RESEARCH AND TECHNOLOGY ADVISORY COUNCIL,

AD HOC PANEL ON TERMINAL CONFIGURED VEHICLES

REPORT OF MEETING

SEPTEMBER 14-15, 1977
The Fifth Meeting of the NASA Research and Technology Advisory Council, Ad Hoc Panel on Terminal Configured Vehicles (TCV), was held on September 14-15, 1977, at the Langley Research Center, Hampton, Virginia. The meeting was open to the public. Sixty-two persons registered.

Panel Resolutions:

TCV PROGRAM MANAGEMENT

The NASA briefing to the Panel was well organized, well presented, and was indicative of a significantly improved and business-like management of the program.

The TCV staff are urged to continue the programs organization and presentation along this line.

The Panel is well aware of the schedule constraints imposed upon NASA by other Governmental influences, e.g., the Argentina demonstration (of TRSB MLS).

FOLLOW-ON INDUSTRY COORDINATION

The Panel believes it is imperative that NASA continues frequent industry interactions. It is also strongly recommended that the TCV program continues with formal industry advisory panel associations.

ADVANCED DISPLAY DEVELOPMENT

All industry indicators and development trends clearly show an increasing use of automated airplane navigation and flight control systems. The prime need is for improved displays so that the crew can monitor and maintain total situation awareness throughout all regimes of flight and visibility conditions. Improved warning systems and possibly new sensors should also be explored to support this requirement.
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MEMBERS IN ATTENDANCE

Chairman: Mr. John Gorham, Gorham Associates

Mr. James P. Andersen, Transportation Systems Center
Mr. John D. Howell (Vice DeCelles), Air Line Pilots Association
Mr. George B. Litchford, Litchford Associates
Mr. Paul H. Patten, Douglas Aircraft Co.
Mr. Siegbert B. Poritzky (9/24/77), Federal Aviation Admin.
Mr. Robert S. Stahr, Eastern Airlines, Inc.
Mr. Harry Verstynen (9/25/77) (Vice Poritzky), Federal Aviation Admin.
Mr. Frank Wright, Lockheed Aircraft Corp.

Ex Officio Members Present:

Mr. James E. Stitt, Langley Research Center
Mr. John P. Reeder, Langley Research Center
Mr. Kenneth E. Hodge, NASA Headquarters
Mr. Lee D. Goolsby, NASA Headquarters

Members Absent:

Capt. Larry DeCelles, Air Line Pilots Association
Capt. George T. Henderson, United Air Lines, Inc.
Mr. Charles D. House, Federal Aviation Admin.

Ex Officio Member Absent:

Mr. Brent Y. Creer, Ames Research Center
INVITED GUESTS AND VISITORS:

Mr. Malcolm Burgess
Mr. Alan Mulally
Mr. D. R. Clifford
Mr. Nathan Novack
Mr. Richard V. Wible
Mr. Howard Seal
Mr. Harry Strunz
Dr. Charles L. Britt Jr.
Mr. T. J. Ray
Mr. Frank Brady
Mr. Stydren J. Smith
Mr. Gene Lyman
Mr. Bill Duff
Mr. Tony Lambregh
Mr. Larry Wood
Mr. J. R. Temple
Mr. Orin Nicks
Mr. Robert W. Boswinkle
Mr. William D. Mace
Dr. Thomas Walsh
Mr. Eugene Schult
Mr. Seymour Salmirs
Mr. Leonard Clark
Mr. Royce H. Sproull
Mr. James R. Hall
Mr. Milton Holt
Mr. William F. White
Mr. Andrew Graham
Mr. W. A. Southall
Mr. R. T. Taylor
Mr. R. J. Tapscott
Mr. John F. Garren
Mr. Leonard Credeur
Mr. Ray V. Hood
Mr. Amos Spady
Mr. Bruce A. Conway
Mr. Richard M. Hueschen
Mr. George G. Steinmetz
Mr. W. T. Bundick
Mr. George Boyles, Jr.
Ms. S. C. Chaney

National Transportation Safety Bd.
The Boeing Company
The Boeing Company
Wallops Flight Center
Air Force Flight Dynam. Lab.
The Boeing Company
The Mitre Corporation
Research Triangle Institute
Eastern Airlines
Air Transport Association
Arma Corporation
NASA Headquarters
Atlantic Research Corporation
The Boeing Company
Federal Aviation Admin.
McDonnell Douglas Corp.
Langley Research Center
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Mr. Kimball Miller  
Mr. Jacob A. Houck  
Mr. James E. Dieudonne  
Mr. Lee H. Person  
Mr. W. H. Phillips  
Dr. J. F. Creedon  
Dr. Charles E. Knox  

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OPENING REMARKS AND WELCOME

The Panel was welcomed to the Langley Research Center by Mr. James E. Stitt, Director for Electronics. Chairman Gorham also welcomed members and visitors to the fifth meeting of the Panel. He noted that Captain George Henderson was unable to attend because of illness. Captain Larry DeCelles was unable to be present, but he was represented by Mr. John D. Howell, Air Line Pilots Association. Mr. Charles House, FAA, was absent also and without an alternate.

Mr. Stitt stated that previous meetings of the Panel had been very useful to the Langley Research Center. This Panel has been quite critical of the TCV program at times especially in the formulation of more definitive objectives, technical approaches, and planned research activities. This has resulted in the Panel having been much more useful to NASA than some other RTAC panels and committees whose meetings he has attended. He urged the Panel members to continue to offer constructive criticism of the TCV program plans and objectives.

APPROVAL OF MINUTES

The minutes of the previous meeting of this Panel were approved as written.

Mr. Gorham stated that he and Panel members offered a correction to the minutes of the meeting of the RTAC Panel on Aviation Safety and Operating Systems on May 24-26, 1977, at Ames Research Center. On page 16 the word "greater" should be deleted in line 3 under "TCV Ad Hoc Panel Report."

CHAIRMAN'S REPORT

Mr. Gorham showed the charts he used in reporting this Panel's activities to the parent Panel on Aviation Safety and Operating Systems. The recommendations resulting from the previous meeting on July 21-22 were approved by the parent panel.
The chairman requested that members should make sure they understand the research activities during the progress reports given at this meeting and that they give their opinions of the results and whether the tasks being performed are the proper things that needed to be done and with the appropriate relative priority.

EXECUTIVE SECRETARY'S REPORT

Mr. Kenneth Hodge reported the following recent changes and impending changes in NASA since the last Panel meeting:

Dr. Robert A. Frosch has replaced Dr. Fletcher as Administrator. Dr. James J. Kramer is the Acting Associate Administrator for Aeronautics and Space Technology. The Directors of Ames Research Center and Lewis Research Center have resigned and no new directors have been selected. There are rumors of a reorganization of NASA Headquarters which will enable the agency's program offices and field centers to report directly to the Administrator and Deputy Administrator. The FY 78 NASA budget is up approximately 8% over FY 77. A restructuring of the Research and Technology Advisory Council, Committees, and Panels is in progress. He is not able to supply any details at this time. However, it does appear that both this panel and its parent Panel will be abolished. NASA's personnel ceiling will be reduced by an additional 500 in FY 1978. The Subcommittee on Transportation, Aviation, and Weather, Committee on Science and Technology, House of Representatives will conduct a review of NASA's aeronautics technology program on September 20, 1977.

TCV PROGRAM OVERVIEW

Mr. Stitt stated that commitments made this morning at another meeting concerning NASA's participation with FAA in TRSB MLS demonstrations during the Organization of American States Annual Meeting at Buenos Aires and other demonstrations of MLS during the ICAO All Weather Operations Meeting can affect the schedules, especially in the near term, which will be shown during the TCV overview. However, emphasis will be on what progress has been made during the past year and long term major milestones. Dr. Thomas Walsh, TCV Program Office, Langley Research Center, used the charts
shown in Appendix A to give an overview of the TCV program objectives, program elements, accomplishments to date, planned near term activities, and major milestones.

Discussion:

With reference to the second chart Mr. Poritzky requested a definition of "reduced visibility." Dr. Walsh replied that this has not yet been defined. Mr. Poritzky stated that it is very significant whether "reduced visibility" means zero visibility or not. Mr. Gorham stated that some air carrier aircraft are already certified to CAT IIIA approach category. Air carriers are going autoland but not beyond CAT IIIA. Dr. Walsh said that the TCV program objectives are trying to provide safe guidance independent of weather or type of display. Mr. Andersen stated it will not be technology but economics which will be the deciding factor in zero-zero operations. Mr. Gorham stated that the Panel had recommended earlier not to try to land aircraft beyond CAT IIIB—don't try for zero-zero (CAT IIIC). However, he felt the Panel could give some support to research for CAT IIIC conditions even though zero visibility landings are not likely in air carrier service before 1990. Mr. Poritzky stated that he had no problem with this position.

Regarding the chart entitled "The Challenge," Mr. Poritzky stated that this chart implies that the concern is for only one aircraft in the terminal area. The thinking should be oriented to the problems involving multiple aircraft in the terminal area.

With reference to the "Program Element" chart, Mr. Patten asked what per cent of the TCV effort goes to the element entitled "Joint FAA/NASA Flight Experiments." Dr. Walsh responded 25-30%. Regarding the chart entitled "Accomplishments to Date," Mr. Patten asked what were the constraints which prevented decreasing the final straight portion of the precision curved approach to less than 1 1/2 miles. Mr. Walsh stated that approaches were made with final straight segments of 1 mile, but the pilot felt that the aircraft was not fully stabilized or properly trimmed during 1 mile straight finals. Mr. Patten asked if Langley had concluded that direct lift control (DLC) is a required system
for future aircraft. Dr. Walsh responded in the negative. Langley is still looking at tracking accuracy improvements and reduced touchdown dispersions. While the "Near Term Activities" were being reviewed, Mr. Patten requested that the landing gear be properly instrumented during the high speed turnoff evaluations in order to gather data on loading of the landing gear. Mr. Taylor stated that Langley will try to obtain the data that is needed if Mr. Patten would let Langley know what is desired. Mr. Patten responded that he will send the requirements to Langley later.

Mr. Poritzky observed that aviation community interest in high speed turnoffs seems to go in 3-4 year cycles. He stated also that relative to the evaluation of energy-efficient descent and approach, there is a need to consider the multiple aircraft problem in the terminal area as well as single aircraft energy efficient descents.

With reference to the major milestone schedules, Mr. Stitt stated that those milestones which involved only laboratory work and/or simulation would be largely unaffected by the MLS demonstrations. Those involving flight experiments in the TCV 737 aircraft would have to be rescheduled to some later date. Mr. Poritzky requested a description of "strategic control" as used in the schedule charts. Dr. Walsh responded that strategic control as far as the aircraft is concerned includes 4D RNAV. With reference to CDTI, Mr. Poritzky stated the question to be answered is what are the genuine, real possibilities with CDTI. Most answers can be gotten in simulation and laboratory investigations without the need of flight experiments. Mr. Poritzky asked how much new information or technology is needed beyond the capabilities of the L-1011 and DC-10 to do curved, decelerating approaches. Dr. Walsh stated that the goal in this area includes simplification of avionics and sensors needed for curved, decelerating approaches. Dr. Walsh invited attention to the list of TCV related publications listed in Appendix R.

**MLS RELATED RESEARCH**

Mr. William F. White, TCV Program Office, Langley Research Center, used the charts shown in Appendix B to summarize the activities at Langley Research Center relating to
development of MLS avionics and flight demonstrations of
the capabilities of the TRSB MLS system.

Discussion:

Mr. Patten recommended that steeper bank angles be included
in the flight experiments. He stated that bank angles of
about 25 degrees will be needed at some airports (e.g.,
Hong Kong). Mr. Reeder agreed to include this in the TCV
investigations. Mr. Litchford asked if Langley had
determined how many MLS antennas will be required on large
aircraft. Dr. Walsh stated that this will be investigated
but has not been done yet. Mr. Gorham stated that research
is needed to determine when to switch antennas for missed
approaches.

WHOLE WORD COMPUTER SYSTEM STATUS

The flight control computer system in the TCV 737 aircraft
is in the process of being replaced. The incremental
digital computers have been replaced with general purpose
whole word computers with increased capacity. This increase
in capacity will permit greater flexibility and easier ex­
erimental software modifications. Greater capacity will
also permit triple-redundancy testing of MLS signal and
path error processing as well as performance of more complex
flight profiles and control laws. Mr. Milton Holt used the
charts in Appendix C to compare the new computer system with
the old system and to give the status of the changeover.
Testing of the new system in the hot bench is scheduled to
be completed 9/14/77.

FLIGHT PATH ANGLE CONTROL

Mr. Robert T. Taylor, Flight Programs Branch, Flight Research
Division, Langley Research Center, used the charts shown in
Appendix D to give a status report on investigation being
made with flight path angle control concepts. He showed
flight path angle response to step control inputs when using
elevator alone, spoilers alone, and a blended use of
elevator and spoilers. He discussed velocity CWS control
law, incorporation of commanded flight path angle on the
EADI display, and the results of tracking tasks in simulations
using this concept.

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AUTOFLARE LAW IMPROVEMENT

Dr. J. F. Creedon, Measurement Research Branch, Flight Instrumentation Division, Langley Research Center, described activities underway to reduce touchdown dispersion through autoflare law improvement. Using the charts in Appendix E he described the existing autoflare law used in TCV B-737, modification concepts being considered, preliminary results based on 100 runs on a simulator, and future plans and schedules.

Discussion:

Mr. Gorham observed that the flare law changes have decreased touchdown dispersion, but he suggested that the affect that this has had on sink rates at touchdown be examined closely.

HIGH SPEED TURNOFF ANALYSIS

Mr. Robert Taylor, using the charts in Appendix F, described some analysis work which has been done to determine the effects of turnoff speed and touchdown dispersion on runway landing capacity. A guidance and control concept for automatic control during high speed roll out and turnoff is under evaluation. Preliminary results obtained from simulation studies indicate that the concept is effective for turnoff speeds up to 60-70 knots. Alternative guidance information sources are under review. A candidate technique utilizing a magnetic leader cable is currently undergoing preliminary field tests to determine signal strength and accuracy. High speed turnoff maneuvers were conducted at the Columbia, S.C. airport to determine feasibility of executing 30-70 knot turnoffs using the TCV B-737. Comments of pilots and observers and preliminary analysis of performance data indicate that turnoffs at these speeds are feasible. Lateral accelerations experienced during these tests fell within acceptable bounds. Additional tests are required to ascertain desirable turn entry angle and turn radius. A high speed turnoff is planned for the Wallops Flight Center for future research.
Discussion:

With reference to the chart entitled "Aircraft Landing Rate Versus Exit Velocity," Mr. Poritzky felt that the TCV goal of 90 landing operations per hour is visionary to an extreme. He doesn't feel that it is realistic or ever will be. He feels that this number shown as a goal hurts the TCV program, and it must be qualified. Reduced touchdown dispersions and high speed turnoffs are only a part of the solution to increasing runway capacity. Mr. Litchford agreed with Mr. Poritzky saying that the number of 90 landing operations per hour on a single runway is twice too optimistic and can never be achieved. Mr. Taylor stated that the goal was shown assuming that many other constraints such as wing-tip vortices avoidance would be solved. The model used in the study was a simple model of runway landing capacity considering consecutive touchdowns and remembering the basic rule that only one aircraft is allowed on the runway at a time.

METERING AND SPACING SIMULATION STUDIES

Mr. Leonard Credeur, Flight Instrumentation Division, Langley Research Center, described a study, done in cooperation with FAA, of the effectiveness of speed control in a metering and spacing, RNAV and MLS environment. The charts which he used to describe the three phases of the program are included in Appendix G.

Discussion:

Mr. Poritzky felt that the real question was not being addressed in this study. From the viewpoint of optimization of capacity, the question which should be looked at is can the pilot using RNAV and MLS for navigating do better than the controller using radar vectoring as far as precision path following and reduction in dispersion of arrival times at waypoints and at runway threshold? Can a significant capacity increase be obtained through the use of 4D RNAV which takes advantage of the accuracy of the new MLS and on-board control system?
VTOL APPROACH AND LANDING TECHNOLOGY

Mr. John Garren, Rotorcraft Research Branch, Flight Research Division, Langley Research Center, was scheduled to give a brief report to the Panel summarizing progress and accomplishments in developing technology for helicopter IFR operations in a terminal area. This report was not given due to time constraints. However, the charts which he would have used are included for information of the Panel as Appendix H.

OCULOMETER STUDIES IN DEFINING PILOT INFORMATION NEEDS

Mr. Amos A. Spady, Simulation and Human Factors Branch, Flight Dynamics and Control Division, Langley Research Center, reported on the status and future thrusts of research using an oculometer in developing new cockpit display arrangements and evaluating new display concepts. The charts which he used in his presentation are in Appendix I. Analysis of oculometer data from the Piedmont Airline simulation experiment is continuing. This effort is expected to determine the relationships between lookpoint and dwell time to aircraft excursions and subsequent control activity. The first phase of this analysis has succeeded in identifying the pertinent parameters. An additional study has been conducted with the use of the oculometer to examine transitions from head-down to head-up flight during approach. The cooperative Langley/Ames study with Piedmont Airlines has been completed and documentation is underway. An oculometer has been installed in the TCV cockpit simulator and is being used to compare pilots' use of the additional fundamental information on the electronic displays with the standard airline electro-mechanical instrument array.

Discussion:

Mr. Howell asked if go-arounds on abandoned approaches are being looked at. Mr. Spady responded in the affirmative saying, however, that he has just received the data and no analysis of it has been made yet. Mr. Spady pointed out that in the measurement of workload the pupil diameter increases with workload; however, the time constant is so long that it cannot be used for specific events such as wind shear. Pupil diameter can be correlated with Cooper/Harper pilot ratings (long time constants).
ADVANCED DISPLAY CONCEPTS

Mr. Samuel A. Morello, Flight Programs Branch, Flight Research Division, Langley Research Center, reported on recent results of flight and simulation studies of manually controlled flight phases of terminal area operations. He stated that a team has been formed at Langley to investigate cockpit displayed traffic information (CDTI). Initial experiments are being defined and engineering planning is underway for the integration of a real-time version of the TCV air traffic simulation with the TCV cockpit simulator using the Electronic Horizontal Situation Indicator. He explained a display which is being used in profile descents and display concepts for use in curved decelerating approaches. His charts comprise Appendix A.

INTEGRATED SITUATION DISPLAY

Mr. Morello described a study which has been initiated into the use and potential benefits of predictive information in the Electronic Altitude Director Indicator (EADI). Previous manual RNAV and MLS approach flight tests have demonstrated the value of such information to the pilots when presented in map displays. The desirability of presenting similar information in vertical situation displays is under investigation. Some results were given of both simulation flight experiments. Situation information only was used on the displays; there were no commands displayed. The key to the concept is bringing up information from the HSI to the EADI.

Discussion:

Mr. Gorham was of the opinion that Mr. Morello's concept would help the pilot monitor an automatic approach and would permit him to take over manually if required. He is concerned about the redundancy problem when going below 100 feet during the approach. He recommended that the emphasis should be on improving the display of situation information to the pilot. Work should be continued on the assumption that the
landings in very low visibility will be autoland, and that displays will not be used for actual landings. Mr. Stahr stated that he was impressed with what could be done on the vertical display. This could result in the elimination of some CRT's in future aircraft. Mr. Litchford stated that he felt that if the pilot is given the proper information on a display he can land the aircraft as well as an autoland system. Mr. Gorham, Patten, and Stahr disagreed. Mr. Gorham stated that autoland systems do a good job, but the pilot needs to be given better information than he now has so that he can monitor the automatic approach and autoland and take over manually if required.

VELOCITY VECTOR CONTROL WHEEL STEERING

Mr. George G. Steinmetz, Analysis and Simulation Branch, Analysis and Computation Division, Langley Research Center, described a control system and display concept that gives the pilot direct control over the inertial flight path angle through the control column. It provides automatic holding of the pilot commanded flight path angle upon release of the column. This has been accomplished, as shown in the charts in Appendix L, by adding a gamma reference to the display and providing a more responsive, well damped control system. This concept has decreased pilot workload in simulation experiments.

SIMULATION STUDY IN WIND SHEAR

Mr. Sam Morello described for the Panel some recent results of simulation studies which were conducted to investigate integrated display information in a wind shear environment. The results showed physical workload was significantly less for an integrated display format and a significant difference in speed error between two different display formats. His charts are in Appendix M.

Discussion:

In response to a question by Mr. Patten, Mr. Morello stated that all runs were made using manual throttle. Following a recommendation by Mr. Andersen, Mr. Morello agreed that future simulation runs would be conducted using the real
world wind shear which was encountered by Flight 66 at JFK and that the runs would be started from further back in the approach. Mr. Stahr stated that an L-1011 on autopilot in simulation using the wind shear which Flight 66 had encountered had made a safe landing. The ultimate solution seems to be through the use of automatic flight control and good training.

WIND SHEAR DATA GATHERING AND A WIND SHEAR DETECTOR

Mr. Bob Taylor described the capabilities to measure and record wind shear information during flight. Some sample data was shown. He also described a total energy probe which has been developed at Langley as a candidate wind shear detector. The sensor has been evaluated in wind tunnel test and engineering is underway to install the sensor on the TCV B-737 for flight testing. Measurements from this sensor will be integrated into the display and control systems. The concept is illustrated in the charts in Appendix N.

AIRCRAFT LONGITUDINAL STABILITY AND CONTROL AS AFFECTED BY WIND SHEAR

Using the charts in Appendix O, Mr. Windsor L. Sherman, Aerospace Dynamics Branch, Flight Dynamics and Control Division, Langley Research Center, presented the results of a theoretical study of shear effects on aircraft control and stability.

HEAD UP DISPLAY CONCEPT PROGRAM

Overview:

Mr. Alan B. Chambers, Chief of Man-Vehicle Systems Research Division, Mr. Richard F. Haines and Mr. Richard S. Bray, Ames Research Center, presented via telephone conference service from Ames an overview of an FAA/NASA program to determine the advantages and disadvantages of the head up display (HUD) concept in approach and landing operations. Copies of the viewgraphs used in presenting the overview are contained in Appendix P. Mr. Chambers gave the history and background of the HUD program. This program started
with a request about 10 months ago from FAA to NASA. A program plan was drafted jointly with FAA and was approved in February after it had been discussed with ATA and ALPA representatives. This program which is investigating HUD in transitioning from IFR to visual during the approach, has five phases of which the background review and literature search has been completed. The next two phases (laboratory/simulator tests and full operational simulations to evaluate the full potential effectiveness of candidate HUD's will cover 12-14 months. Engineering flight evaluation and flight demonstrations will follow the simulations. Mr. Haines and Mr. Bray described the features of the simulation and flight experiments.

Discussion:

Mr. Andersen asked if an operational requirement for HUD had been defined. Mr. Howell said he was concerned about the symbology assessment and cognitive switching assessment work without having defined a formal role for HUD. Mr. Reeder expressed an interest in having the study carried on down into CAT III conditions. Mr. Haines stated that this will be done in due time. He said also that the program shouldn't limit too early the questions or issues which should be addressed. Mr. Litchford inquired if the tests will include misalignment of the symbology with the real world. He stated that a NASA study in 1968 had looked into this and found that it could be a problem.

Mr. Patten stated that a DC-9-80 which is being delivered to a non-US airline customer with HUD will be certified. He stated that a definition of HUD requirements have been made for this aircraft. Mr. Chambers concluded the overview by inviting Panel Members to visit Ames Research Center and discuss the program with him and his staff.

COOPERATIVE INTERDISCIPLINARY DEVELOPMENT OF ON-BOARD PERFORMANCE COMPUTERS AND ADVANCED AIR TRAFFIC CONTROL

Mr. R. S. Stahr, Director, Development Engineering, Eastern Airlines, Inc., presented the Eastern Airlines' concept of the essential elements of an onboard performance computer and described some of the logical growth opportunities.
The outline which he used in his presentation is contained in Appendix Q. He supplemented his presentation with a film which described the capabilities and use of one concept of a flight management advisory system. Mr. Stahr feels that the aviation community can combine the size, cost and speed of microprocessors with the intelligence of pilots and predictability of the modern jet transport into a man-machine system that will make ATC easier for the FAA to manage, more efficient for the airlines, more economical for the travelling public, and safer for all the people involved. The microprocessor revolution may be the most significant thing since the introduction of the autopilot. Mr. Stahr expressed the hope that NASA and FAA would become more involved and supportive of the exploitation of the digital, onboard performance computers. One area where NASA could help is by vigorous development and refinement of delayed flap approach procedures. He noted that the Concorde is making decelerating approaches at Dulles.

PANEL RECOMMENDATIONS

After a discussion of the relevancy, timing, scope, and efficacy of the activities presented at this Panel meeting, the Panel arrived at the following recommendations and resolutions:

TCV Program Management

The NASA briefing to the Panel was well organized, well presented, and was indicative of a significantly improved and business-like management of the program.

The TCV staff was urged to continue the programs organization and presentation along this line.

The Panel is well aware of the schedule constraints imposed upon NASA by other Governmental influences, e.g., the Argentina demonstration.

Follow-On Industry Coordination

The Panel believes it is imperative that NASA continues frequent industry interactions. It is also strongly recommended that the TCV program continues with formal industry advisory panel associations.
Advanced Display Development:

All industry indicators and development trends clearly show an increasing use of automated airplane navigation and flight control systems. The prime need is for improved displays so that the crew can monitor and maintain total situation awareness throughout all regimes of flight and visibility conditions. Improved warning systems and possibly new sensors should also be explored to support this requirement.

Discussion:

Mr. Hodge said that in view of the impending reorganization of NASA's RTAC, the best techniques or methods to use to continue frequent industry interactions are not clear at this time. Perhaps this would be through ad hoc groups, seminars, workshops, or similar activities. Mr. Gorham observed that he likes the present arrangement. It was disciplined, and provided continuity. The Panel Members had become well acquainted with TCV personnel, their procedures, and methods of operation. Mr. Stitt suggested that a possible technique would be to hold minisymposia of a few days length, consisting of a small number of paid consultants. Mr. Patten feels that Langley should take a strong stand to keep the Panel in operation. Mr. Gorham and Mr. Stahr noted the good and improved relations between NASA and FAA in this area. In response to questions by the Chairman regarding the status of establishing an FAA Technical Liaison Office at the Langley Research Center, Mr. Versytnen stated that there has been an agreement in principle between Administrators regarding establishing the office. However, staffing of the office has not been defined yet. For example, the number of people and whether the assignments would be permanent as opposed to annual rotating positions had not been settled.
Mr. Hodge thanked the members for their participation on the Panel and for their valuable assistance to the TCV program. The meeting was adjourned at 4:00 p.m., September 14, 1977, except for a tour of Langley Research Center facilities and small group discussions by several of the Panel Members on September 15.

Submitted:  

Concur:  

Lee D. Goolsby
Recording Secretary

Kenneth E. Hodge
Executive Secretary
TCV PROGRAM OVERVIEW
CONDUCT RESEARCH TO ASSURE AIRBORNE SYSTEMS TECHNOLOGY READINESS FOR IMPROVED LONG HAUL AIRCRAFT OPERATIONS IN FUTURE TERMINAL AREA ENVIRONMENTS.

PLANNING PREMISE:

0 FLIGHT WILL BE IN TIME-CONTROLLED, ENERGY-EFFICIENT OPERATIONS THROUGH RUNWAY TURNOFF IN REDUCED VISIBILITY.

0 AIRCRAFT OPERATIONS WILL INVOLVE FLIGHT CREW IN APPROPRIATE RELATIONSHIPS WITH AIRCRAFT AND ATC SYSTEMS.
**TCV RESEARCH OBJECTIVES**

**TCV GOAL:** IDENTIFY A/C AND FLIGHT MANAGEMENT TECHNOLOGY THAT WILL BENEFIT CTOL TERMINAL AREA OPERATIONS

<table>
<thead>
<tr>
<th>OBJECTIVES</th>
<th>ELEMENTS</th>
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</table>
| I. Improve terminal area capacity and efficiency | A. Systems and Procedures for ATC Evolution  
B. Systems and Procedures for Runway Capacity  
C. Profiles and Procedures for Fuel Conservation |
| II. Improve approach and landing capability in adverse weather | A. Human Factor Elements for Effective Fit Management  
B. Systems and Information to Minimize Wind-Shear Haz.  
C. Airborne Sensors for Weather-Penetration |
| III. Reduce Noise Impact | A. Profiles and Configurations for Noise Reduction |
RESEARCH AND TECHNOLOGY
ADVISORY COUNCIL,
AD HOC PANEL ON TERMINAL
CONFIGURED VEHICLES

REPORT OF MEETING
July 21–22, 1976

OFFICE OF AERONAUTICS & SPACE TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Discussion:

Panel members had been given a copy of the above goals and objectives prior to the meeting and were prepared to make positive recommendations on each item. It was agreed that "terminal area operations" should commence from the start of letdown. After considerable discussion the Panel recommended that the TCV Program Objectives be revised as follows:

TCV Program Goal:

Identify aircraft and flight management technology that will benefit CTOL terminal area operations.

The Major Objectives to Achieve the Goal are:

- Conduct research that will support improvements in:
  - Terminal area capacity and efficiency.
  - Approach and landing capability in adverse weather.
  - Reduction of Noise Impact.

Areas of Emphasis:

I. Improve terminal area capacity and efficiency

A. Airborne systems and procedures which aid in the evaluation of, and provide supporting information for, ATC system evolution (cooperation with FAA):

1. Define and evaluate transition techniques and maneuvers through landing that will permit close-in acquisition of runway heading including downwind entry; and, stabilized flight within MLS coverage ensuring maximum simplification of onboard system interfaces and sensor requirements.

2. Examine the noise characteristics and potential noise reduction of aircraft utilizing curved paths in congested terminal areas.
3. Examine the minimum (simplest acceptable) and optimum arrangement of information and displays to help pilots achieve confidence on the safety and satisfactory execution of complex approach paths, flown either manually or automatically.

4. Respond to FAA recommendations in research efforts which could result in safe maximum utilization of congested air space or add capacity to the ATC system including simplified crew interfaces with ATC, and better ways to display navigation and clearance communications for the pilots' rapid assimilation and assessment.

B. Airborne systems and procedures for increased runway capacity:

1. Demonstrate curved-path following that could permit reduced runway separation requirements for simultaneous approaches through reduction of overshoot and tracking errors.

2. Investigate the degree to which aircraft configuration and procedural changes could reduce longitudinal separation and enhance the runway feeding process.

II. Improved approach and landing capability in adverse weather.

A. Human factor elements that contribute to effective flight management operations in cooperation with Ames' human factors program.

1. Explore critical information needs and decision processes for crew participation in terminal area operations, including transition to outside cues for landing in very poor visibility.
2. Evaluate display requirements including format, field of view, motion cues, and real-world perspective, for approach, missed approach, landing, rollout, high-speed turnoff, and taxi operations in very poor visibility.

3. Explore simplified computer-address techniques, including methods for direct entry of navigational way-point data into a display.

B. In response to FAA recommendations conduct research on reduction of wind shear effects by improved autoland design and optimization of information for thrust management and flight path control.

C. Determine the weather-penetrating potential of airborne sensor technology.

II. Reduction of noise impact.

A. Effective flight profiles and configurations:

1. Examine effect of curved paths (within MLS coverage) on noise footprint and distribution.

Major Features of the Upgraded Third Generation Air Traffic Control System:

As one means of complying with the Panel recommendation "that NASA strengthen and maintain its coordination with FAA to ensure that the TCV program will relate to and provide supporting information for air traffic control systems evolution", NASA requested that the Office of Systems Engineering Management, FAA, provide a briefing on features of the Upgraded Third Generation Air Traffic Control System which could impact or be impacted by the TCV program technology.

Mr. Neal Blake, Acting Director of Systems Engineering Management, headed a team of briefers from the FAA. The subjects covered and presenters were:

ORIGINAL PAGE IS OF POOR QUALITY
I. Improve terminal area capacity and efficiency

C. Airborne systems and procedures for reduced fuel consumption.

1. Define and examine control techniques and aircraft modifications for minimized fuel consumption.

2. Investigate the degree to which curved path following and procedural changes can enhance reduced fuel consumption.
INTERFACES

- Program Review Exchanges: FAA, WPAFB, Ames
- Technical Meetings: AFFDL, ATA, Navy, Army, Ames, Industry
- Industry Program Planning: Airlines, Aircraft Cos. (Automatic Systems Test)
- Joint Human Factors Experiments: Ames
HIGH CAPACITY TERMINAL AREA OPERATIONS IN LOW VISIBILITY, UTILIZING RNAV/MLS/DABS
THE CHALLENGE

APPROACH AND LANDING DISPLAY REQUIREMENTS FOR TCV

SELECTION

TRANSITION RNAV TO MLS

DISPLAY OF DESIRED OR ASSIGNED PATH

CURVED DECELERATING APPROACH

STAR AND CIRCLE

PATHWAY WITH OR WITHOUT PREDICTIVE INFORMATION

TUNNEL AIRSPEED AND CONFIGURATION MONITORING

WINDSHEAR

DISPLAY FORMAT TRANSITION

PATH POSITION

ACQUISITION, FLARE & LANDING

GE COMPUTER GENERATED

U OF ILL. SYMBOLIC PERSPECTIVE

STEREO

SITUATION WITH COMMAND FLARE

HUD

DECELERATING TURNOFF AT SPEED AND POSITION

EADI

EHSI

ANTICIPATION

PREDICTION

RNAV DESCENT

CDTI

FORMAT

PREDICTION

ENERGY EFFICIENT DESCENT

EFFECTIVE TIME

AIRSPEED

GROUND SPEED

INTEGRATION

ORIGINAL PAGE IS OF POOR QUALITY

7/8/77 J. P. REEDER
PROGRAM ELEMENTS

- TRANSITION TECHNIQUES RNAV/MLS
- COMPLEX APPROACH PATHS (3 AND 4D - DECELERATING)
- AUTOLAND WITH AUTOThROTTLE/FLARE
- METERING AND SPACING CONCEPTS (BENEFITS, A/C IMPACT)
- SYSTEM SIMPLIFICATION (REDUNDANCY REQUIREMENTS, ETC.)
- REDUCTION OF PATH ERROR (LATERAL, LONGITUDINAL, VERTICAL)
- PILOT/CREW INFORMATION REQUIREMENTS
- DISPLAY INFORMATION ENHANCEMENT
- PILOT/COMPUTER INTERFACE
- SHEAR DETECTION/DISPLAY/FLIGHT CONTROL
- DETERMINATION OF CURVED-PATH NOISE SENSITIVITY
- ENERGY-EFFICIENT OPERATION
- HIGH-SPEED RUNWAY OPERATION
- JOINT FAA/NASA FLIGHT EXPERIMENTS.
ICAO/MLS Demonstration with TCV B-737 showed superior precision under automatic control during close-in curved approaches and landings under very adverse wind conditions.

Advanced display concepts permitted manually controlled precision curved approaches to flare height with only 1 1/2 mile straight final.

Exploratory high-speed turn-off tests made with TCV B-737.

Oculometer data from Piedmont studies providing new measurements of crew scan patterns and visual workload to correlate with control functions.

Wind shear (wind components) obtained with inertial system on every TCV-737 approach and landing.

Wind shear display information allows pilots to cope with shear effectively in simulation.

Baseline noise measured, including that under straight glide paths up to 5 NPERFF.
ACCOMPLISHMENTS TO DATE, con.

DLC PROVES EFFECTIVE IN ACQUISITION AND TRACKING IN SIMULATION.

SOFTWARE VALIDATION TECHNIQUES DEVELOPED HAVE SIGNIFICANTLY IMPROVED PRODUCTIVITY OF SOFTWARE DESIGN AND VERIFICATION.
NEAR-TERM ACTIVITIES

- Evaluate advanced display concepts for precision curved-path following (simulator).
- Evaluate flight-control concepts (including DLC, advanced flare and auto throttle control laws) for precision-path following, touchdown control, and reduction of pilot workload (simulator).
- Evaluate runway guidance concept for high-speed turnoff at WFC.
- Implement simulated MLS at WFC: characterize approach-path operational envelope and airborne-system functional requirements.
- Provide airborne capability for evaluating cockpit-displayed traffic information.
- Evaluate metering and spacing strategies to improve capacity.
- Evaluate airborne sensor for predicting wind shear.
- Evaluate energy-efficient descent and approach procedures.
- Joint FAA/NASA MLS experiments.
MAJOR MILESTONES*

I. IMPROVE TERMINAL AREA CAPACITY AND EFFICIENCY

II. IMPROVE APPROACH AND LANDING CAPABILITY IN ADVERSE WEATHER

*III. REDUCE NOISE IMPACT AND FUEL CONSERVATIVE OPERATIONS ARE INTEGRATED INTO I AND II.
**LANGLEY RESEARCH CENTER**

**TERMINAL CONFIGURED VEHICLE PROGRAM**

**IMPROVE TERMINAL AREA CAPACITY & EFFICIENCY**

**TCV-8737**

**RESPONSIBILITY:**

**APPROVAL:**

**ACCOMPLISHMENT:**

**DATE:**

**LEVEL:**

**ORIGINAL SCHEDULE APPROVAL:**

**LAST SCHEDULE CHANGE:** SEPTEMBER 13, 1977

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- **1. IMPROVED AUTOFLAP & AUTOBRAKE**
  - 1977: Evaluate, Implement
  - 1978: Concept, Evaluate
  - 1982: Implementation

- **2. PRECISION APPROACH & LANDING**
  - 1977: Concept, Evaluate
  - 1978: Simulation
  - 1981: Implementation

- **3. 3-D GUIDANCE & CONTROL**
  - 1977: Concept, Evaluate
  - 1978: Simulation
  - 1981: Implement without Turnoff

- **4. 3-D INTEGRATED GUIDANCE & CONTROL**
  - 1977: Concept, Evaluate
  - 1978: Simulation, Implement
  - 1981: Implementation of 3-D Curved Path

- **5. ADVANCED RECEIVER**
  - 1977: Design, Analyze
  - 1978: Development, Test

- **6. ROLLOUT TURNOFF**
  - 1977: Implementation
  - 1978: Evaluation

- **7. 4-D INTEGRATED GUIDANCE & CONTROL**
  - 1977: Design, Test
  - 1978: Development, Implementation

- **8. GENERALIZED CURVED-PATH**
  - 1977: Concept, Evaluate
  - 1978: Simulation
  - 1981: Implementation of 3-D Curved Path

- **9. OPTIMIZATION STUDIES**
  - 1977: Concept, Evaluate
  - 1978: Simulation

- **10. CURVED PATH NAVIGATION**
  - 1977: Design, Analyze
  - 1978: Development, Test

- **11. BLIND TO MLS TRANSITION**
  - 1977: Design, Analyze
  - 1978: Development, Test

- **12. SHEAR DETECTION & ALLEVIATION**
  - 1977: Concept, Evaluate
  - 1978: Simulation, Implementation

- **13. MULTIPURPOSE BASED DEVELOPMENT**
  - 1977: Concept, Evaluate
  - 1978: Simulation, Implementation

- **14. ADVANCED SYSTEM DEVELOPMENT (AUGMENTED PROGRAMS)**
  - 1977: Concept, Evaluate
  - 1978: Simulation, Implementation

- **15. ADAPTIVE CONTROLS**
  - 1977: Concept, Evaluate
  - 1978: Simulation

- **16. IMPROVED STATE ESTIMATORS**
  - 1977: Concept, Evaluate
  - 1978: Simulation

- **17. MANUAL/AUTOCONTROL INTERACTION**
  - 1977: Concept, Evaluate
  - 1978: Simulation

- **18. DECELERATING CONTROL SYSTEM**
  - 1977: Concept, Evaluate
  - 1978: Simulation

- **19. NOISE ABATEMENT PATHS**
  - 1977: Concept, Evaluate
  - 1978: Simulation

- **20. ALTERNATIVES/SUPPLEMENTS TO MLS**
  - 1977: Concept, Evaluate
  - 1978: Simulation

**NOTES:**

- **FLIGHT TEST PERIOD**
- **AUGMENTED PROGRAMS**
### Terminal Configured Vehicle Program

#### Milestones

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#### Notes

- Flight Test Period
- Augmented Progress
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**NOTES**

**TERMINAL CONFIGURED VEHICLE PROGRAM**

**STATUS AS OF SEPTEMBER 1, 1977**

**ATC OPERATIONS ANALYSIS**

**LEVEL**

**FLIGHT TIME**

**AUGMENTED PROGR**
**Milestones**

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**Notes:**

1. Schedule depends on contract award at this point.
2. Decision point for aircraft installation.
MLS RELATED RESEARCH

- SUMMARY OF 1976 ICAO DEMONSTRATION PERFORMANCE RESULTS
- MLS AIRBORNE ANTENNA DESIGN STUDIES (FFA REQUEST)
- FLIGHT TEST VALIDATION OF ANTENNA PATTERN PREDICTIONS
- MLS RECEIVER CONCEPT DEVELOPMENT (AHOP RECOMMENDATION)
- REAL AND SIMULATED MLS AT WALLOPS
  - NEW SOFTWARE CHECKOUT
  - RNAV/MLS TRANSITIONS (VOLUMETRIC COVERAGE)
  - ADVANCED CONTROL LAW DEVELOPMENT
- 1978 TRSB DEMONSTRATION TO ICAO
SUMMARY OF FLIGHTS

AUTOMATIC CONTROL:
208 APPROACHES (3 AND 2 NAUTICAL MILE FINALS)
205 FLARES TO TOUCHDOWN
< 15 METERS OVERSHOOT ON FINAL TURN

MANUAL CONTROL:
41 APPROACHES (3, 11/2, 1 NAUTICAL MILE FINALS)

DISPLAY UTILIZATION:
- MANUALLY CONTROLLED NAVIGATION
  3-D NAVIGATION
  DIVERSIONS: FLIGHT PLAN CHANGE
  INTRUDERS
  WEATHER

- MONITORING OF AUTO APPROACHES TO LANDING
  MANUALLY CONTROLLED APPROACHES

WIND ENVIRONMENT:
20-25 KNOT TAILWIND COMPONENTS
STRONG GUSTS
20-25 KNOT QUARTERING WINDS
20 KNOT CROSS WIND COMPONENTS
SHEARS IN EXCESS OF 50 KNOTS/30 METERS (100 FEET)
DTA, MEAN AND TWO-SIGMA STATISTICS FOR INITIAL APPROACH
DZA, MEAN AND TWO-SIGMA STATISTICS FOR INITIAL APPROACH
ICAO TRACKING PERFORMANCE

WIND CONDITIONS
- AVERAGE WINDS: 16-20 KTS
- 20 KT/100 FT SHEARS
- GUSTS: 15KT HORIZONTAL 5KT VERTICAL

Dual-DME RNAV
2σ DELIVERY PATH ERRORS
MLS RNAV 2σ ERRORS

Approach Path

ICAO 2σ PERFORMANCE

CAT II ILS DECISION HEIGHT WINDOW
AIRBORNE ANTENNA STUDIES - FY 77 ACCOMPLISHMENTS

- COMPUTERIZED ANTENNA SITING PROGRAM OPERATIONAL ON REMOTE GRAPHICS TERMINAL - 12 LARGE AIRCRAFT STUDIED
- PUBLISHED MLS POLARIZATION STUDY
- COMPLETED ANALYSIS OF MICROSTRIP ANTENNAS WHICH ALLOWS COMPUTERIZED DESIGN, INCLUDING FEED CIRCUITS AND HYBRIDS
- PRELIMINARY ANALYSIS OF MLS FLIGHT TEST DATA INDICATES SCALE MODEL AND CALCULATED ANTENNA PATTERNS SHOULD PREDICT FULL SCALE AIRCRAFT PATTERNS WITHIN 5 DB.
COMMERCIAL AIRCRAFT SELECTED FOR MLS ANTENNA SITING STUDY

- BOEING 707*
- BOEING 727 = 200
- BOEING 737 = 100*
- BOEING 747
- LOCKHEED L-1011*
- LOCKHEED JET STAR II
- MCDONNELL DOUGLAS DC-9
- MCDONNELL DOUGLAS DC-10
- BOEING YC-14
- MCDONNELL DOUGLAS YC-15
- LOCKHEED L100-20
- LOCKHEED C-130 E

*EXPERIMENTAL AND/OR CALCULATED DATA AVAILABLE FOR COMPARISON WITH LANGLEY RESEARCH CENTER CALCULATIONS.
Station 180.5 = Ku-band horn
Station 239 = C-band omni, Ku-band omni
Station 946.5 = C-band omni
Station 1170 = C-band omni

ANTENNA LOCATIONS USED FOR FLIGHT EXPERIMENT
Start data at Waypoint ANTCA

All headings magnetic
Constant 3' descent

STAR AC349
MLS ANTENNA FLIGHT TEST PROFILE FOR RUN 8.

Elevation (E1) scanning beam antenna data

Error (dB)
- < -5
- -5 to -3
- -3 to -1
- -1 to +1
- +1 to +3
- +3 to +5
- > +5

PLOT OF ERRORS BETWEEN PREDICTED AND MEASURED SIGNAL LEVELS AS A FUNCTION OF AIRCRAFT ANTENNA LOOK ANGLES FOR RUN 8.
OPTIMAL MLS RECEIVERS

A high performance receiver has been demonstrated in simulation:

- **No multipath:** equal to or better than conventional receiver
- **Heavy multipath, 5 Hz scalloping rate**
  
  Conventional receiver peak error $\sim 0.5^\circ$
  Optimal receiver peak error $\sim 0.02^\circ$

But the following problems exist:

- **Very close tracking of scalloping frequency ($\pm 0.4$ Hz) required**
  to insure adequate tracking of phase difference ($\pm 10^\circ$)

- **Difficult acquisition:** initialization of 5 or 6 parameters
  required, some to high accuracies
RECOMMENDATION:

MODIFY THE DESIGN TO ELIMINATE

PHASE difference, $\beta$

SCALLOPING frequency, $f_{sc}$

EXPECTED PROS AND CONS OF NEW DESIGN:

PROS:

- Performance superior to Threshold Receiver
- Eliminates high accuracy tracking requirements
- Reduced acquisition requirements

CONS:

- Some loss in performance relative to Optimal Receiver

ORIGINAL PAGE IS OF POOR QUALITY
ONBOARD ELEMENTS FOR ICAO NAVIGATION, GUIDANCE AND CONTROL SYSTEM

- Antenna
- MLS Receiver
- MLS Signal Processor (SKC-2000)
- Onboard B737 Aircraft Sensors
- Navigation and Guidance (C4000)
- Autoland and Autopilot (FCC)
- Surface Command
RMAV/MLS TRANSITIONS

1. ANALYTICAL STUDY OF ANTENNA COVERAGE REQUIREMENTS

FOR SELECTED TERMINAL AREA PATHS, TIME HISTORIES OF:

- Azimuth angle from ground station antenna to aircraft
- Elevation angle from ground station antenna to aircraft
- Range from ground station antenna to aircraft
- Transmission loss over path
- Azimuth angle of ground station from aircraft antenna (Beta)
- Elevation angle of ground station from aircraft antenna (Alpha)
- Aircraft position coordinates
- Aircraft heading, attitude and speed
LYONS

PLATTE.

60°

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ELIZABETH

DENVER TERMINAL AREA MODEL USED IN ANTENNA REQUIREMENTS STUDY
TYPICAL AIRBORNE ANTENNA REQUIREMENT FOR DENVER TERMINAL AREA SIMULATION

LOOK ANGLES ARE TO FPS-16 ANTENNA
INITIAL APPROACH FROM NORTHWEST
PROPOSED ICAO DEMONSTRATION AT NAFEC, MARCH 1978

NEW FEATURES:

- USE OF PRECISION L BAND DME FOR APPROACH AND AUTOLAND
- USE OF AUSTRALIAN C BAND FLARE SYSTEM FOR AUTOLAND
- MORE COMPLICATED MLS GEOMETRY (OFFSET DME)
- SHORTER TURN RADIUS AND SHORTER FINAL APPROACH (1½ MILE GOAL)
- TRANSITION TO BACK AZIMUTH GUIDANCE FOR MISSED APPROACH
- ANTENNA SWITCHING TO CHIN ANTENNA FOR S.E.P. DEMONSTRATION
PROPOSED TRSB DEMONSTRATION TO O.A.S. MEETING

BUENOS AIRES, ARGENTINA, OCT. 31-NOV. 4

0 BASIC NARROW TRSB MLS INSTALLED AT EZEIZA AIRPORT
0 SMALL COMMUNITY TRSB MLS AT DOWNTOWN AIRPORT (AEROPARQUE JORGE NEWBERRY)
0 RNAV FLIGHTS BETWEEN AIRPORTS
0 CURVED DESCENDING APPROACHES AT EZEIZA, AUTOLANDS USING RADIO ALTIMETER FLARE
0 CONVENTIONAL ILS-TYPE AUTOMATIC OR MANUAL APPROACHES AT AEROPARQUE
WHOLE WORD COMPUTER SYSTEM STATUS

(WMCS)
WHOLE WORD: COMPUTER SYSTEM STATUS:

(WMCS):

* COMPUTER SYSTEM COMPARISON:

* INTERFACE WITH GUIDANCE AND CONTROL SYSTEM:

* SUMMARY OF FLIGHT CONTROL COMPUTER STATUS:

* FLIGHT CONTROL COMPUTER SYSTEM:
FLIGHT CONTROL COMPUTER CHARACTERISTICS

OLD

- GE ICP-723
- Digital Variable Increment
- Special Purpose
- No Expansion Capability
- Difficult to Program
- Some Functions Inefficient (Logical, Discrete)

NEW

- GE MCP-703 (WMCS)
- Digital General Purpose
- External Memory for Expansion
- Proven Design
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<th>ICP-723</th>
<th>MCP-703 (VMCS)</th>
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<td><strong>Type</strong></td>
<td>Digital Variable Increment</td>
<td>Digital General Purpose</td>
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<tr>
<td><strong>Word Length</strong></td>
<td>16 Bits</td>
<td>16 Bits</td>
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<tr>
<td><strong>Memory</strong></td>
<td>4K x 18 Bit Core</td>
<td>32K x 18 Bit Core</td>
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<tr>
<td><strong>Timing</strong></td>
<td>48 μSEC/ALGORITHM</td>
<td>2 μSEC/INSTRUCTION</td>
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<td>6.144 MSEC/ITERATION</td>
<td>6.144 MSEC/MINOR FRAME</td>
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<tr>
<td><strong>Computational Capability</strong></td>
<td>256 Algorithms (128/ITERATION)</td>
<td>LIMITED ONLY BY MEMORY, SIZE AND TIMING</td>
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<td><strong>Inputs</strong></td>
<td>64 SERIAL</td>
<td>64 SERIAL</td>
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<td>32 DISCRETE</td>
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<td><strong>Outputs</strong></td>
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<td>8 SERIAL</td>
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<td>15 ANALOG</td>
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FLIGHT CONTROL SYSTEM BLOCK DIAGRAM

- NAVIGATION CONTROL AND DISPLAY UNIT
- AGCS MODE SELECT PANEL
- NAVIGATION GUIDANCE COMPUTER
  
  - Litton C-6000

- FLIGHT CONTROL COMPUTERS
  
  - GE MCP 703

- SERVOS

- FLIGHT CONTROL SENSORS

- NAVIGATION SENSORS

- VOR DME AIR DATA INS

- AUTO THRUST SERVO

- ELECTRONIC DISPLAYS AND ANNUNCIATORS

- RATE GYROS
  
  - INS
  
  - ILS
  
  - AIR DATA
  
  - RADIO ALTIMETER
  
  - CONTROL WHEEL FORCE
  
  - COLUMN FORCE

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<td>Operational</td>
<td>3D research flights</td>
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<td>Design and fabrication complete</td>
<td>Design and coding complete</td>
<td>simplex system tests complete</td>
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<td>ILS auto land</td>
<td>Receiver interface</td>
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FLIGHT PATH ANGLE CONTROL
RESEARCH OBJECTIVES

- EVALUATE LONGITUDINAL CONTROL RESPONSE REQUIREMENTS
  - FLIGHT PATH ANGLE TIME CONSTANT
  - DISPLAY INFORMATION
  - TRACKING

- EVALUATE ROLL CONTROL SYSTEM RESPONSE REQUIREMENTS
  - PRECISION TRACK CHANGES (MANUAL)
  - TRACK ANGLE HOLD
  - TURN COORDINATION

- EVALUATE FLARE SYSTEM RESPONSE
  - DISPERSION
  - SINK RATE ON TOUCH DOWN
VELOCITY CWS CONTROL LAW

PMG PITCH

0.1 IN DEADZONE

\[
\frac{3.28}{.093s + 1}
\]

\[
\frac{4.32}{s}
\]

\[
\frac{.432}{s}
\]

FLIGHT PATH ANGLE (\(\gamma\))

PITCH RATE (\(\dot{\gamma}\))

\[
\frac{16s}{16s + 1}
\]

\[
2.16
\]

ROLL ATTITUDE (\(\phi\))

\[
.004
\]
SYSTEM RESPONSE TO A STEP CONTROL INPUT
FLIGHT PATH ANGLE RESPONSE TO STEP CONTROL INPUTS

FLIGHT PATH ANGLE, $\gamma$, DEG

TIME, SECONDS

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SPOILERS ALONE

ELEVATOR ALONE
COMPARISON OF SYSTEM RESPONSE TO STEP CONTROL INPUT
RESULTS OF 6 ILS GLIDESLOPE TRACKING TASKS
FLIGHT PATH ANGLE CONTROL
RESEARCH OBJECTIVES

  - F L I G H T  P A T H  A N G L E  T I M E  C O N S T A N T
  - D I S P L A Y  I N F O R M A T I O N
  - T R A C K I N G

  - P R E C I S I O N  T R A C K  C H A N G E S  (M A N U A L)
  - T R A C K  A N G L E  H O L D
  - T U R N  C O O R D I N A T I O N

  - D I S P E R S I Ó N
  - S I N K  R A T E  O N  T O U C H  D O W N
VELOCITY CWS CONTROL LAW

PM C PITCH

0.1 IN DEADZONE

\[ \frac{0.774}{s} \]

\[ \frac{3.28}{0.093s + 1} \]

DISPLAY

FLIGHT PATH ANGLE (\( \gamma \))

\[ \frac{16s}{16s + 1} \]

\[ \frac{4.32}{s} \]

\[ \frac{0.432}{s} \]

ROLL ATTITUDE (\( \phi \))

\[ \frac{0.004}{\text{cross}} \]

PITCH RATE (\( \dot{\gamma} \))

VELOCITY CWS CONTROL LAW
SYSTEM RESPONSE TO A STEP CONTROL INPUT

\[ \gamma \]
\[ \gamma_c \]

VCWS

TURBULENCE
AUTOFLARE LAW IMPROVEMENT

OBJECTIVE - REDUCE TOUCHDOWN DISPERSIONS TO PROVIDE INCREASED TERMINAL AREA CAPACITY

ADVANCED AUTOFLARE

REDUCED TOUCHDOWN DISPERSIONS

HIGH SPEED ROLLOUT AND TURNOFF
AUTOFLARE LAW IMPROVEMENT

0 EXISTING AUTOFLARE

  DESCRIPTION
  PERFORMANCE

0 AUTOFLARE MODIFICATIONS

  CONCEPTS CONSIDERED
  PRELIMINARY SIMULATION RESULTS

0 ADVANCED DESIGN

  DESIGN GOALS
  SIMULATION PERFORMANCE
TCV B-737 AUTOFLARE

ALGORITHM \[ \delta_e = \text{RAMP} + K(s) \left[ \hat{H} + T (H + H_B) \right] + \text{DAMPING TERMS} \]

FLARE INITIATION \[ F(H) < 0 \]

EXPONENTIAL PATH \[ H = (H + H_B) e^{-cT} - H_B \]

THROTTLE COMMAND RETARDED TO IDLE AT FIXED RATE

FACTORS CONTRIBUTING TO TOUCHDOWN DISPERSION INCLUDE:

- WIND CONDITIONS
- ERRORS IN FILTERED \( \hat{H} \)
- VARIATIONS IN THROTTLE SETTING
Comparison of $h_{CF}$ and $h$ derived from $h_{INS}$

Flight 117 Run B3
ALTITUDE

15 KT SIMULATION RESULTS

GPIP

365' = 1σ

11/74 FLIGHT TESTS

HEADWIND TAILWIND

XTD XTD
AUTOFLARE MODIFICATIONS

$H_B$ MODIFICATION

$$H = (H_0 + H_B) e^{-\frac{T}{H_B}}$$

$H_B = H_B (V_G)$ TO FIX $X_{TD}$

$T$ MODIFICATION

INITIATE FLARE AT CONSTANT $H$

MODIFY $T$ TO FIX $X_{TD}$

$$T = \frac{T_0 V_G}{V_{GO}} \quad H = (H_0 + H_B) e^{-\frac{T_0 X}{V_{GO}} - H_B}$$
MODIFIED AUTOFLARE PERFORMANCE
-(PRELIMINARY SIMULATION RESULTS).

(MEAN TOUCHDOWN POINT FROM GPIP IN FT)

<table>
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<tr>
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<th>15 KT HEADWIND</th>
<th>15 KT TAILWIND</th>
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<tr>
<td>TCV B-737</td>
<td>634</td>
<td>1024</td>
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<td><strong>H_B MODIFICATION</strong></td>
<td>649</td>
<td>574</td>
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<td><strong>T MODIFICATION</strong></td>
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<td>CONSTANT H_0</td>
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ADVANCED DIGITAL AUTOLAND CONTROL LAWS

CLOSE-IN CAPTURE OF LOCALIZER AND STEEP MLS GLIDESLOPE

DECRAB AND ADVANCED FLARE

EL

3° ILS GLIDESLOPE

PRECISION TOUCHDOWN
ADVANCED DIGITAL CONTROL SYSTEM

- Integrated Design of Guidance and Control Algorithms
  - Digital design for 3-D and 4-D
  - Low sample rate to reduce computations
  - Uses inherent cross-coupling to enhance performance

- Advanced Estimation Algorithms
  - Uses discrete TRSB MLS data
  - INS not required
  - Filters noise in position, rates, and attitudes

- Alleviation of Wind Effects
  - Steady state winds, gusts and shears estimated
  - Estimates used in control law
CAPTURE, TRACK, AND FLARE FOR SIX DEGREE GLIDESLOPE (A)

SETTLING TIME OF CURRENT CONTROL LAW FOR 3° GLIDESLOPE

PITCH

SINK RATE

ALTITUDE

TIME

FITTED ESTIMATE

FITTED RATE ESTIMATE

FITTED ESTIMATE
CAPTURE, TRACK, AND DECRAB OF LOCALIZER PATH

SETTLING TIME OF CURRENT CONTROL LAW

TIME (SEC)

ROLL DEG.

YAW DEG.

NASA Langley Research Center
AUTOFLARE DEVELOPMENT OBJECTIVES

AUTOFLARE MODIFICATION DESIGNED 12/77

FLIGHT DEMONSTRATION OF MODIFICATION 3/78

FLIGHT TEST 3-D DIGITAL DESIGN 10/78

FLIGHT TEST 3-D AND TURNOFF 12/79
APPENDIX F

HIGH SPEED TURNOFF ANALYSIS
RESEARCH OBJECTIVES

1. Determine the effects of turnoff speed and touch down dispersion on single runway landing capacity

2. Design a high speed turnoff for the Wallops Flight Center research runway
AIRCRAFT LANDING RATE VERSUS EXIT VELOCITY

EXIT DISTANCE FROM THRESHOLD

120
100
90
80
70
60
50
40
30
20
10

EXIT VELOCITY $V_E$ KTS

LANDING OPERATIONS PER HOUR

TCV GOAL

CURRENT TURN-OFF DESIGN SPEED

9 ft/sec²
3 ft/sec²

GOAL
REQUIRED ACCELERATION VS TOUCHDOWN POINT  \( V_A = 140 \)

NOMINAL TOUCHDOWN POINT
1,542 FEET

TURN-OFF SPEED

LIMIT ACCELERATION

LONGITUDINAL ACCELERATION, 
FT/SEC\(^2\)

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SHORT

TOUCHDOWN POINT, FT

LONG
REQUIRED ACCELERATION VS TOUCHDOWN POINT FOR TWO TURNOFF DISTANCES $V_A = 140$

$V_E = 80$

LONGITUDINAL ACCELERATION, FT/SEC$^2$

SHORT TOUCHDOWN POINT, FT

LONG

ACCELERATION

LIMIT 3700'

3000'

4000'

-12

-10

-8

-6

-4

-2
LATERAL ACCELERATION VS TIME

MANUAL TURNOFF \( V_E = 75 \text{ KT} \)

COLUMBIA, S.C

ATTEMPT TO FOLLOW TURNOFF CENTER LINE

FOLLOWED COMPOUND CURVE

LATERAL ACCELERATION, FT/SEC^2

TIME, SEC
CONSTRUCTION OF HIGH SPEED RUNWAY TURNOFF
WALLOPS FLIGHT CENTER

- **VAS-1**
- **FPS-16 LASER TRACKER**
- **MLS EL#1**
- **MLS EL#2**
- **RUNWAY GUIDANCE SYSTEM**
- **1.6 ACRES (COMBED SURFACE)**

**SCALE IN FEET**
- 0
- 1000
- 2000

**SCALE IN METERS**
- 0
- 200
- 400
- 600
PILOLETED GROUND SIMULATOR STUDIES

- SIMULATOR MODEL VERIFICATION
- TURN-OFF DESIGN STUDIES
- GUIDANCE, CONTROL, AND DISPLAY STUDIES
EVALUATION OF USING MLS TOGETHER WITH
A FIXED-PATH METERING AND SPACING SYSTEM

LEONARD CREDEUR
TESTING: ENVIRONMENT AND SYSTEM MODELS

CONFIGURATION

DENVER GEOMETRY WITH CLOSE-IN INTERCEPT CAPABILITY
IFR SEPARATION CRITERION
ACTUAL DENVER TRAFFIC DISTRIBUTION AND MIX OF AIRCRAFT TYPES
PEAK TRAFFIC DENSITY OF 35 TO 40 AIRCRAFT PER HOUR
DENVER WIND MODEL

NAVIGATION SYSTEMS:
VOR/DME AND ILS
VOR/DME AND +40° MLS
VOR/DME AND +60° MLS

ERROR MODELS
NAVIGATION
AIRBORNE EQUIPMENT
GROUND STATION
PILOTAGE
SURVEILLANCE
WIND

CONTROL LOGIC MODELS
ENROUTE METERING
TENTATIVE SEQUENCING
DELAY SPACING
FIRM SEQUENCING
DIRECT-COURSE-ERROR READOUT (DICE)
Enroute Metering

Tentative Sequencing

Delay Spacing

Longmont Arrival Fix

DICE Computation to point A

Firm Sequencing

DICE Computation to point P with SLT slippage possible

DICE Computation to point G with SLT slippage possible
MEASUREMENT OF OVERALL SYSTEM PERFORMANCE

DELIVERY ACCURACY AT OUTER MARKER

INTER-ARRIVAL ERRORS AT OUTER MARKER

SEPARATION ERRORS OVER RUNWAY THRESHOLD

TIME BETWEEN ARRIVALS AT RUNWAY THRESHOLD

IMPOSED ENROUTE DELAYS

IMPOSED HOLDING DELAYS

AVERAGE FLIGHT TIME IN THE TERMINAL AREA

LANDING RATE

HISTOGRAMS OF RANGE TO CLOSEST AIRCRAFT

NOISE CONTOURS
INTER-ArrIVAL TIME ERRORS (SEC.)

IDEAL

\[ \sigma = 2.71 \]

WIND

\[ \sigma = 4.35 \]

WIND, ILS

\[ \sigma = 13.82 \]

WIND, MLS (SHORT-RANGE)

\[ \sigma = 10.23 \]

WIND, MLS (LONG-RANGE)

\[ \sigma = 9.32 \]

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VTOL
(VTOL APPROACH AND LANDING TECHNOLOGY)

OBJECTIVE

SCOPE

RESULTS

RESEARCH SYSTEMS

SCHEDULE
SUMMARY OF RECENT LRC IFR RELATED RESEARCH

|----|------|------|------|------|------|------|------|------|------|------|

1. VTOL TERMINAL-AREA OPERATIONS STUDIES:
   - P. 1127 (VECTORED THRUST)
   - XC-142 (TILT WING)
   - DO-31 (MIXED PROPULSION)
   - X-22 TASK III (TILT DUCT)

2. IFR FLIGHT CONTROL AND GUIDANCE (CH-46)

3. VALT INTEGRATED SYSTEMS STUDIES (CH-47)

4. "REAL WORLD" DISPLAY STUDIES (SH-3A)

5. TERMINAL CONFIGURED VEHICLE (TCV) PROGRAM
TYPICAL ALL-WEATHER OPERATION OF FUTURE ROTORCRAFT
VALT PROGRAM

OBJECTIVE: TO DEVELOP TECHNOLOGY BASE FOR VTOL TERMINAL AREA OPERATIONS FOR THE 1980'S

PERFORMANCE REQUIREMENTS:
- NEAR ZERO-ZERO IFR CAPABILITY
- OPTIMAL TRAJECTORIES (NOISE, FUEL, RIDE QUALITIES)
- LOW ALTITUDE NAVIGATION

SYSTEM FEATURES:
- HIGH DEGREE OF AUTOMATION
- HIGH-GAIN MANUAL CONTROL MODES
- ADVANCED DISPLAYS BASED ON CRT TECHNOLOGY
- REASONABLY LOW COST
VTOL APPROACH AND LANDING TECHNOLOGY (VALT) PROGRAM

OBJECTIVE: TO DEVELOP TECHNOLOGY BASE FOR VTOL TERMINAL-AREA OPERATIONS FOR 1980'S

TECHNOLOGY AREAS:

VEHICLE SYSTEMS (RA)

OPERATING SYSTEMS (RO)

GUIDANCE SYSTEMS (RE)

RESEARCH ELEMENTS:

CONTROL CONCEPTS
STABILIZATION REQUIREMENTS
GUIDANCE LOGIC
DISPLAY FORMAT AND SYMBOLOGY
CONTROLLER CHARACTERISTICS
TOLERABLE-FAILURE MODES
PILOT/AUTOMATIC SYSTEM INTERACTION

ATC INTERFACE
CROSSWIND OPERATION
STEEP APPROACH
OPTIMAL APPROACH
MLS INTEGRATION
AUTOMATIC OPERATIONS

LOW ALTITUDE NAVIGATION
HEMISPHERIC LANDING GUIDANCE
CONTROL ALGORITHM TECHNOLOGY
DISPLAY TECHNOLOGY
LOW-COST RADIO/INERTIAL SYSTEM
MONITORING DISPLAY TECHNOLOGY
SENSOR TECHNOLOGY
DECELERATING APPROACH TASK

SLOW TO 45 knots GROUND SPEED

TRANSITION TO GLIDESLOPE

BEGIN DECELERATION

HOVER

VERTICAL LETDOWN

ALTITUDE

CROSS RANGE

POWER COMMAND

ROLL COMMAND

CAPTURE CENTERLINE

750 ft

DECELERATION 750 ft
SIX DEGREES MANUAL DECELERATING APPROACHES

**GROUND SPEED, ft/sec**

**LATERNAL DEVIATION, ft**

**WINDS, 15 knots**

**ALTITUDE, ft**

**RANGE, ft**
PILOT CONTROL ACTIVITY

LONG STICK POSITION, IN.

LAI STICK POSITION, IN.

COLL STICK POSITION, IN.

RUDDER PEDALS, IN.

TIME TO HOVER AT PAD, SEC

ACQUIRED PAD

5000 ft 2000 ft 1000 ft 500 ft

RIGHT

LEFT

UP

DOWN

FWD

AFT

LEFT

RIGHT

1

0

-1

-2
RELATIVE PILOT WORKLOAD AS A FUNCTION OF THE APPROACH PHASE

UNACCEPTABLE LIMIT

RELATIVE PILOT WORKLOAD

INCREASING

CONSTANT SPEED  DECELERATION  HOVER  LETDOWN

APPROACH PHASE

TOUCHDOWN
FEATURES

DUAL CRT DISPLAYS

WIDE-BAND VIDEO LINK

TELEMETRY DOWNLINK

ELECTROMECHANICAL DISPLAY OPTION

CONVENTIONAL NAV-AID OPTION

HARDOVER MONITORING SYSTEM

DIGITAL COMPUTING SYSTEM

ANALOG COMPUTING SYSTEM

RADAR-LASER TRACKING AIDS

TWO-WAY DIGITAL DATA LINK

DIGITAL CONTROL SYSTEM

COMPUTING SYSTEM

CONTROLLING SYSTEM

COMPUTING SYSTEM

CONTROLLING SYSTEM

COMPUTING SYSTEM

CONTROLLING SYSTEM

COMPUTING SYSTEM
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<td>1) SHORT TERM</td>
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<td>2) LONG TERM</td>
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<td>CROSS WIND TECHNIQUES</td>
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<td>HIGH-GAIN CONCEPT VALIDATION</td>
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VALT (RO AND RA) SCHEDULE
VALT TECHNOLOGY DEMONSTRATION

CONTROL CONCEPT:
ATTITUDE COMMAND SYSTEM
TURN COORDINATION
SPLIT AXIS AUTOMATION
FULLY AUTOMATIC APPROACH AND LANDING

DISPLAY CONCEPT:
3-CUE FLIGHT DIRECTOR
ELECTRONIC HORIZONTAL SITUATION INDICATOR (HSI)

TRAJECTORY:
$\gamma = 6^\circ$; CONSTANT ATTITUDE DECELERATION PROFILE;
VERTICAL DESCENT PATH TO TOUCHDOWN

MISCELLANEOUS:
Pilot assist modes for cruise
Unrestricted wind direction
Path capture logic
Oculometer As A Research Tool

Analytical Efforts

- Workload
  - Pupil Diameter
  - Regression Analysis

- Statistical Efforts
  - Analysis by Control Inputs
  - Correlation Analysis
    - (1) Pilot Differences/Consistencies
    - (2) Categorization of Conditions
    - (3) Information Groups

- Data Reduction
  - EADI
  - Out-of-the-Window
OCULOMETER STUDIES

- INITIAL IN-HOUSE WORK
- AIRLINE PILOT STUDIES
  - INSTRUMENT APPROACHES
  - VISUAL STUDIES
  - PMA (AMES/LRC)
  - TAKEOFF
  - MOTION/NO MOTION
- TCV AFT COCKPIT STUDIES
  - DISPLAYS

PLANNED

- TCV AIRCRAFT PROGRAM
- CDTI
## PERCENT TIME ON INSTRUMENTS

(ONE NASA TEST PILOT)

### TEST CONDITIONS

<table>
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<tr>
<th>DISPLAY</th>
<th>CONTROL</th>
<th>TURB</th>
<th>AS</th>
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<th>BA</th>
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## Advanced Display Concepts

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<th>Flight Phase</th>
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<td>Descent</td>
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<td>ENERGY DESCENT</td>
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<tr>
<td>Final Approach-to-Landing</td>
<td>MLS INTEGRATED SITUATION</td>
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<td>COMMANDED GAMMA</td>
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<td>WINDSHEAR INFORMATION</td>
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<tr>
<td>Curved Decelerating Approach</td>
<td>PATHWAY</td>
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<td></td>
<td>TUNNEL</td>
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<td>OTHERS</td>
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</table>
Figure 10 - The PITS display: Airplanes displaced above the path.
INTEGRATED SITUATION DISPLAY OBJECTIVE.

INTEGRATE THE INTEGRATION OF HORIZONTAL INFORMATION INTO A BASELINE VERTICAL SITUATION DISPLAY.
Localizer offset path

R = 2290 m. (7500 ft.)

MLS ELEVATION

AC132

FAF311

0.1 n.mi.

3 n.mi.

RUNWAY

GPI04
INTEGRATED DISPLAY FORMAT
LOCALIZER TRACKING PERFORMANCE USING THE BASELINE DISPLAY FORMAT
LOCALIZER TRACKING PERFORMANCE USING THE INTEGRATED DISPLAY FORMAT
30.5 - M (100 FT) WINDOW DATA OF VERTICAL AND LATERAL FLIGHT PATH DEVIATIONS
COMPARISON WITH SIMULATION RESULTS

COMPARISON WITH CATEGORY II FLIGHT-DIRECTOR CRITERIA

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CONCLUDING REMARKS

1 INTEGRATED FORMAT INCREASED FLIGHT PATH ACCURACY OVER BASELINE FORMAT.

2 INTEGRATED FORMAT BROUGHT ABOUT A BETTER UNDERSTANDING OF THE AIRPLANE'S POSITION AND TRAJECTORY RELATIVE TO THE RUNWAY AND EXTENDED CENTERLINE.

3 INTEGRATED FORMAT ALLOWS THE PILOT TO MAKE CORRECTIVE CONTROL INPUTS DEPENDING ON THE SIZE OF THE ERROR AND THE REMAINING DISTANCE TO THE THRESHOLD.
CONTROL WHEEL STEERING

\[ \theta = \frac{V}{V \text{ GROUND SPEED}} \]

- RATE COMMAND SYSTEM
- FLIGHT PATH ANGLE HOLD
- BANK ANGLE HOLD
- TRACK ANGLE HOLD
- DISPLAY
- ELECTRONIC CRT
- SITUATION INFORMATION

ORIGINAL PAGE IS OF POOR QUALITY.
WHAT IS (PITCH) VELOCITY CONTROL WHEEL STEERING (VEL CWS)?)

- VEL CWS IS A CONTROL SYSTEM THAT GIVES THE PILOT DIRECT CONTROL OVER THE INERTIAL FLIGHT ANGLE ($\gamma_1$) THROUGH THE BROLLY HANDLES (COLUMN) AND PROVIDES AUTOMATIC HOLDING OF THE PILOT COMMANDED INERTIAL FLIGHT-PATH ANGLE UPON RELEASE OF THE BROLLY HANDLES.

- $VA =$ AIRSPEED VELOCITY VECTOR
- $VI =$ INERTIAL VELOCITY VECTOR
- $\gamma_1 =$ INERTIAL FLIGHT PATH ANGLE
- $\gamma_A =$ AIR MASS REFERENCED FLIGHT PATH ANGLE
- $\alpha =$ ANGLE OF ATTACK
- $\theta =$ PITCH ANGLE

"LANDING IN A HEADWIND"

"LANDING IN A TAILWIND"
DEFICIENCIES IN PRESENT SYSTEM

CONTROL SYSTEM

- Relatively long lag in response
- Mismatch of rates
- Overshoot of hold reference
- Low damping

DISPLAY SYSTEM

- Looseness of V symbol
- No V reference information
\[ y \] (DEG)

\[ v_t \]

\[ \text{TIME ~ SECONDS} \]

\[ \text{COL INPUT (INCHES)} \]

\[ \text{TIME ~ SECONDS} \]
THE DISPLAY OF FPA ($\gamma$) IS INADEQUATE TO GUIDE THE PILOT IN SETTING UP AND INDICATING THE FPA REFERENCE ($\gamma_R$) BECAUSE OF:

1. Lag between column input and FPA response
2. Disorienting FPA response overshoot
3. Long FPA response settling time (low damping)
4. Disorienting FPA activity in turbulence

These problems result in inability to assess value of $\gamma_{\text{REF}}$ from $\gamma_I$. 
PILOT DESIRES IN NEW SYSTEM

- Quicker Response
- Increased Sensitivity
- Minimum overshoot in $V$ and $\omega$
- High Damping
- $V$ Reference
APPRAOCHE

- ANALYTIC STUDY
- MODIFICATION OF CONTROL SYSTEM
- REAL-TIME SIMULATION
SUMMARY

- Added Y Reference to Display
- More Responsive Control System
- Matched Rate with Minimum Overshoot
- Well Damped
- Decreased Workload
SIMULATION STUDY IN WIND SHEAR

OBJECTIVE:

- Investigate baseline display information (Flight Director format) and integrated display information in the wind shear environment.

EXPERIMENT DESIGN:

- $30^\circ$, straight-in instrument approach
- 5 wind profiles
- 2 display/control configurations
Shear 3

Along Track Axis

CROSS TRACK AXIS

Shear 4

(10 kts)

(25 kts)

(6'/s)

UPDRAFT

UPDRAFT

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FLIGHT-DIRECTOR FORMAT
TIME HISTORY OF APPROACH WITH WIND SHEAR 1
Pilots

Time from start of shear at throttle inc, sec

F/D ATT CWS

INTEGRATED VEL VEC

DISPLAY/CONTROL CONFIGURATION

THRUST RESPONSE FOR WIND SHEAR 3
SUMMARY DATA FOR SHEARS 1, 3, 5

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SUMMARY OF RESULTS

- Statistical analysis shows significant difference between display formats in speed error.

- Mean localizer and vertical tracking data show no significant difference between display formats.

- Physical workload significantly less for integrated format.
WIND SHEAR RESEARCH

OBJECTIVES

- MEASUREMENT OF SHEAR
- A WIND SHEAR DETECTOR
ENERGY CONCEPT

SPECIFIC ENERGY

\[ E = \frac{e}{w} = h + \frac{v^2}{2g} \]

ENERGY RATE

\[ E = h + \frac{vv}{g} \]

\[ C_p = \frac{p_1 - p_s}{\frac{q}{g}} = 1 \]

ALTITUDE, FEET

DECREASING LOCAL PRESSURES

SPEED, KNOTS

DECREASING LOCAL PRESSURES
PRESSURE COEFFICIENTS AS FUNCTION OF HOLE POSITION

$(\theta = 160^\circ - 180^\circ \text{ AVG.} ; \gamma = 0^\circ, \gamma = -20^\circ)$

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$M = .15 \quad 1,500,000$

$M = .30 \quad 3,800,000$
PLANS

WIND MEASUREMENT

- Compute wind components and transmit to FAA
- Perform sensitivity and error analysis
- In-house statistical analysis

SENSOR

- Determine installation effects
- Determine signal characteristics
- Develop laws for automatic control using sensor
AIRPLANE LONGITUDINAL STABILITY AND CONTROL

AS AFFECTED BY WIND SHEAR

WINDSOR L. SHERMAN
DEFINITION OF WIND SHEAR

\[ V_{wind} \]

\[ U \]

**Positive Wind Shear** changes a head wind into a tail wind, that is,

\[ \frac{dV_w}{dt} \] is positive

or

\[ V'_{w} = \frac{dV_w}{dh} \; (\text{sgn } \Gamma) \text{ is positive} \]

Wind shear parameter:

\[ \sigma_u = \frac{V'_w U_0}{g} \]
WIND SHEAR EFFECT ON THE LONG PERIOD LONGITUDINAL MODE, ROOT LOCUS

\[ \sigma_u = -3.5 \]

\[ \sigma_u = 0 \]

\[ \sigma_u \approx 1.0 \]
VALID FOR ALL AIRPLANES

$V_W^i$, Wind gradient, sec$^{-1}$

$V_W = 0.25$ sec$^{-1}$

$\sigma_u = 1.0$

$U_0$, speed, m sec$^{-1}$
EFFECT OF WIND SHEAR ON ALTITUDE TRACK
CONTROL FIXED CASE

Shear starts
\[ \sigma_u = -2.0 \]

Shear ends
\[ \sigma_u = 0.0 \]

Altitude, meters

Distance along approach path, m

Original page is of poor quality
FLIGHT PATH CONTROL - AIRPLANE STALLS IN ABOUT 16 SECONDS

PITCH ATTITUDE CONTROL - AIRPLANE STALLS IN ABOUT 6 SECONDS

AIRSPEED CONTROL - CONTROLS AIRPLANE IF ON WHEN SHEAR OCCURS AND ENGINE TIME CONSTANT SMALL

AIRSPEED AND FLIGHT PATH CONTROLS - PROVIDES GOOD CONTROL

AIRSPEED AND PITCH CONTROLS - PROVIDES GOOD CONTROL
ALTITUDE TRACK CONTROL BY AUTO PILOTS

AIRSPEED AND FLIGHT PATH CONTROLS

\[ \sigma_u = 2.0 \]

Shear starts

Shear ends

With automatic controls

Control fixed

\[ \tau_E = 2.5 \]

\[ \tau_E = 0.1 \]

Distance along approach path, m.

Altitude, m

\( \tau_E \) is engine time constant
SUMMARY

NEGATIVE WIND SHEAR (TAIL WIND TO HEAD WIND)

NO ADVERSE EFFECTS ON AIRPLANE STABILITY

POSITIVE WIND SHEAR (HEAD WIND TO TAIL WIND)

(1) CONTROL FIXED CASE

WIND SHEAR STABILITY BOUNDARY FOR LONG PERIOD LONGITUDINAL MODE DEFINED

AIRPLANE DIVERGES DOWNWARD

IMPACTS SHORT OF THRESHOLD

(2) AUTOMATIC CONTROL

AIRSPEED AND FLIGHT PATH CONTROL SYSTEMS PROVIDE GOOD CONTROL AS AIRPLANE TRANSITS WIND SHEAR

FUTURE PLANS

STUDY ONBOARD WIND SHEAR DETECTORS TO CONTROL AUTOMATIC PILOTS
MORE INDEPTH STUDY OF WIND SHEAR CONTROL PROBLEM.
OBJECTIVE

To determine the advantages and disadvantages of the Head Up Display concept in approach and landing operations.
HUD CONCEPT PROGRAM OVERVIEW

I. BACKGROUND REVIEW/LITERATURE SEARCH

II. LABORATORY/SIMULATOR TESTS

III. FULL OPERATIONAL SIMULATIONS TO EVALUATE THE POTENTIAL EFFECTIVENESS OF "CANDIDATE HUD(s)"

IV. ENGINEERING FLIGHT EVALUATION

V. FLIGHT DEMONSTRATION/OPERATIONAL EVALUATION

FAA/NASA HUD
January, 1977
### HUMAN FACTORS/PERCEPTION TESTS - SCHEDULE (1977)

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<td>2A COGNITIVE SWITCHING ASSESSMENT</td>
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<td>MOVING BASE AMES' SIMULATORS</td>
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<td>4A HEAD DOWN/UP TRANSITION</td>
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<td>5 PILOT EYE MOTION</td>
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<td>HUD HARDWARE ARRIVES/CHECKED OUT</td>
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- Viewgraph D
- R. F. Haines 9-8-77
HUMAN FACTORS/PERCEPTION TESTS - SCHEDULE (1977 - 1978)

TESTING FACILITY

VISION LABS


8 9 10 11 12 13 14 15

- 3A VISUAL ACCOMMODATION (luminance effects)
- 3B VISUAL ACCOMMODATION (eye location effects)
- 1A' HUD SYMBOLOGY ASSESSMENT

MOVING BASE AMES' SIMULATORS

- HUD SYSTEM INSTALLATION IN SIMULATOR (S-06)
- 2B COGNITIVE SWITCHING ASSESSMENT
- 4B HEAD DOWN/UP TRANSITION
- 8 CROSS-WIND VISUAL FIELD REQUIREMENT

1B SYMBOLOGY ASSESSMENT (FSAA)

OPTICS LABORATORY

- SELECTED OPTICAL MEASURES

Viewgraph E
R. F. Haines 9-9-77
Figure 9

Experimental Design for 737 Simulator Study at Ames

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<tr>
<th>Visibility</th>
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<th>Night</th>
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<tr>
<td>Clear</td>
<td>Cat. I</td>
<td>Cat. II</td>
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<tr>
<td></td>
<td>615'</td>
<td>360'</td>
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<td>RVR 2400 ft.</td>
<td>RVR 2400 ft.</td>
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<td></td>
<td>1600 ft.</td>
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<tr>
<td>Continuous</td>
<td>DH=200'</td>
<td>DH=200'</td>
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<td></td>
<td>DH=150'</td>
<td>DH=150'</td>
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<tr>
<td>Intermittent</td>
<td>300'</td>
<td>245'</td>
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<td>230'</td>
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<td>180'</td>
<td>170'</td>
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<td>130'</td>
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Ceilings noted by each stair step per cell.
ONBOARD PERFORMANCE COMPUTER R&D AID PROJECT

1. Introduction

- Microprocessor revolution has already begun.
- Evidence all around us. Chances are, even in your briefcase, or shirt pocket!

2. Reason for RSS Comments Today

- Wish to ask NASA for support in performing “war games” simulations in concert with FAA, for the purpose of assisting both the airlines and the FAA in developing practical procedures for pilots and controllers to exploit to the fullest the capabilities of the modern, digital, onboard performance computers now in the early stages of development.

- Why Addressing TCV Program Management?

The goals of the TCV Program closely parallel the goals of those working on the OPC concepts.

- Improve efficiency of descent, approach, landing in the Real World with ATC, WX, mix of aircraft types, wing vortices, wind shear, etc.
- Reduce volume of communications, air-ground and ground-air, without sacrificing safety or knowledge of situation both in the cockpit and control center.
- Reduce community noise by facilitating optimum approach procedures under all WX conditions.
- Save Fuel

3. Who's Involved Today?

- TWA/Simmonds Precision/727 (Line Flying - Fall of 1976) (Slides)
- CAL/Lear-Siegler/Boeing/727-200 (Line Flying - June 1977)
- DLH/Lear-Siegler/Boeing/737-200 (Line Flying - July 1977)
4. Where Are We Today?

1. We know how airplanes want to fly for best efficiency.
2. We know how to program this perf. data into light, cheap digital memory.
3. We know how to program procedures for applying these data.
4. We know most of the situations where the pilot can use help.
5. We know how much fuel can be saved by flying on the numbers.
6. We think there are important benefits in ATC.
7. We think pilots are going to like the OPC. (Early returns are most encouraging at CAL.)
8. We believe the pay-back will be fairly easy to prove. (1-2 yrs.)

5. Where Do We Go From Here?

1. Finish the job of verifying fuel savings. (Airlines/Mfgrs.)
2. Develop Profile Descent procedures with time flexibility. (NASA/FAA)
3. Develop and refine Delayed-Flap Approach procedures. (NASA/FAA)
4. Integrate with Advanced ATC Metering & Spacing.
5. Refine software up-dating procedures and discipline.
6. Modify the fleet!

6. Why Is All This Important?

1. Fuel is precious
2. Time is precious.
3. Pilots are people. Human beings.

Motivation relates to confidence in system, machines, team.

4. ATC controllers are people. Human beings.

They need to delegate all that can be delegated to the pilots whose planes are equipped to accept time & place commitment responsibility. So they can concentrate on those that aren't.

5. New applications will be found/developed for these powerful computers.

6. Ten years from now, we will look back on this development and say to ourselves,
## TCV Related Publications

<table>
<thead>
<tr>
<th>Report No.</th>
<th>Title</th>
<th>Author(s)</th>
<th>Date Transmitted</th>
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<tr>
<td>CR-112195</td>
<td>Development of Simulation Techniques Suitable for the Analysis of Air Traffic Control Situations and Instrumentation</td>
<td>Triangle Institute</td>
<td>8/72</td>
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<tr>
<td>Mathematical Programing Society Symposium on Nonlinear Programing, George Washington University, Washington, DC</td>
<td>Near Terminal Optimal Sequencing and Flow Control As a Mathematical Programing Problem</td>
<td>Stephen K. Park, Terry A. Straeter</td>
<td>3/14-16/73</td>
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<tr>
<td>AIAA 12th Aerospace Sciences Meeting, Washington, DC</td>
<td>Electronic Displays and Digital Automatic Control in Advanced Terminal Area Operations</td>
<td>Seymour Salmirs, Harold N. Jobie</td>
<td>2/74</td>
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<td>NASA TN D-7611</td>
<td>Preliminary Study of a Possible Automatic Landing System</td>
<td>Windsor L. Sherman, Sylvia W. Winfrey</td>
<td>7/74</td>
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<td>NASA TN D-7652</td>
<td>Parametric Analysis of an Imaging Radar for Use As an Independent Landing Monitor</td>
<td>W. Thomas Bundick</td>
<td>8/74</td>
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<tr>
<td>18th Symposium of the Society of Experimental Test Pilots Los Angeles, CA</td>
<td>Future Airborne Systems for Terminal Area Operations</td>
<td>John P. Reeder</td>
<td>9/26-29/74</td>
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<tr>
<td>TM X-72006</td>
<td>New Design and Operating Techniques and Requirements for Improved Aircraft Terminal Area Operations</td>
<td>John P. Reeder, Robert I. Taylor, Thomas M. Walsh</td>
<td>12/74</td>
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<tr>
<td>CR-132562</td>
<td>Development and Modification of a Digital Program for Final Approach to Landing</td>
<td>William G. Duff, Charles R. Guarino</td>
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<tr>
<td>AIAA 13th Aerospace Sciences Meeting Pasadena, CA</td>
<td>Empirical Comparison of a Linear and a Nonlinear Washout for Motion Simulators</td>
<td>R. V. Parrish, D. J. Martin, Jr.</td>
<td>1/20-22/75</td>
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<tr>
<td>1974 International Conference on System, Man and Cybernetics</td>
<td>On the Quadratic Sampled-Data Regulator With Unstable Random Disturbances</td>
<td>N. Halyo, R. H. Foulkes</td>
<td>10/74</td>
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<td>NASA TN D-7876</td>
<td>A General Algorithm for Relating Ground Trajectory Distance, Elapsed Flight Time, and Aircraft Airspeed and Its Application to 4-D Guidance</td>
<td>Edwin C. Foudriat</td>
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<td>University of Virginia Charlottesville, VA</td>
<td>Microwave Landing System Airborne Receiver Analysis</td>
<td>G. A. McAlpine, J. H. Highfill, III, S. H. Irwin, Jr.</td>
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<td>Position Accuracy of Aircraft Area Navigation Systems and the Effect of System Parameters</td>
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<td>The Effect of Measurement Errors and Computational Approximations on a Perspective ILM Radar Image</td>
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<tr>
<td>CR-132713</td>
<td>Refinement and Validation of Two Digital Microwave Landing System (MLS) Theoretical Models</td>
<td>William G. Duff, Charles R. Guarino</td>
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<td>NASA TM X-72715</td>
<td>Wind Tunnel/Flight Data Correlation for the Boeing 737-100 Transport Airplane</td>
<td>Francis J. Capone</td>
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<td>NASA TN D-7971</td>
<td>Effect of External Disturbances and Data Rate on the Response of an Automatic Landing System Capable of Curved Trajectories</td>
<td>Windsor L. Sherman</td>
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<td>University of Virginia, Charlottesville, VA</td>
<td>Optimization and Sensitivity Studies of Flight-Path Trajectories</td>
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<td>Paper</td>
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<td>Guidance and Control Laboratory Stanford University, Stanford, CA</td>
<td>Aircraft Digital Control Design Methods</td>
<td>J. David Powell, Eric Parsons, Michael G. Tashker</td>
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<td>Semi-Annual Report Ohio State University, Columbus, OH</td>
<td>Research on MLS Airborne Antenna</td>
<td>C. L. Yu, W. D. Burnside</td>
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<td>Technical Report Ohio State University, Columbus, OH</td>
<td>Volumetric Pattern Analysis of Fuselage-Mounted Airborne Antennas</td>
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<td>Masters Thesis VPI and State University Blacksburg, VA</td>
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<td>Information and Display Requirements for Independent Landing Monitors</td>
<td>J. A. Sorensen, J. S. Karmarkar</td>
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<td>The Design, Development, and Flight Test Results of the Boeing 737 Aircraft Antennas for the ICAO Demonstration of the TRSB Microwave Landing System</td>
<td>T. G. Campbell, W. F. White, M. C. Gilreath</td>
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<td>NASA CR-2720</td>
<td>Development of an Optimal Automatic Control Law and Filter Algorithm for Steep Glideslope Capture and Glideslope Tracking</td>
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<td>Annual Report University of Virginia, Charlottesville, VA</td>
<td>Use of Steepest Descent and Various Approximations for Efficient Computation of Minimum Noise Aircraft Landing Trajectories</td>
<td>G. Cook, R. M. Witt</td>
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<p>| REPORT NO.                     | TITLE                                                                 | AUTHOR(S)                  | DATE TRANSMITTED |
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| Computer Program Decision Science San Diego, CA | A Computer Program for the Use of Sensitivity Analysis in Display Evaluation | Michael L. Mout, George H. Burgin | 10/76 |
| Paper Research Triangle Institute | Research in Ground-Based Near Terminal Area 4D Guidance and Control | C. L. Britt, E. Credeur, C. M. Davis, W. Capron | 10/76 |
| Final Report Youngstown State University Youngstown, OH | Digital Flight Compensation for Descending Constant Velocity Spiral Paths | Dr. Robert Foulkes, Richard Hueschen | 11/24/76 |
| University of Virginia Charlottesville, VA | Optimization of MLS Receivers for Multipath Environments | G. A. McAlpine, J. H. Highfill, S. H. Irwin | 12/76 |
| CR-145121 | Transport Airplane Flight Deck Development Survey and Analysis | D. K. Graham | 1/77 |</p>
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<td>Nsg-1170 Geo. Wash. U.</td>
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