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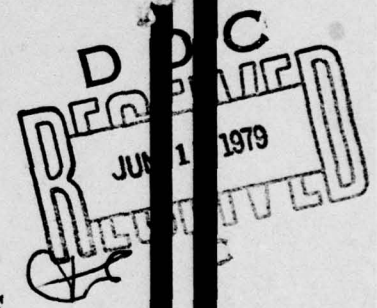
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AGARD ADVISORY REPORT No. 129

## Technical Evaluation Report on the 25th Guidance and Control Panel Symposium on Guidance and Control Design Considerations For Low Altitude and Terminal Area Flight



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~~AGARD~~ Advisory Report, ~~129~~

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**TECHNICAL EVALUATION REPORT**  
on the  
**25th GUIDANCE AND CONTROL PANEL SYMPOSIUM**  
on  
**GUIDANCE AND CONTROL DESIGN CONSIDERATIONS**  
**FOR LOW ALTITUDE AND TERMINAL AREA FLIGHT**

10  
A. Ostgaard  
Air Force Flight Dynamics Laboratory  
USA

Morris

12 15p.

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The 25th GCP symposium was held in Dayton, Ohio, USA 17-20 October 1977.  
The program as presented at the symposium is appended to this report.  
The complete compilation of papers has been published as Conference Proceedings No. 240.

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- Improving the co-operation among member nations in aerospace research and development;
- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
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## SUMMARY

### CONCLUSIONS

Lack of well-defined operational concepts and requirements appear to be an area that impedes development of multi-discipline efforts to fulfill low altitude operational needs and stimulate innovative concepts that are cost effective.

Crew workload becomes the predominant factor in low altitude operation; in particular, position information and display.

The application of control technology to provide gust alleviation is considered highly desirable and essential for sustained low altitude operation to relieve crew fatigue and enhance precision control.

### RECOMMENDATIONS

Increase development emphasis in crew systems functional integration to reduce crew workload and assure compatibility with future command and positioning systems.

Establish a panel working group to investigate functional concepts architecture and requirements for crew station visualization needs and crew workload reduction.

## EVALUATION REPORT

by

Morris A. Ostgaard

### 1. INTRODUCTION

The 25th Guidance & Control Panel Symposium on Guidance and Control Design Considerations for Low Altitude and Terminal Area Flight was held in Dayton, Ohio, U.S.A., on 17 through 20 October 1977. The co-Chairmen for the meeting were Mr. G. C. Howell of the Royal Aircraft Establishment of the U.K. and Mr. M. A. Ostgaard from the Air Force Flight Dynamics Laboratory. The program presented at this symposium is appended to this report. The complete compilation of papers has been published as AGARD Conference Proceedings CP-240.

### 2. SYMPOSIUM THEME

Future operational needs dictate that conventional and VTOL aircraft and helicopters be operated close to the ground in a wide range of operational tasks and weather conditions. The proximity of the ground produces many common factors that apply in all such situations. In particular, these relate to precision and modes of control of the aircraft subject to specific environmental conditions near the ground, the requirements for sensing position relative to ground features, and the high importance of establishing a necessary safety and integrity standard commensurate with vulnerability to enemy defenses. The purpose of this symposium was to review the current state-of-the-art in actual operation, and to identify the future trends leading to cost effective solutions to these difficult problems. An area of special interest is the advanced techniques in achieving direct-lift control and technology to improve the aircraft terrain-following capability and resistance to disturbances such as wind shear gust.

### 3. SYMPOSIUM PROGRAM :

A program of the symposium was arranged in five specific sessions:

Session I, *Operational Problems and Considerations*; included papers on concepts of low altitude operation, ground attack penetration models, compensation for wind shear effects, and pilot workload and performance in the simulated terrain-following mode.

Session II, *Terrain-Following*; included specific discussions on terrain-following system design in terms of aircraft vulnerability to ground defenses, cost effective radar navigation systems for low altitude, and design considerations for ground avoidance monitor. In addition, several discussions were held on system integration and a discussion on the B-1 terrain-following system.

Session III, *Terminal Area and Landing Considerations*; included several discussions on tactics, steep gradient approaches for all-weather landing operation, test results on electronic display formats, scanning behavior during approaches, and performance including integrity of microwave landing aids.

Session IV, *Weapon Delivery*; included only two papers, the first being an assessment of low altitude performance navigation accuracy, and the second was control techniques associated with low level weapon delivery.

Session V, *System Integration*, included discussion on definition and capabilities of 4D navigation guidance and control, use of direct-lift for precision flight path, control navigation aspects of low altitude flight, and recent advances in flight director systems.

### 4. TECHNICAL EVALUATION

Because of the scope and duration of the symposium, it was extremely difficult to fully assess and address all issues and concerns which were discussed. In an attempt to aid the evaluator in gathering necessary data and providing consensus of the conferees, a "Comments" or "Reviewer's" form was developed which is attached as Appendix 2 of this report. This approach was quite successful in providing many of the comments, observations, and assessments in the various technical areas of this report.

The keynote address was delivered by Colonel Charles Hausenfleck, Vice Commander of AFTEC, Kirtland AFB, New Mexico. This address did an outstanding job of setting the stage for the overall meeting by outlining a conventional air and land battle that could conceivably occur between NATO and the WARSAW Pact forces in Europe. Although only a concept, it did provide an excellent framework for the remainder of the papers. Of particular interest was that the critical problems of strategy, timing, force ration and

the projected short duration of the battle which indicated a need for quick reaction. This address was very well accepted by the participants which was quite evident in the later discussions throughout the meeting.

*Session I* covered primarily operational problems and considerations which were presented by military leaders or their representatives from the various NATO countries. These papers varied considerably in terms of concepts, solutions, and possible considerations. Of particular interest was the Royal Air Force paper on "Guidance and Control for Low Level Offensive Aircraft" which outlined, in considerable detail, some of the fundamental requirements associated with low altitude operations. This was followed by a paper on analytical penetration model and with two papers relating to cockpit displays and simulation. Another paper of extreme interest was the one on ride-smoothing systems and the need to provide capabilities for atmospheric disturbance rejection. The general consensus resulting from the discussions indicated the need for a gust and load alleviation capability for precision control and reduce crew fatigue while operating at high speed, low altitude conditions.

*Session II* dealt predominantly with terrain-following concepts which involved the aspects of low cost radar navigation system for low altitude terminal area flight, and techniques to achieve integrity in the low altitude flight regime. Of particular interest was a paper by Mr. Barfield on "Terrain Following Criteria" which defined some critical criteria for evaluating terrain-following systems considering performance, safety, and disturbance rejection. The last paper on the B-1 terrain-following development showed the activity involved from design through flight test including a film of the B-1 in actual low altitude operation and the effectiveness of ride control to reduce acceleration at the pilot station and permitting lower altitude operations. The need for more cost effective designs to increase safety and integrity was stressed.

*Session III* stressed primarily the terminal area and landing considerations and was, by far, the largest of the sessions with the most papers. These papers ranged all the way from accurate timing in landings using air traffic control through integrity of the ground control systems. Of particular interest were papers on flight control design of VTOL for approach and landing, recent flight test results of electronic display, and steep gradient approaches using the NASA B-737 airplane. Again, the major emphasis was placed on the need for accurate positioning, reduction in crew workload, integrity of the total systems, and system cost.

*Session IV* stressed weapon delivery and included only two papers, the first being an assessment of low altitude performance navigation accuracy on weapon delivery performance; the final one being a paper on guidance and control techniques associated with low level weapon delivery. The areas of intense interest in this session were the capability of assessing low altitude performance and a critical need for increased positioning accuracy for both low altitude operation and weapon delivery.

*Session V* stressed areas systems integration which covered topics from experimental determination of navigation error in the 4D navigation guidance problem to recent advances in helicopter flight director systems. One paper which generated considerable interest was the use of direct-lift control for precision flight path control, and the capability to provide disturbance rejection during the approach and final landing mode. Again, the interest in navigation or positioning accuracy, and pilot workload, and the need for disturbance rejection capability were the highlights of the session. Although there was considerable interest in 4D navigation for civil operation in the ATC environment, the concept of on-board time-space positioning for military operation presented a potential for use in the military ATC environment.

## 5. CONCLUSIONS

One of the most difficult aspects in establishing a set of conclusions is to base these conclusions solely on the results of the conference. In a conference of this type with a large number of disciplines represented, it is difficult to maintain the necessary objectivity. The following conclusions represent the best summation possible by the author but may not necessarily contain an awareness of other issues that may, or may not, be gleaned from the conference proceedings themselves.

5.1 Lack of well-defined operational concepts and requirements appear to be an area that impedes development of multi-discipline efforts to fulfill low altitude operational needs and stimulate innovative concepts that are cost effective.

5.2 Crew workload becomes the predominant factor in low altitude operation; in particular, position information and display.

5.3 The application of control technology to provide gust alleviation is considered highly desirable and essential for sustained low altitude operation to relieve crew fatigue and enhance precision control.

## 6. RECOMMENDATIONS

6.1 Increase development emphasis in crew systems functional integration to reduce crew workload and assure compatibility with future command and positioning systems.

6.2 Establish a panel working group to investigate functional concepts architecture and requirements for crew station visualization needs and crew workload reduction.

ANNEX  
GENERAL COMMENTS

1. SELECTION OF PAPERS

Over 40 abstracts were received in response that called for papers, some of which were received too late for consideration at the meeting of the program committee. A committee had a difficult task in selecting approximately 25 papers which was considered to be the optimal number for a four day symposium, and was obliged to reject a large number of the abstracts submitted. The objectives were to provide a selection of high quality papers for each of the sessions that would fit well within the theme of the meeting and give a good impression of the range of interest and quality of work in the countries participating. In a few cases, it was found possible to combine a small number of individual proposals into a joint paper. The distribution of papers per country is shown below:

1	France
7	Germany
6	UK
12	US
2	The Netherlands

Attendance: The total number of participants was 145 including 16 panel members. The National distribution was:

Belgium 0, Canada 3, France 7, Germany 21, Italy 1, Netherlands 6,

Norway 1, UK 17, USA 89, NATO Organizations none.

2. LOCAL ARRANGEMENTS

The symposium was held in the recently constructed Stouffer's Dayton Plaza Hotel which offered excellent facilities and services. The University of Dayton provided valuable support, and their personnel (Audrey Saks, and others) should be congratulated on the thoroughness and successful execution of final arrangements. Maj Gen Rushworth, Vice Commander of Aeronautical Systems Division, presented the opening address. The official reception was held in the Wright-Patterson AFB Museum thereby affording all participants an opportunity to view the magnificent collection of aircraft and its history. This opportunity was made possible through the cooperation of Colonel R. L. Uppstrom, Commander of the Air Force Museum. Special thanks go to Host Country Coordinator, Mr. Lou Urban.

## APPENDIX I

## FINAL PROGRAM

GUIDANCE AND CONTROL DESIGN CONSIDERATIONS  
FOR  
LOW-ALTITUDE AND TERMINAL-AREA FLIGHT  
Dayton, Ohio 17-20 October 1977

*Opening Ceremonies.*

*Opening Address* by Maj General R. A. Rushworth, Vice Commander, Aeronautical Systems Division, Wright-Patterson AFB.

*Keynote Address* by Colonel Charles H. Hausenfleck, Vice Commander, AFTEC, Kirtland AFB, New Mexico.

SESSION I — OPERATIONAL PROBLEMS AND CONSIDERATIONS  
Chairman: Dr.-Ing. R. Onken, Germany

- Guidance and Control for Low Level Offensive Aircraft — A Royal Air Force View — G. A. Barnes, Ministry of Defence, UK;
- The "Ground Attack/Penetration" Model: A Monte Carlo Simulation Model to Assess the Survivability and to Evaluate Tactics for Low-Altitude Military Missions in an Environment of Groundbased Air Defence Systems by M. H. W. Bovy, NLR, The Netherlands;
- Open-Loop Compensation of Wind-Shear Effects in Low Level Flight by R. Brockhaus, Technische Universität Braunschweig and P. Wust, Bodenseewerk Geratetechnik GmbH, Germany;
- Aircraft Ride-Bumpiness and the Design of Ride-Smoothing Systems by J. G. Jones and D. E. Fry, RAE, UK;
- Flight Control System Design for Ride Qualities of Highly Maneuverable Fighter Aircraft by J. F. Moynes and J. T. Gallagher, Northrop Corp., USA;
- Flight Performance and Pilot Workload in Helicopter Flight Under Simulated IMC Employing a Forward Looking Sensor by R. Beyer, DFVLR, Institut für Flugführung, Germany;
- Human Engineering Evaluation of a Cockpit Display/Input Device using a Touch Sensitive Screen by K-P. Gartner and K.-P. Holzhausen, Forschungsinstitut für Anthropotechnik, Germany.

SESSION II — TERRAIN FOLLOWING  
Chairman: Mr. G. C. Howell, U.K.

- Proposal for a Cost Effective Radar Navigation System for Low Altitude and Terminal Area Flight by E. Wildermuth, Universität Stuttgart;
- Design Considerations for a Ground Avoidance Monitor for Fighter Aircraft by D. A. Whittle, BAC Ltd, U.K.;
- System Integration and Safety Monitoring to Achieve Integrity in Low Altitude Flight Control Systems by D. Sweeting, Marconi-Elliott Avionic Systems Ltd., U.K.;
- Terrain Following Criteria — The Need for a Common Measure by A. F. Barfield, AF Flight Dynamics Laboratory, USA;
- B-1 Terrain-Following Development by C. W. Brinkley and P. S. Sharp, Air Force Flight Test Center, and R. Abrams, Rockwell International, USA.

SESSION III — TERMINAL AREA AND LANDING CONSIDERATIONS  
Chairman: Mr. R. W. Wedan, USA

- Steep Gradient Approach Systems Research for All-Weather Operations by A. D. Brown, RAE, U.K.,
- Recent Flight Test Results using an Electronic Display Format on the NASA B-737 by S. A. Morello, NASA-Langley Research Center, USA;
- Airline Pilot Scanning Behavior During Approaches and Landing in a Boeing 737 Simulator by A. A. Spady, Jr., NASA-Langley Research Center, USA;

- Evaluation of Digital Flight Control Design for VTOL Approach and Landing by P. W. Berry, R. F. Stengel, and J. R. Broussard, The Analytic Sciences Corp., USA;
- Automatic Flight Performance of a Transport Airplane on Complex Microwave Landing System Paths by T. M. Walsh, NASA-Langley Research Center and E. F. Weener, The Boeing Company, USA;
- Accurate Timing in Landings Through Air Traffic Control by M. Pelegrin and N. Imbert, ENSAE/CERT, France;
- Propagation Integrity for Microwave Instrument Landing Systems by P. S. Demko, U.S. Army Avionics Laboratory, USA;
- DME Based System for Enroute/Terminal Navigation, All-Weather Landing and Air Traffic Control by K. D. Eckert, SEL, Germany.

## SESSION IV — WEAPON DELIVERY

Chairman: Dr. O. C. Williams, USA

- The Analysis of Operational Mission Execution: An Assessment of Low-Altitude Performance, Navigation Accuracy and Weapon Delivery Performance by T. J. Stahlie, The Netherlands;
- Aiming Techniques Associated with Low Level Weapon Delivery<sup>(1)</sup> by P. Manville, RAE, U.K.

## SESSION V — SYSTEM INTEGRATION

Chairman: Dr. J. J. Pelegrin, France

- Experimental Determination of the Navigation Error of the 4-D Navigation Guidance and Control Systems on the NASA B-737 Airplane by C. E. Knox, NASA-Langley Research Center, USA;
- Direct Lift Control for Flight Path Control and Gust Alleviation by G. Schanzer, Technische Universitat Braunschweig, Germany;
- Navigation System Aspects of Low Altitude Flight by P. A. Bross, Elektronik System GmbH, Germany;
- Recent Advances in Helicopter Flight Director Systems<sup>(2)</sup> by P. G. Cooper, Kaiser Aerospace and Electronics Corp., USA, and R. J. van den Harten, KLM Noordzee Helikopter B. V., The Netherlands.

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(2) Not available at time of printing.

## APPENDIX II

## (EVALUATION FORM)

COMMENTS ON AGARD GCP SYMPOSIUM  
Dayton, Ohio 17-20 October 1977

TO ALL ATTENDEES

Considerable time and effort was expended by a number of countries in the organization and hosting of this symposium. As a result, the Program Committee Chairman is obligated to prepare an evaluation report. To aid him in preparing a timely, meaningful report, and since we have assembled here leading technical experts in the field, we solicit any feedback or comments you may desire to submit. These may be handwritten notes, and anonymous. If you have any questions, please contact the AGARD staff, the Program or Panel Chairman.

The following are typical examples of areas in which observations, comments and assessments are desired:

(a) General observations

1. Quality, and relevance of papers, sessions and questions;
2. Did papers support the theme?
3. Did symposium live up to your expectations?

(b) Technical observations

Views on operational use and requirements;  
Assessment of technology (State of the Art);  
Views on pacing technology or critical need for R&D;  
What do you see as major challenges and trends?  
Views on systems integration;  
What areas or problems are unresolved?

(c) Suggested improvement for symposium (procedures for enrolment, authors' instructions, logistics, etc.)

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Please write your comments overleaf and hand them in  
to the Authors' Desk before the end of the Symposium.  
Thank you for your contribution and cooperation.

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