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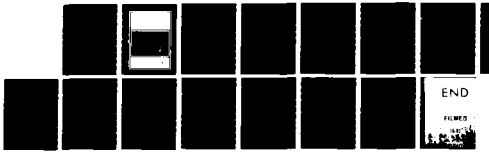

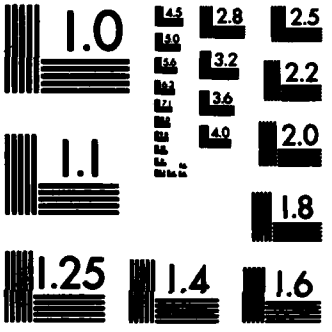

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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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**AGARD ADVISORY REPORT No. 195**

# Technical Evaluation Report on the Guidance and Control Panel 35th Symposium on Advances in Guidance and Control Systems





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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.195

# TECHNICAL EVALUTION REPORT

on the

# GUIDANCE AND CONTROL PANEL 35TH SYMPOSIUM

on

# ADVANCES IN GUIDANCE AND CONTROL SYSTEMS

by

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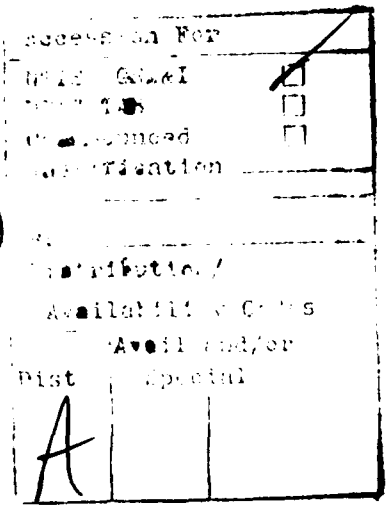




This Advisory Report was prepared at the request of the Guidance and Control Panel of AGARD.

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- 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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# TECHNICAL EVALUATION REPORT

by

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Director, Aircraft Technology
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## 1. INTRODUCTION

The 35th GCP Symposium on Advances in Guidance and Control Systems was held at the Instituto da Defensa Nacional, Lisbon, Portugal, 12-14 October 1982. The program Chairman for this meeting was Mr. Morris A. Ostgaard of the Air Force Wright Aeronautical Laboratories, USA. The compilation of the written papers is published in the Conference Proceedings AGARD CP-321 and AGARD CP-321(Supplement) Classified.

Many significant advances in optimal control theory, synthesis techniques and design methodology have taken place since the last symposium held in this technical area in 1973. The rapidly developing technologies in computation, data distribution, computer aided design methods and data basis now permit application of theories and synthesis methods heretofore impractical. The increased emphasis on functional and performance capability at reduced cost suggests application of technologies and methods for more common use of information and higher levels of integration.

The purpose of this meeting was to review and discuss all aspects of those emerging technologies ranging from theory through applications including aircraft, space vehicles, and unmanned vehicles. The Symposium was organized into the following six sessions:

I. APPLICATIONS OF CONTROL THEORY
II. ADVANCED DESIGN CONCEPTS
III. ADVANCED SYSTEM DESIGN
IV. SYSTEMS SYNTHESIS - SIMULATION AND VALIDATION
V. RECENT SYSTEMS EXPERIENCE
VI. PANEL DISCUSSION

The complete program including session chairmen, paper titles, and authors is listed in Appendix I.

## 2. SYMPOSIUM PROGRAM

The program of this Symposium was organized into five technical sessions, preceded by a keynote address and followed by a panel discussion.

Session I, Applications of Control Theory, presented a representative selection of recent applications of control theory to aircraft control and guidance including nonlinear analysis and design methods, microprocessor implementation issues, and examples of systems for high performance tracking and terrain following/terrain avoidance control.

Session II, Advanced Design Concepts, included papers on computer aided design techniques, a flight control system incorporating an airborne laser doppler sensor for predicting wind shear, an image contour-sensor for low altitude navigation system and an intelligent tracking algorithm for an imaging missile seeker for a fire-and-forget anti-tank weapon.

Session III, Advanced System Design, presented several papers on key elements of advanced control and guidance systems, including redundant air data sensor systems, multiplex data buses for use in high integrity utility control systems, design techniques for optimized performance in fire control and navigation computers, and techniques for generating high reliability software. The session also included a tutorial paper on robust observers in flight control system design.

Session IV, Systems Synthesis - Simulation and Validation, focused on computer language and software issues, including a special language designed to combine multiple disciplines in system engineering numerical simulation technqiues, validation of mission-software and building integrity in a higher order language.

Session V, Recent Systems Experience, covered five examples of advanced aircraft control systems, including digital control for tactical aircraft flutter suppression, the Tornado autopilot control law design and testing, nonlinear control flight research, a digital integrated guidance and control system in a Control gured Vehicle (CCV) fighter aircraft and the quadruplex digital fly-by-wire testi.. perience in the Jaguar.

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The Panel discussion focused on the significant advances made in controls and guidance over the past ten years, with views expressed by the panel members and from the audience.

## 3. TECHNICAL EVALUATION

This technical evaluation is based on the author's observations, results of a participants questionaire and comments solicited by the author from a cross-section of participants during the course of the Symposium. The Participant Evaluation of Symposium questionaire and summary of the results are presented in Appendix II.

### 3.1 Opening Session - Advances in Control

Mr. Ostgaard, the Symposium Chairman, opened the Symposium with the observation that this is a "snap-shot" in time of the continuing process of advances in guidance and control systems. The Guidance and Control Panel held a similar symposium about ten years before and will probably hold another one ten years hence. The intent at the Symposium is to cover the breadth of technology from theory to applications and from manned aircraft to missiles and unmanned aircraft. However, it is only possible to present a small but representative sample of the advances made over the past ten years in a three and one-half day meeting.

The Keynote Paper, delivered by Mr. Duane McRuer, President and Technical Director, Systems Technology, Inc., in the United States, presented a thought provoking observation that there are potential pitfalls as well as benefits associated with advanced flight control systems. A great deal of attention has been given to the technological advances that make high integrity digital fly-by-wire flight controls systems possible and in turn the reliance on such systems to further optimize aircraft efficiency and performance.

The speaker designated aircraft that depend heavily on augmentation systems as "superaugmented aircraft." Several of the unfavorable side effects that may accompany such systems include: flying qualities deficiencies; excessive lags and time delays; and, various digital system peculiarities. A strong case was made for paying more attention to these potential pitfalls and technology that can assist the designer in avoiding them.

### 3.2 Session I - Applications of Control Theory

A representative sample of applications of control theory to aircraft guidance and control was presented in this session. The first paper gave an interesting comparison of three nonlinear techniques used to analyze the stability of the Space Shuttle lateral-axis control system during entry. The principal system nonlinearities for stability analysis are the yaw jet relay command and a nonlinear gain in the bank-angle-to-aileron feedback path. The three analysis methods used were: describing function; Tsypkin's method; and, nonlinear simulation. The importance of the paper lies in showing the relative strengths and deficiencies of each method for a real system application. The second and fifth papers presented examples of applying different multivariable control optimization techniques to high performance aircraft for control law and automatic terrain following/terrain avoidance (TF/TA) system designs respectively. The advanced automatic TF/TA study was an excellent example of applying a constrained nonlinear optimization technique to provide real-time onboard computation of an optimum three-dimensional trajectory for maneuvering over/around terrain, evading threats and executing target maneuvers. The problem formulation and constraints were sufficiently representative of the real world situation that the solution could be directly implemented in a flight system. A technique for compensating for computational time delay in a direct digital design was described in the third paper. The concept was demonstrated on a microprocessor controller for a linearized longitudinal model. The fourth paper in the session presented the application of a transformation theory based on modern differential geometry to simplify the design of a helicopter autopilot for full flight envelope operation. It provides a systematic and effective technique for designing control systems for dynamical systems that are highly nonlinear, multiaxes, and cross-coupled.

As one might expect at a meeting that draws from both the analytical and applied aerospace community, this session had a mixed reception. A few participants found it to be of special interest while a like amount found it of least interest. The paper on Automatic TF/TA was particularly well presented and received and generated considerable discussion.

It is obviously not possible to cover all of the current topics of interest in the limited time available. Some additional topics that might have been expected in a session on applications of control theory are: applications of robust controller design techniques (two subsequent papers covered some aspects of robustness); direct digital design techniques for digital flight controls systems; and, advanced techniques for fault identification, isolation and recovery in flight control systems.

### 3.3 Session II - Advanced Design Concepts

This session focused on relatively new technologies incorporated into guidance and control systems. The first paper had a different theme, that of a control system

synthesis technique, and might have more logically fit into Session IV. The computer aided synthesis technique described uses nonlinear parameter optimization of a vector valued performance index which allows incorporation of the multiple dimensions of practical design specifications. Although not treated explicitly in the paper, the approach is amenable to multiple constraint boundaries.

The remaining three papers in the session covered novel concepts in sensors and their incorporation in autopilots and guidance systems. The second paper used a laser dappler velocimeter to detect local wind shear which is then used in the lateral control mode to improve performance during precision landing approach. The concept is interesting and needs experimental verification. The third paper which presented an automated image recognition scheme for navigation system update was particularly well presented and received. It presented a high technology concept in a manner that could be easily understood and appreciated by the non-specialists. An overall systems concept incorporating an IR imaging seeker was presented in the fourth paper. It did an excellent job of identifying the mission requirements and technical issues; defining an overall systems concept for a fire-and-forget anti-tank weapon; and, describing the IR image processing and intelligent tracking algorithm used in the missile guidance. The paper was well written, well presented and well received. Image processing and techniques for combining information derived in real time from images with other position reference data such as stored digital maps and other navigational data is currently a very important topic for guidance systems. Two very good unclassified examples were presented, however, this is a topic in which several good classified papers should have been presented in order to cover the most recent technology.

### 3.4 Session III - Advanced System Design

The title of this session is not particularly descriptive of the papers presented. The papers tended to cover subsystem elements and related systems implication. The first paper discussed two methods of including a redundant air data systems in high integrity flight system for the next generation of aircraft. A redundant integrated systems approach for control of aircraft utility systems to achieve high integrity was the topic of the second paper. The MIL-STD-1553B multiplex data bus was selected as the data transfer mode, however, some deficiencies were noted for use in high integrity applications. The Program Committee should be commended for including this topic in the Symposium and the authors should be commended for an excellent treatise of the topic. Subsystems are too often slighted at meetings on high technology when, in fact, subsystems too frequently are major contributors to total system failure. It is time that the system architecture and redundancy management include the critical subsystems with the same level of technology as the signal paths. This paper was a significant contribution in that direction. The third paper, on the F-111 Weapons/Navigation Computer, was somewhat disappointing. The excessive reference to the company's capabilities, accomplishments and product detracted from what otherwise could have been a good technology example of the design issues involved in incorporating a central computer on a weapon and navigation system. The fourth paper covers one aspect of a very important topic for flight crucial digital flight control systems: the process of generating and assuring high integrity software. The authors made the observation that "software production techniques have not kept pace with advances in hardware." The paper presents an interesting modular approach to high reliability software generation for the control law portion of the problem. It should be pointed out that another very important part of the system software, that associated with the digital system management and executive operations and redundancy management, was not addressed in the paper. The final paper of the session on design of robust output observers for flight control systems was presented in a style to stimulate interest and discussion. The author presented a tutorial on observer theory in a manner acceptable to the practical designer as well as the analyst. The principal message was that the observer theory can be very effectively used to quickly obtain feedback control system configurations that satisfy flying qualities requirements and are robust. The resulting systems look similar to those designed by classical techniques. It's difficult to make general comments on the session because of the diversity of topics covered.

### 3.5 Session IV - Systems Synthesis - Simulation and Validation

The prinicpal theme of this session was software related. The first paper in Session II would have fit well in this session. The exception is the second paper, which fits the session title under simulation but deals with rather straight forward flight path control law simulation. A special computer language, called Advanced Continuous Simulation Language (ACSL), appears to be very efficient for creating engineering non-real-time simulation. Some of the interesting features included are: automatic input/output functions; canned integration algorithms; sorting operations; macro library; multiple derivative blocks; and, provisions for various special functions. The third paper discussed the importance of real-time hardware-in-the-loop simulation in the validation process of mission-software. An overview was presented of validation techniques including both quantitative and qualitative procedures. The hardware-in-the-loop simulation was described as a progressive process, first using open-loop hardware tests to update subsystem simulation models then gradually substitute hardware for various subsystems to eventually approaching the complete flight system hardware in the simulation loop. The approach was illustrated using a solid ram-jet-powered missile guidance and control system. The final paper of the session addressed a relatively new and important topic for future systems because

of the desire to program embedded computers in higher order languages (HOL). To use HOL for flight critical and mission critical tasks requires that high integrity must also be built into the HOL, specifically the compiler. The paper discusses the key issues and presents an approach for obtaining high integrity with standard HOL's or by developing a new HOL. The author did an excellent job of making the subject interesting and stimulating discussion.

Overall, this session was rated the lowest in interest of all the sessions by the respondents to the evaluation questionaire, which is somewhat surprising in view of the importance of software issues in guidance and control systems. Verbal feedback from several participants supported the importance of this area but indicated mixed feelings about the specific papers presented.

### 3.6 Session V - Recent Systems Experience

This session presented actual ground and flight test experience for several advanced systems and systems concepts. The first paper covered the design and testing of a digital controller for active flutter suppression on a tactical airplane. Although flutter suppression has been demonstrated with analog mechanizations, there has been some concern as to whether a digital mechanization would be possible. The experimental results presented from testing the action flutter control system in a dynamic wind tunnel proved the feasibility of a digital system. The paper also provides guidance on the design techniques for flutter control. The second paper was an excellent example of the practical constraints and complexities that complicate the design of digital autopilots for modern high performance military aircraft and the iterative nature of the design process that continues into flight test. Linear design methods were of only limited use. It became necessary to introduce nonlinear control laws to meet the broad spectrum of requirements. Flight test experiments of some nonlinear control laws were reported in the third paper. The objective of the nonlinear control algorithms was to improve both control performance and handling qualities. The paper served a secondary purpose of describing a rather unique flight testing capability termed "remotely augmented vehicle facility" which allows experimental control laws to be flight tested in a safe and relatively low cost manner. The early flight test experience led to improvements in nonlinear control laws. The fourth paper described the integrated guidance and control system for a CCV fighter aircraft and presented the key results and lessons learned from the design, development, and flight testing. The aircraft was flight tested up to a 22% negative static margin. Future work is to concentrate on backup and dissimilar software concepts. The final paper of the session and symposium presented the ground and flight testing results of the first aircraft to be flown with a full-time digital fly-by-wire system that has no dissimilar backup channel(s) or reversion capability. The primary importance of the statement about "no dissimilar backup" is the extreme demand that it places for obtaining and assuring high integrity in the software that is common to all channels. The paper focused on ground and flight testing aspects of the program. It detailed the steps necessary to generate high confidence in the airworthiness of the entire system. Heavy emphasis was placed on use of a ground test rig facility that provided hardware-in-the-loop simulation of all key items, which is a further endorsement of hardware-in-the-loop simulation for software validation that Neubauer's paper addressed in Session IV. Unfortunately, the paper did not provide much insight into the procedures used for the software development and validation that assures the airworthiness of the common software. The paper was very well prepared, delivered, and received. It provided a fitting note to conclude the formal papers presented at the Symposium.

Technical papers and sessions that present actual test experience of advanced guidance and control systems are generally the best received at the AGARD Guidance and Control Panel Symposia and that was certainly true in this case as evidenced by the positive response to the topic on the evaluation questionaire and through verbal feedback of several participants.

### 3.7 Session VI - Panel Discussion and Closing Remarks

The moderator asked the roundtable discussion members and the audience to highlight what they believed were some of the most significant advances made in guidance and controls over the past ten years, identify the key problem areas today and comment on any topic which they felt should have been covered in the Symposium but were not. After addressing those questions the discussion was open to any comments related to the symposium.

One of the most significant advances has been the emergence of digital fly-by-wire systems which have now been flight tested in several aircraft. It was pointed out that it has been accomplished only through extensive and diligent attention to software generation and validation efforts. A real challenge facing the technical community is to develop more effective software techniques, particularly verification and validation techniques and methods for predicting software "reliability," and testing the hardware/software combination.

Another significant advance noted was the application of certain active control functions on operational aircraft such as relaxed static stability on the General Dynamics F-16 and the wing load alleviation system on the Lockheed L-1011-500. There were several comments on the need to develop better interdisciplinary design tools, particularly computer aided design (CAD). There was an expression of disappointment that this subject was not covered at the Symposium.

A third significant advance mentioned was the emergence of more integrated systems, such as integrated fire and flight control and integrated flight and propulsion systems control. It was pointed out by the moderator that the Fall 1981 Symposium was devoted to the topic of G&C technology for highly integrated systems and that the Spring 1983 Symposium will cover integration of fire control, flight control and propulsion control systems.

The discussion drifted away from identifying significant advances over the past ten years and towards topics not covered and key problem areas.

One panel member wished that the Symposium would have contained more material on interdisciplinary problems involving controls such as interactions of structures, aeroelasticity and controls. That led to a discussion of the need for better CAD techniques for interdisciplinary design and for nonlinear systems. There are currently several research activities in the U.S.A. and Europe on these topics which should be reported in future GCP symposia. This subject also provides an excellent opportunity for interactions with other AGARD panels which was encouraged by several participants.

The aircraft control problem should be addressed as including all the following elements: aircraft dynamics; pilot displays and controller; the pilot; and, the control laws. It was disappointing that this view was not presented at this Symposium. It was recommended that it be included in future meetings. The moderator pointed out that some aspects were covered in the Spring 1981 Symposium on "The Impact of New G&C Systems on Military Aircraft Cockpit Design."

Software verification and validation continues to be identified as a major problem area that is too manpower intensive. It was pointed out that there is a wide disparity in capability techniques and procedures across various companies. Better, more systematic and possibly automated methods should be developed. They need to start back at the software specifications and design stages to avoid pitfalls and provide better visibility to the designer of very complex systems.

Other software issues were raised and discussed including the possibility of "fault tolerant" software; standard software modules; and, reducing software complexity by using hardware intensive system designs that isolate software modules.

An alternate opinion was expressed that the "software problem" has been blown out of proportion and that diligent application of current technology is totally satisfactory. Operation experience with numerous digital systems has generally been outstanding.

Analytical redundancy concepts were identified as providing exciting new options for high integrity systems. With the advent of data buses and highly integrated systems these concepts become very attractive.

Our customers for guidance and control systems, particularly the military, are very concerned over the ever increasing cost of these high technology systems. Unless low cost is seriously emphasized on new concepts, the customer will not be able to buy the product.

The final comment from the audience noted that if the main objective of an aircraft is to be a weapons platform, then the control and guidance system should be considered an integral part of the weapons control problem. The technology should focus on that end objective not intermediate ones.

## 4.0 GENERAL COMMENTS, CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the Symposium as a whole is that it clearly served its intended purpose well. It provided good representative examples of advances in guidance and control systems, from applications of theory to recent test experience. It provided a forum for discussing emerging technologies. It generated thoughtful discussion of the key technology problems and opportunities. The program was effectively organized. Some slight regrouping of papers in the sessions and more descriptive session titles would have enhanced the program. There was a good balance among applied theory, methods and techniques, advanced concepts, and actual experience. The recent systems experience papers were clearly of most interest and systems synthesis techniques of least interest. The technical level of all but one or two papers was just right for the audience. A general impression was that having a symposium on the broad topic of guidance and control periodically is highly desirable but that the technology is advancing so rapidly that five year intervals may be better than ten.

### 4.1 Presentational and Administrative Remarks

Lisbon, Portugal was a superb location for the Symposium, the auditorium and other facilities were excellent and the Protugese people were gracious hosts. The local arrangements, interpreter services, and the administrative functions were handled very well. A few minor problems were noted by some participants. Transportation between the hotels and the meeting site was a problem for some people. Some disappointment was expressed that there was no general reception for all participants as is usually done at AGARD symposia.

The pace of the Symposium was quite relaxed, in fact some people felt that the breaks were unnecessarily long. Adequate time was allowed for discussion throughout the meeting. A few speakers had very poor slides because of too much detail and/or too small print. Periodic difficulties with projection equipment was distracting. One or two papers contained obvious marketing material for a company's product or services which distracted from the technical content.

The only major complaint was that the Symposium did not warrant a Secret classification. There appeared to be substantial resentment over the classification. If a meeting is to be classified Secret, the participants expect to hear about some of the major projects that are indeed classified Secret. Putting up with the constraints and procedures of a classified meeting when it appears unwarranted is disturbing.

## 4.2 Conclusions

The major conclusions of this technical evaluation are the following:

a. The Symposium was successful and the general theme of advances in guidance and control should continue to be visited periodically. The content did not appear to warrant Secret classification.

b. Digital fly-by-wire has provided the capability for superaugmented aircraft with increased performance and mission effectiveness but can result in several unfavorable side effects.

c. Multi-variable design and nonlinear optimization techniques are now being used effectively in major weapon systems control and guidance applications.

d. Image processing, automatic feature recognition schemes, and intelligent tracking algorithms have become important elements for precision navigation and/or guidance systems.

e. Control and redundancy management of utility systems requiring high integrity are beginning to be addressed with similar rigor as flight critical flight control systems. The Program Committee is to be commended for including a paper on this topic. The technology for high integrity utility systems and other subsystems is lagging and should be accelerated.

f. Software and related issues for flight critical digital systems continue to be high priority technology topics. Interest in using higher order languages brings a new set of issues such as assuring high integrity in the compiler.

g. Experience with some very advanced systems indicate that control law design procedures are still iterative up into flight test; the software generation, verification and validation process is people intensive; and, that hardware/software-in-the-loop simulation is a very important aspect of airworthiness procedures for digital fly-by-wire systems.

h. Adequate analytical and testing techniques are not yet available for assuring total system reliability (hardware and software) to the degree desired for high integrity digital flight systems.

## 4.3 Recommendations

a. The broad theme of advances on guidance and control should be considered for symposia every five years rather than ten.

b. A multi-panel AGARD Symposium should be held to address interdisciplinary design techniques and concepts involving controls, such as active controls, and should include computer aided design techniques and the man-machine interface.

c. Continue to emphasize software and related issues in all forms of GCP activities.

d. A working group should be formed to address the technology of predicting and assuring the reliability of extremely high integrity digital flight control systems, including both hardware and software.

e. More effort should be made to include the technology of utility and other subsystems in GCP activities where those subsystems are critical to the operation of guidance and control systems.

# APPENDIX I

## FINAL PROGRAM

## ADVANCES IN GUIDANCE AND CONTROL SYSTEMS
Lisbon, Portugal, 12-14 October 1982

OPENING CEREMONY

OPENING ADDRESS by Major General F. J. de Queiroz de Azevedo e Burbon, National Delegate to AGARD

OPENING SESSION - ADVANCES IN CONTROL
Chairman: Mr. Morris A. Ostgaard, USA

- Progress and pitfalls in advanced flight control systems, by D. McRuer, Systems Technology, Inc., USA

SESSION I - APPLICATIONS OF CONTROL THEORY
Chairman: Mr. Morris A. Ostgaard, USA

- Nonlinear methods for stability analysis of the space shuttle lateral-axis control system, by M. F. Barrett, Honeywell, Inc., Systems and Research Center, USA
- On the synthesis of improved tracking regulators for flight control of highly manoeuvring airplanes, by O. L. Mercier, ONERA, DES, Chatillon, France
- Microprocessor implementation of fast-sampling direct digital flight-mode controllers, by B. Porter, A. Bradshaw, A. Garis, and M. A. Woodhead, Department of Aeronautical & Mechanical Engineering, University of Salford, UK
- Design of a helicopter autopilot by means of linarizing transformations, by G. Meyer, Ames Research Center, NASA, Moffett Field, CA, USA
- Advanced automatic terrain following/terrain avoidance control concepts study. by M. J. Wendl, McDonnell Aircraft Co., St. Louis, MO, USA; J. E. Wall, Jr., Honeywell Inc., Minneapolis, MN, USA: and, G. D. Young, AFWAL/FIG, Wright-Patterson Air Force Base, OH, USA

SESSION II - ADVANCED DESIGN CONCEPTS
Chairman: Mr. Antonio Alves-Vieira (PO)

- Systematic computer aided control design, by G. Gruebel and G. Kreisselmeier, DFVLR, Inst f Dynamik d Flugsysteme, Oberpfaffenhofen, GE
- Digital implementation of a laser active flight control system with processed decoupled status, by A. Danesi, Servo-System Department, University of Rome, IT
- Image supported navigation in low altitudes based on detection of roads and rivers, by R-D Therburg, Lehrstuhl f Regeltechnik u Elektronik, Clausthal-Zellerfeld, GE
- Design and simulation of an intelligent missile seeker, by J. Hayman, RCA, Government Systems Division, Cherry Hill, NJ, USA

SESSION III - ADVANCED SYSTEM DESIGN
Chairman: Dr. Ing Reiner Ch Onken (GE)

- Systemes anemobarometriques pour avions de la prochaine decennie, by J. Mandel, Division "Aerospatial," Crouzet, Valence, FR
- The use of multiplex data buses in high integrity systems, by P. Crouch, Smiths Industries, Aerospace and Defense Systems Co., Cheltenham, UK, and A. G. Seabridge, Advanced Control Systems Department, British Aerospace PLC, Warton, Lancs, UK
- Advanced design and performance optimization techniques utilized to develop the F-111 WNC (Weapons/Navigation Computer), by A. J. Shapiro, The Singer Co., Kearfott Division, Wayne, NJ, USA
- A modular approach to high reliability software generation with applications to non-linear control, by S. M. Wright, ACT Design Group, British Aerospace PLC, Kingston-Brough Division, Brough North Humberside, UK, and J. S. Winter, Flight Systems Department, Royal Aircraft Establishment, Farnborough, Hants, UK
- Flight control system design using robust observers, by E. G. Rynaski, Arvin/Calspan ATC, Buffalo, NY, USA

**SESSION IV - SYSTEMS SYNTHESIS - SIMULATION AND VALIDATION**
**Chairman: IPA H Radet (FR)**

- **Use of the ACSL language to combine multiple disciplines for system engineering applications, by R. D. Agler, Martin Marietta Corporation, Denver, Co., USA**
- **Numerical simulations of longitudinal and lateral flight path control by an integrated computer system, by V. Losito and G. Torella, Academia Aeronautica, Pozzuoli, Napoli, IT**
- **On validation of mission-software by closed loop testing in real time, by H. Neubauer, Messerschmitt-Boelkow-Blohm GmbH, Muenchen, GE**
- **Building in integrity to a higher order language, by N. J. B. Young, Ultra Electronic Controls Ltd., Acton, London, UK**

SESSION V - RECENT SYSTEMS EXPERIENCE
Chairman: Mr. G. C. Howell (UK)

- Development and application of digital control for tactical aircraft flutter suppression,by D. S. Joshi, D. F. Kesler, Flight Control Research, E. H. Johnson, Structural Dynamics Research, Northrop Corporation, Aircraft Division, Hawthorne, CA USA
- Tornado autopilot: Control Law design including flight test and simulation, by U. Butter, and W. Schmidt, Messerschmitt-Boelkow-Blohm GmbH, Muenchen, GE
- NASA/RAE collaboration on nonlinear control using the F-8C digital fly-by-wire aircraft, by G. F. Butler, M. J. Corbin, S. Mepham, Flight Systems Department, Royal Aircraft Establishment, Farnborough, Hants, UK, and J. F. Stewart and R. R. Larson, NASA Dryden FRF, Edwards, CA, USA
- Flight test experience with a digital integrated guidance and control system in a CCV fighter aircraft, by U. Korte, Messerschmitt-Boelkow-Blohm GmbH, Muenchen, GE
- Ground and flight test experience on the fly-by-wire Jaguar equipped with a full time quadruplex digital integrated flight control system, by T. D. Smith, and C. J. Yeo, British Aerospace PLC, Warton Division, Preston, Lancs, UK, and R. E. W. Marshall, Marconi Avionics, Airport Works, Rochester, Kent, UK

SESSION VI - PANEL DISCUSSION AND CLOSING REMARKS
Chairman: Mr. M. A. Ostgaard, USA

Panel Members: D. McRuer, Systems Technology, Inc., USA
R. Onken, DFVLR Institut fluer Flughuehrung, GE
G. Howell, Royal Aircraft Establishment, UK

## APPENDIX II

## PARTICIPANTE EVALUATION OF SYMPOSIUM

Each participant was asked to fill out an evaluation form and make comments on the Symposium. A total of eighteen forms were returned with evaluation comments. The form used and a summary of the results are presented below.

EVALUATION FORM

AGARD GUIDANCE AND CONTROL PANEL SYMPOSIUM
Advances in Guidance and Control Systems

We are pleased that you took the time and trouble to attend our meeting and are interested to know what you think of it - whether it comes up to your expectations and if you have any suggestions as to how it might be improved. Please be good enough to answer this questionnaire and then hand it back to a member of the staff. Thank you.

---

1 Were the topics selected for presentation of interest to you?

2 Which topic was of especial interest to you?

3 Which topic was of least interest to you?

4 Was the general level of papers satisfactory? Too deep? Too superficial?

5 Were the speakers effective in presenting their topic?

6 Which speaker was especially effective and why?

7 Was the programme effectively organized (location, duration, schedule, etc.)?

8 Was enough time allowed for discussion?

9 Was language a problem?

10 Did you need interpretation?

11 Quality level of interpretation?

12 Overall, what is your assessment of the meeting?

| Excellent | Very Good | Good | Satisfactory | Poor |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

---

## SUMMARY OF EVALUATION RESULTS

The following summary of answers to symposium evaluation questionnaires represents a small sample of the total participants and may not be statistically significant but does provide useful information that can help in formulating future GCP symposia. Some interpretation and consolidation of answers was necessary to summarize the results.

**Question 1.** Were the topics selected for presentation of interest to you?

Answer: Yes 15 No 0

**Question 2.** Which topic was of especial interest to you?

Answer:

| | |
|---|---|
| Applications of Control Theory | 4 |
| Advanced Design Concepts | 3 |
| Advanced System Design | 6 |
| Systems Synthesis - Simulation and Validation | 2 |
| Recent Systems Experience | 11 |

**Question 3.** Which topic was of least interest to you?

Answer:

| | |
|---|---|
| Applications of Control Theory | 5 |
| Advanced Design Concepts | 2 |
| Advanced System Design | 6 |
| Systems Synthesis - Simulation and Validation | 6 |
| Recent Systems Experience | 0 |

**Question 4.** Was the general level of papers satisfactory? Too deep? Too superficial?

Answer:

| | |
|---|---|
| Satisfactory | 16 |
| Too deep | 1(some papers) |
| Too superficial | 2(some papers) |

**Question 5.** Were the speakers effective in presenting their topic?

Answer: Yes 16 No 0

**Question 6.** Which speaker was especially effective and why?

Answer:

G. Gruebel, GE - Clear presentation, not too much detail.
J. Hayman, USA - Very concise and presented well.
G. Meyer, USA - Good subject, slides and presentation.
E. Rynaski, USA - Interesting material and controvercial.
A. Shapiro, USA - Presented most and best detail.
T. Smith - UK
R. Therburg, GE - Clear presentation.
M. Wendl, USA - Right level of detail and good slides.
N. Young, UK - Spoke clear and slow, with good examples.

**Question 7.** Was the programme effectively organized (location, duration, schedule, etc.)?

Answer: Yes 15 No 0

**Question 8.** Was enough time allowed for discussion?

Answer: Yes 18 No 0

**Question 9.** Was language a problem?

Answer: Yes 2 No 16

**Question 10.** Did you need interpretation?

Answer: Yes 13 No 5

**Question 11.** Quality level of interpretation?

**Answer:** Good to Very Good 13 Satisfactory 1 Poor 0

**Question 12.** Overall, what is your assessment of the meeting?

**Answer:**

| | |
|---|---|
| Excellent | 1 |
| Very Good | 5 |
| Good | 10 |
| Satisfactory | 2 |
| Poor | 0 |

GENERAL COMMENTS

Papers did not warrant SECRET classification.

Should not allow "sales pitch" for company products in AGARD papers.

Excellent auditorium: convenient, comfortable, and good acoustics.

Bus tour of Lisbon was great.

Breaks were too long.

Transportation between hotels and meeting room was a problem.

Disappointed that there was no general reception for participants as has been done in the past.

Name tags should use larger more visible letters.

Difficulties with the projection system was very distracting.

Some slides were very poor: too much detail and print too small.

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14. Abstract

The GCP Symposium was held in Lisbon, Portugal – 12–14 October 1982. The programme presented at the symposium is appended to this report.

The complete compilation of papers was issued as follows: The Keynote paper and 18 papers are published in CP-321 and the remaining five in CP-321 (Supplement) classified.

This Advisory Report was prepared at the request of the Guidance and Control Panel of AGARD.

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|---|---|---|---|
| AGARD Advisory Report No.195<br>Advisory Group for Aerospace Research and Development, NATO<br>TECHNICAL EVALUATION REPORT on the 35TH GUIDANCE AND CONTROL PANEL SYMPOSIUM on ADVANCES IN GUIDANCE AND CONTROL SYSTEMS<br>by Herman A.Rediess<br>Published July 1983<br>16 pages<br><br>The GCP Symposium was held in Lisbon, Portugal – 12–14 October 1982. The programme presented at the symposium is appended to this report.<br><br>The complete compilation of papers are issued as<br><br>P.T.O. | AGARD-AR-195<br><br>Control theory<br>Design Concepts<br>System Design<br>Systems synthesis, simulation and validation<br>Recent systems experience | AGARD Advisory Report No.195<br>Advisory Group for Aerospace Research and Development, NATO<br>TECHNICAL EVALUATION REPORT on the 35TH GUIDANCE AND CONTROL PANEL SYMPOSIUM on ADVANCES IN GUIDANCE AND CONTROL SYSTEMS<br>by Herman A.Rediess<br>Published July 1983<br>16 pages<br><br>The GCP Symposium was held in Lisbon, Portugal – 12–14 October 1982. The programme presented at the symposium is appended to this report.<br><br>The complete compilation of papers are issued as<br><br>P.T.O. | AGARD-AR-195<br><br>Control theory<br>Design Concepts<br>System Design<br>Systems synthesis, simulation and validation<br>Recent systems experience |
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