense information services in support of U.S. research and development efforts. In a general introduction, the importance of scientific and technical information and the need for information centers to acquire, handle, and disseminate it are stressed. Author

N83-31536# Ministry of Agriculture, Fisheries and Food, London (England).
SCIENTIFIC AND TECHNICAL REPORT SERVICES
T. NORTON *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 6 p (SEE N83-31531 19-82) Mar. 1983 refs
Avail: NTIS HC A02/MF A01

A number of topics associated with scientific and technical report services available from defence/aerospace and other technical information centers is addressed. Abstract journals, announcement services and Selective Dissemination of Information (SDI), microfiche, bibliographies and literature searches are covered. Document supply is treated in greater detail and covers the advantages and disadvantages of online document ordering and electronic document supply projects such as ARTEMIS, ADONIS and APOLLO. Finally, a project to control European grey literature, System for Information on Grey Literature in Europe (SIGLE) is described. Author

N83-31537# Netherlands Bibliographical and Documentary Committee, Amsterdam.
INTERNATIONAL INFORMATION EXCHANGE
J. E. VANDIJK, J. H. M. HEIJNEN, P. J. C. ROSENBRAND, and H. F. DEVRIES *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 5 p (SEE N83-31531 19-82) Mar. 1983 refs
Avail: NTIS HC A02/MF A01

Bibliographic data bases in the fields of the physical sciences and technology as well as the publications which are the sources of these data bases are discussed. The importance and size of report literature, some cases of international cooperation in establishing bibliographic data bases, and the disclosure of report literature are considered. A model for international cooperation is discussed in relation to the necessity of making arrangements at a governmental level. Duplication of input should be avoided. It is even questioned whether databases sponsored by international organizations or by national governments should continue to cover publications which are easily available, such as books and journal articles, particularly when commercial database producers already cover these publications. Where financial constraints exist, reports and patents might have higher priority. A.R.H.

N83-31538# Environmental Research Inst. of Michigan, Ann Arbor. Infrared Information and Analysis Center.
INFORMATION ANALYSIS CENTRES AND SERVICES
G. J. ZISSIS *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 5 p (SEE N83-31531 19-82) Mar. 1983 refs
Avail: NTIS HC A02/MF A01

Established to act as readily accessible sources of information for specific user communities, information analysis center (IACs) serve as active information disseminators within areas of specific technical disciplines or well-defined functional, technological activities. Each center collects, reviews, analyzes, appraises, summarizes, stores, reformats and disseminates technical information related to the disciplinary or functional areas. The history of the IAC programs is reviewed. Examples of those which are discipline centered and those which focus on a bounded area of functional application of technology reveal contributions made by the IACs to the R&D programs, problems encountered, a variety of methodologies tried out by IACs to address these problems, and some lessons learned which can provide insight and guidance to future IAC activities. Author

N83-31539# Consiglio Nazionale delle Ricerche, Rome (Italy). Ist. di Studi sulla Ricerca e Documentazione Scientifica.
ON LINE INFORMATION: THE ITALIAN SITUATION
T. M. LAZZARI *In* AGARD *Use of Sci. and Tech. Inform. in the* NATO Countries 5 p (SEE N83-31531 19-82) Mar. 1983
Avail: NTIS HC A02/MF A01

Negative conditions for the development of information systems in Italy and the slow evolution of the European market for the information industry (and the establishment of data bases) are reviewed. The requirements of Italian users could be partially met by English, French, German, and Swedish documentation centers. Participation in the International Nuclear Information System and the FAO agricultural Information System fostered some interest in establishing information service systems in Italy. The transfer of ESA's Information Retrieval Service to Frascati brought the first on-line information system to Italian soil. Since 1973, large and important data bases were implemented in the juridical, legislative, and commercial sectors of the country. The impact of on-line information on economic life is being felt and interest among responsible State officials is noticeably spreading. A.R.H.

N83-31540# National Research Council of Canada, Ottawa (Ontario). Technical Information Service.
BENEFITS TO INDUSTRY (OF COORDINATED DEFENCE/AEROSPACE INFORMATION STRUCTURE)
J. CHANDER and G. KIROUAC *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 7 p (SEE N83-31531 19-82) Mar. 1983
Avail: NTIS HC A02/MF A01

The need for and the sources of information for the defence aerospace industry are considered. Some of the problems that the industry faces are addressed and some of the services available in Canada are described. The issue of possible modifications to the present information system is raised in an attempt to find solutions to the perceived information problems. Author

N83-31541# Centre de Documentation de l'Armement, Paris (France).
ADVANTAGES GAINED BY THE GOVERNMENT FROM A COORDINATION OF DEFENSE-AEROSPACE INFORMATION
C. PAOLI *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 8 p (SEE N83-31531 19-82) Mar. 1983 refs
Avail: NTIS HC A02/MF A01

The benefits derived by government authorities from the coordination of information in the sectors of defense and aerospace are described through the organization of the French Armament Documentation Center (CEDOCAR) as regards bibliographic and factual information, the Research Design and Engineering Directorate (DRET), and its Contractors as regards information relating to research programs. Data flows and transfers within the structures of these agencies are analyzed. Author

N83-31542# Trondheim Univ. (Norway). Library.
BENEFITS TO UNIVERSITIES OF A COORDINATED INFORMATION STRUCTURE
R. A. GJERSVIK *In* AGARD *Use of Sci. and Tech. Inform. in* the NATO Countries 4 p (SEE N83-31531 19-82) Mar. 1983 refs
Avail: NTIS HC A02/MF A01

The university's role as a user and producer of documented knowledge is outlined. Literature retrieval is necessary in study and research, and the importance of education in the literature searching techniques is emphasized. The role of the university library and its resources in the information structure is discussed. The benefits to the students and the academic staff of an effective and simple information retrieval structure is stressed. Author

N83-31543# Ministry of National Defence, Brussels (Belgium).
COMPARISON OF NETWORKS FOR DOCUMENT ACCESS [COMPARAISON DE RESEAUX D'ACCES AU DOCUMENT: LES SCHEMAS DECENTRALISE, SEMI-CENTRALISE ET CENTRALISE]
J. F. MULLER *In* AGARD Use of Sci. and Tech. Inform. in the NATO Countries 9 p (SEE N83-31531 19-82) Mar. 1983 refs In FRENCH
Avail: NTIS HC A02/MF A01

A case study of the cost of books and periodicals as well as of regular library activities associated with the acquisition, preservation and dissemination of documents, is used to show the necessity not only of automating libraries, but also of establishing a laison between them. This network can be decentralized, semicentralized, or centralized. The characteristics of these networks for document access are analyzed to establish the balance of their respective advantages and disadvantages.
Transl. by A.R.H.

N84-17059# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
DEVELOPMENT AND USE OF NUMERICAL AND FACTUAL DATA BASES
Loughton Oct. 1983 123 p refs Lectures held in Gaithersburg, Md., 5-6 Oct. 1983, in London, 10-11 Oct. 1983, and in Lisbon, 13-14 Oct. 1983
(AGARD-LS-130; ISBN-92-835-1459-9; AD-A136559) Avail: NTIS HC A06/MF A01

Numerical and factual data, as sources of information for all levels of aerospace and defence R & D management and staff activity, are increasingly important. These data are necessary to support research and engineering efforts in all fields. They are also increasingly important to support or assist in the decision-making process. Today, a number of numerical data bases are available through national information centers and others are available from academic or commercial information sources. Data in many of these data bases are retrieved and manipulated in display systems currently available. There is, however, a great need to improve the quality, reliability, availability, accessibility, dissemination, utilization and management of these data. The scope of the lecture series includes: generation of numerical data, consideration of the quality and reliability of the data, methods for publishing and disseminating the data, a review of the data bases that are currently available, how these data bases are used, and future needs for numerical data bases. For individual titles, see N84-17060 through N84-17069.

N84-17060# Los Alamos Scientific Lab., N. Mex.
STATUS AND FUTURE OF THE USE OF NUMERICAL AND FACTUAL DATA
R. F. TASCHEK *In* AGARD Develop. and Use of Numerical and Factual Data Bases 12 p (SEE N84-17059 07-82) Oct. 1983
Avail: NTIS HC A06/MF A01

The nature of numerical and factual data and data bases is discussed and their place in modern industrial society is reviewed. The components of the process by which data is produced, made public, extracted, assessed, evaluated and finally put to use, either as a single item or part of a data base, are examined. The present status of this process (the data cycle) is described and shortcomings briefly analyzed. The costs and organizational structures of various components are crudely evaluated and the data generation component dominates cost, while the evaluation component is least well developed. A detailed data cycle flow chart is presented for guidance in future more detailed approaches to critical data generation and utilization. Author

N84-17061# University Chemical Labs., Cambridge (England). Crystallographic Data Centre.
TYPES OF TECHNICAL CONTENT OF DATA
D. G. WATSON *In* AGARD Develop. and Use of Numerical and Factual Data Bases 3 p (SEE N84-17059 07-82) Oct. 1983 refs
Avail: NTIS HC A06/MF A01

The various uses of the word "data" are noted and a convenient definition of numeric data is proposed. Data are broadly categorized in terms of the uses to which they are put or in terms of who uses them. A brief overview of the characteristics of scientific data is provided and does so with respect to a simple classification scheme. This scheme categorizes data with respect to time, location, mode of generation, nature of the quantitative values, terms of expression and mode of presentation. Examples taken from the physical, earth and biological sciences are illustrated. Finally some of the special problems associated with, for example, geophysical and biological data are noted. Author

N84-17062# Dow Chemical Co., Midland, Mich. Thermal Group.
SOURCES GENERATING AND REPORTING NUMERICAL AND FACTUAL DATA
M. W. CHASE *In* AGARD Develop. and Use of Numerical and Factual Data Bases 11 p (SEE N84-17059 07-82) Oct. 1983
Avail: NTIS HC A06/MF A01

The re-use of experimental data is a frustrating endeavor. This is frequently due to the re-use of data in an attempt to solve problems for which the original experimental work was not directed. An experiment (or set of experiments) which is designed properly to solve a specific problem may well be severely lacking in sufficient information when applied to unrelated problems. The nature of the laboratory (university, government, or industry) normally will often dictate whether the information is required for basic or applied technological purposes. Time, money and internal political pressures in turn affect the thoroughness of the study and resulting publication. Often these pressures detract from the authors' awareness of the greater utility of results. Thus minimal data are even further limited as a result of the attitudes and publishing policies of the laboratory and journal. Examples of this interplay and its effects are given in the areas of low temperature calorimetry and vapor pressure. Author

N84-17063# General Electric Co., Schenectady, N. Y. Materials Information Services.
EXTRACTION AND COMPILATION OF NUMERICAL AND FACTUAL DATA
J. H. WESTBROOK *In* AGARD Develop. and Use of Numerical and Factual Data Bases 15 p (SEE N84-17059 07-82) Oct. 1983 refs
Avail: NTIS HC A06/MF A01

Extraction and compilation of data embrace the processes of achieving awareness of the existence of data, gaining access to the data, extraction of data from its source, knowledge organization and the compilation procedures preliminary to the critical evaluation of data. Each of these processes in turn subsumes a number of individual steps. In reviewing the subject, cognizance is taken of the individual needs and viewpoints of both generators and users of data. Changing norms of practices, work-habits and technology are also having significant impact on extraction and compilation procedures. Author

N84-17064# ESDU International Ltd., London (England).
THE EVALUATION/VALIDATION PROCESS: PRACTICAL CONSIDERATIONS AND METHODOLOGY FOR THE EVALUATION OF PHENOMENOLOGICAL DATA
A. J. BARRETT *In* AGARD Develop. and Use of Numerical and Factual Data Bases 14 p (SEE N84-17059 07-82) Oct. 1983 refs
Avail: NTIS HC A06/MF A01

Scientists and engineers strive to ensure that their work is based upon objective principles and that it is repeatable to close tolerances. The factual and numerical data resources which are available to them, however, do not always assist this intention particularly where data are being used as a basis of decision in the engineering design process which is directed at the realization of a practical product goal. Subjective influences, related to imparted or acquired skills and experience, often apply in such cases. These have to be taken into account during the construction of numerical and factual data bases. The practical consequences of inadequately refined data are reflected in unnecessary costs and uncompetitive product performance. Careful management of data refinement is always needed and seen to be increasingly important as a greater proportion of data is stored electronically or becomes embedded in computer aided engineering and design systems. Author

N84-17065# Dow Chemical Co., Midland, Mich. Thermal Group.
THE EVALUATION/VALIDATION PROCESS: DATA FROM DISCIPLINES RESTING ON GOOD THEORETICAL FOUNDATIONS
M. W. CHASE *In* AGARD Develop. and Use of Numerical and Factual Data Bases 9 p (SEE N84-17059 07-82) Oct. 1983 refs
Avail: NTIS HC A06/MF A01

Experimental and theoretical techniques are used to solve problems efficiently. To this end, however, the techniques must be used with a well defined plan in mind. A literature survey is first required to reveal available information which relates to the problem. The meshing of this information and any other soon to be released data is an important second step. The experiments and/or theoretical calculations must then be coordinated to reduce time and expense and to provide maximum data at minimum expense. From experience in developing the JANAF Thermochemical Tables, examples will be given where calculations were of sufficient accuracy to reduce the need for experimentation as in the thermodynamic properties of some chemical species. Comparisons and trends in data are also valuable to extend or replace data. Four thermodynamic studies are used to illustrate the value of theoretical efforts. Author

N84-17066# Department of Trade and Industry, London (England). Scientific and Technical Information Unit.
DISSEMINATION OF DATA AND INFORMATION
J. R. SUTTON *In* AGARD Develop. and Use of Numerical and Factual Data Bases 7 p (SEE N84-17059 07-82) Oct. 1983 refs
Avail: NTIS HC A06/MF A01

The differing needs of several different kinds of data users are considered. These should influence the format and packaging of the data product and the choice of distribution channels. Numerical data is used differently from nonnumerical information and the data provider needs to know how his customers use his product. The presentation of original data to assist the compiler and evaluator is considered. Tagging and flagging may make it easier to find data. Author

N84-17067# National Bureau of Standards, Washington, D.C. Office of Standard Reference Data.
GENERAL REVIEW OF NUMERICAL DATA BASES
D. R. LIDE, JR. *In* AGARD Develop. and Use of Numerical and Factual Data Bases 10 p (SEE N84-17059 07-82) Oct. 1983 refs
Avail: NTIS HC A06/MF A01

Quantitative data resulting from measurement or calculation play a key role in every field of science and technology. The organization of such data into compilations or data bases has become more difficult as the amount and complexity of information in the technical literature increases. Current efforts to prepare data bases of interest to the scientific and engineering communities are surveyed. Emphasis is placed on computer searchable data bases and their dissemination through on-line networks and other means. Mechanisms for international cooperation are discussed. Author

N84-17068# General Electric Co., Schenectady, N. Y. Materials Information Services.
PROGRESS TOWARD A COORDINATED SYSTEM OF DATABASES COVERING THE ENGINEERING PROPERTIES OF MATERIALS
J. H. WESTBROOK *In* AGARD Develop. and Use of Numerical and Factual Data Bases 9 p (SEE N84-17059 07-82) Oct. 1983 refs
Avail: NTIS HC A06/MF A01

All show the great need for computer access to engineering properties information on materials. All find such a system to be technically within the capabilities of modern computerized information technology. What is now required is a massive and continuing cooperative effort by a diverse group of stakeholders in such an information system. Author

N84-17069# Department of Trade and Industry, London (England). Scientific and Technical Information Unit.
DATA ORGANISATIONS AND THEIR MANAGEMENT
J. R. SUTTON *In* AGARD Develop. and Use of Numerical and Factual Data Bases 12 p (SEE N84-17059 07-82) Oct. 1983
Avail: NTIS HC A06/MF A01

Organizations which are involved in generating, compiling, validating and disseminating data are not all alike. Different types of organizations have different objectives and motivations. These lead to differences in management. Ways of coordinating the activities of data organizations are considered and the scope for overall planning at national and international levels. The costs of data activities cannot be ignored. The economics of subsidies, pump priming and pricing need careful consideration. Author

N84-21425# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
THE APPLICATION OF NEW TECHNOLOGIES TO IMPROVE THE DELIVERY OF AEROSPACE AND DEFENCE INFORMATION
Loughton, England Dec. 1983 110 p refs Meeting held in Ottawa, 14-15 Sep.1983
(AGARD-CP-357; ISBN-92-835-0345-7; AD-A140161) Avail: NTIS HC A06/MF A01

The pace of development of new technologies in communication networks and information delivery systems was extremely rapid over recent years. These developments and the ways in which they are applied to increase the effectiveness of managers, engineers and scientists are reviewed. Attention was directed particularly to the interconnecting of data bases and information centers within communication systems that permit the retrieval and post processing by end-users. Ways and means by which intelligent terminals, micro and mini computers are used in the actual aggregation and post-processing of data information were examined. Example of how the new technologies increase the productivity of scientists and engineers to improve the decision making capabilities of program managers were provided. For individual titles, see N84-21426 through N84-21436.

N84-21426# Oak Ridge National Lab., Tenn. Computer Sciences.
OPEN SYSTEMS INTERCONNECTION FOR THE DEFENCE COMMUNITY
N. B. GOVE *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 5 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

The area of Open Systems Interconnection is a very active area. The concept of a layered approach to communication standards is generally accepted and the OSI Reference Model appears to be successful as a working aproach toward integration of the many standards involved in open connection. The Reference Model is not in itself a communication standard but rather a framework for standards development. As such, it will permit evolution of standards as needed in a changing technology, while providing a coherent approach to the many problems involved in Open Systems interconnection. Author

N84-21427# National Research Council of Canada, Ottawa (Ontario). Automated Systems and Networks.
THE INET GATEWAY TRIAL
P. H. WOLTERS *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 11 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

The iNet Gateway is an intelligent network concept developed by the Computer Communications Group (CCG) of the TransCanada Telephone System (TCTS). iNet has evolved in recognition of the requirement for more universal accessibility to information providers and other computer based service. The iNet Gateway is designed to simplify the process of gathering, using and communicating information by offering a single point of access to satisfy the information needs of a user. In order to test the concept of intelligent networking a one year field trial is being conducted. The purpose of the trial is to provide the business and information communities with a single point of access to a great variety of computer systems including international, national and local networks as well as offline services provided by

information specialists or intermediaries. The trial is expected to further define the requirements for value-added network services. Author

N84-21428# Telsystemes Questel, Paris (France).
SHARING COMMAND LANGUAGES AND SOFTWARE
P. BUFFET *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 5 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

One of the first sevices available through the computer was that of selective disemination of information (SDI). Then, late in the sixties, two major technical host computers- namely LIS, (LOCKHEED Information Services) from LMSC. (LOCKHEED Missile and Space Company) and ORBIT Search Service from SDC (System Development Corporation) appeared in the United States. One host computer was installed in Europe in the context of ESRO (the European Space Reseach Orgaization,) because of the relationships of this organization with the NASA. At this time, a user, librarian or information scientists, had to learn two languages, RECON and ORBIT, to access the major international data bases, in particular in Engineering and related disciplines. Later, new vendors gave worldwide online access to new files, e.g., BRS (Bibliograhic Retrieval Services) in the States, and the Europe, representing ten online services, offering access to hundreds of databases. Some solutions for simplifying this access in terms of command languages are explored. The concept of portable software also is examined, as providing the opportunity to share the same language on various computers. Author

N84-21429# Office of the Secretary of Defense, Washington, D.C. Plans and Resources Div.
WORD PROCESSORS IN AEROSPACE/DEFENSE INFORMATION SERVICES: USE OF DISTRIBUTED INFORMATION SYSTEMS BY THE OFFICE OF THE SECRETARY OF DEFENSE
J. M. POWERS *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 5 p (SEE N84-21425 11-82) Dec. 1983
Avail: NTIS HC A06/MF A01

The utilization of word processing and distributed information systems within the Office of the Secretary of Defense (OSD) are described. The OSD is the principal management staff of the Secretary in the exercise of: policy definition, planning, resource management, program evaluation, and fiscal evaluation. Thus, there *are in fact certain general management functions that agree* common to both OSD and to many civilian industrial organizations. The real common denominator in the management of both military and industrial programs, however, is information - information that is accurate, up-to-date, specific, yet comprehensive - information that is needed to assess and evaluate programs and to make better, *more informed decisions.* Author

N84-21430# National Research Council of Canada, Ottawa (Ontario).
SCIENTIFIC NUMERIC DATABASES
G. H. WOOD *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 6 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

Scientific numeric databases (SND) are powerful, relately new research tools for the scientific and technical community. Practical examples are used to illustrate their use. The attributes and capabilities of such databases are described and a survey of the activity in this field is given. The SND permit the direct location, retrieval and the subsequent analysis/manipulation of evaluated numeric data. Advances in telecommunications and increases in the number and types of SND produced greatly enhance the likelihood in relevant data being readily available. Although only 5% of all data bases accessible online in North America and Europe are SND, they are growing in importance and acceptance as more databases are developed and scientists and engineers become aware of their potential. The National Research Council of Canada is active not only in the production of SND, involving *some international collaboration,* but also in the dissemination by means of a nation-wide online packet-switched network. Author

N84-21431# Institut fuer Rundfunktechnik, Munich (West Germany).
GRAPHIC AND VISUAL PRESENTATION OF AEROSPACE DATE
H. WILKINS *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Iinform. 7 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

The efficiency of computer-based information retrieval systems is substantially improved by presenting the information subject on a television monitor not only in alphanumeric but also in pictorial form. For systematic retrieval of a specific information, a large information base for alphanumeric and pictorial data must be carefully structured. Special technical equipment for storing and presenting the information must be available, especially when a large number of users will have access to the information base simultaneously. Author

N84-21432# Royal Library of Belgium, Brussels.
THE STANDARDIZATION OF BIBLIOGRAPHIC DATA
P. C. GOOSSENS *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 9 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

The development of large machine-readable bibliographic data bases, functioning a.o. as union catalogues, is a remarkable step forward in the evolution of the library and information world. Library networks, like all co-operative projects, only efficiently function if the composing parts are constructed according generally accepted norms. The different aspects of the standardization of bibliographic data are discussed. First the bibliographic contents part is handled. Cataloguing rules, the Paris Principles, the ISBD, filing rules and also subject indexing are looked at. Subsequently the more computer oriented aspects are treated, namely the content designation and the physical format structure. These concern the MARC II format, UNIMARC, the UNISIST refeence manual and the CCF. As well the progress made in the library community as in the instrumentation world is surveyed. Finally a pratical application of the standards is presented through the description of NEWWAVE, which is the on-line cataloguing and information retrieval system developed and used at the Royal Library in Brussels. Much important work was realized in the field of the standardization of bibliographic data, but also that some problems are left for the future. Author

N84-21433# Defence Research Information Centre, Orpington (England).
THE APPLICATION OF MANAGEMENT TECHNIQUES TO DEFENCE AND OTHER INFORMATION SERVICES: THE BRITISH APPROACH
G. W. HART *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 16 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

The Aslib catalog was searched for books, reports, and periodical articles on applications of management techniques to information services and libraries which were published in Great Britain or written by British authors. Also the last eight years of Aslib Proceedings were searched and an on-line search of the LISA (Library and Information Science Abstracts) files was conducted. A logical approach was made, from planning a new system, through measurement and evaluation, to the application of different technique for improvement of a system, finishing with the more esoteric ones. The aim throughout was to give the flavor of a technique rather than a detailed description. Author

N84-21434# Department of Energy, Oak Ridge, Tenn. Data Processing Div.
MANAGEMENT OF AEROSPACE CONTRACT DOCUMENTATION BY INDUSTRY AND GOVERNMENT
E. G. COPPOCK *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 17 p (SEE N84-21425 11-82) Dec. 1983
Avail: NTIS HC A06/MF A01

Method of documenting and tracking contract requirements and deliverables from the inception of a project through its completion are reviewed. One specific system, the Technical Information Monitoring System, is discussed in detail. Emphasis is placed on

the tracking of deliverables in the form of technical reporting requirements for research and development contracts for the U.S. Department of Energy. In addition, the application of new technologies to improve productivity and reduce overlap in energy research and development are examined and to enhance contract documentation and accelerate the dissemination of contractor research and development reports and technical information.
Author

N84-21435# Stockholm Univ. (Sweden). Computing Centre.
COMPUTER-BASED CONFERENCING
J. PALME *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 7 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

Computer conferencing is a more powerful communication medium than electronic mail. The important difference is that computer conferencing provides structing facilities on the data base of text documents, by putting text items into conferences and sub-discussings within a conference. The system has a data base, consisting of a large number of text messages. Each such text message can contain any text written in ordinary human language which the author wants to put there. There are two main kinds of messages: the first, called a letter, is a message from one user to a single or a number of other users. The second type, called a conference entry is stored in one of several computerized conferences. A number of users are members of the computerized conference. Each member normally reads all that is written in the conference and also can freely write messages into the conference, which are then made available to all the other members of the conference.
Author

N84-21436# British Library Lending Div., Boston Spa (England).
AUTOMATED DOCUMENT REQUEST AND DELIVERY SYSTEMS IN THE UNITED KINGDOM
S. EDE *In* AGARD The Appl. of New Technol. to Improve the Delivery of Aerospace and Defence Inform. 8 p (SEE N84-21425 11-82) Dec. 1983 refs
Avail: NTIS HC A06/MF A01

There are already in use in the UK a variety of methods for the telecommunication of requests: *through* direct terminal to computer and computer to computer links or via information retrieval database systems. These are described with particular reference to the British Library Lending Division's Automted Request Transmission (ART) services. Possible extensions of these services are also outlined. A rapid document delivery service based on facsimile transmission between British Library sites was in operation for some time, and the results of a pilot service to international users employing more advanced equipment are reported. The increasing provision of satellite links and developments in digital optical recording (DOR) discs and electronic publishing are stimulating the planning of more revolutionary electronic document delivery systems. Factors affecting the provision of such services are discussed as a prelude to a review of a number of UK and European initiatives.
Author

N84-22509# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
GUIDES TO AEROSPACE RESEARCH AND DEVELOPMENT IN NATO COUNTRIES. BIBLIOGRAPHY
H. BEHRENS (Fachinformationszentrum Energie, Physik, Mathematik G.m.b.H.) Jan. 1984 11 p (AGARD-R-718; ISBN-92-835-1465-3; AD-A139388) Avail: NTIS HC A02/MF A01

A bibliography representing a comprehensive survey of guides to aerospace research and development in NATO Countries was compiled. It was planned to be as complete as possible; however, only publications considered to be up to date were included. Besides guides specifically dedicated to aerospace, directories on the whole spectrum of research and development, with aerospace a sub-field only, were also considered. The bibliography contains 56 citations.
M.A.C.

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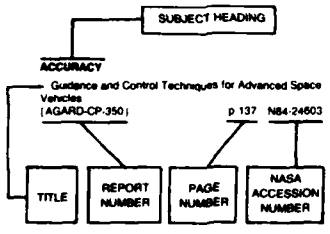

The subject heading is the key to the subject content of the document. A brief description of the document, e.g., title or title and title extension, is included for each subject entry to indicate the subject heading context; these descriptions are arranged under each subject heading in accession number order. The report number helps to indicate the type of document cited. The page number identifies the page in the abstract section (Part 1) on which the citation appears. The NASA accession number denotes the number by which the citation is identified on that page.

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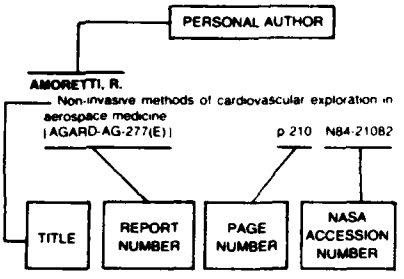

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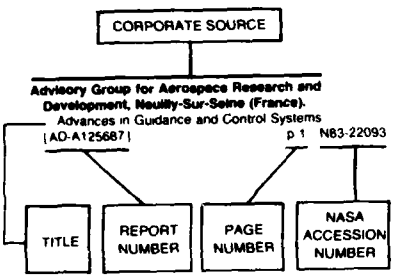

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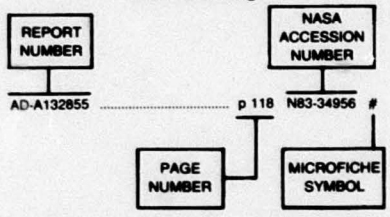

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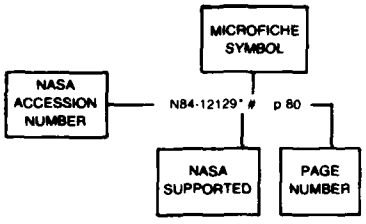

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