RESEARCH AND TECHNOLOGY ADVISORY COUNCIL,

AD HOC PANEL ON TERMINAL CONFIGURED VEHICLES

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REPORT OF MEETING

SEPTEMBER 14-15, 1977

National Aeronautics and Space Administration

OFFICE OF AERONAUTICS & SPACE TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SUMMARY

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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NASA RESEARCH AND TECHNOLOGY ADVISORY COUNCIL

PANEL ON AVIATION SAFETY AND OPERATING SYSTEMS

AD HOC PANEL ON TERMINAL CONFIGURED VEHICLES

LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA
September 14-15, 1977

MEMBERS IN ATTENDANCE

Chairman	Mr. John Gorham	Gorham Associates
Mr. James P. Andersen		Transportation Systems Cent
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 Executive Secretary	NASA Headquarters
Mr. Lee D. Goolsby Recording Secretary	NASA Headquarters

Members Absent:

Capt. Larry DeCelles	Air Line Pilots Associatior
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	National Transportation Safety Brd.
Mr. Alan Mulally	The Boeing Company
Mr. D. R. Clifford	The Boeing Company
Mr. Nathan Novack	Wallops Flight Center
Mr. Richard V. Wible	Air Force Flight Dynam. Lab.
Mr. Howard Seal	The Boeing Company
Mr. Harry Strunz	The Mitre Corporation
Dr. Charles L. Britt Jr.	Research Triangle Institute
Mr. T. J. Ray	Eastern Airlines
Mr. Frank Brady	Air Transport Association
Mr. Stydren J. Smith	Arma Corporation
Mr. Gene Lyman	NASA Headquarters
Mr. Bill Duff	Atlantic Research Corporation
Mr. Tony Lambregh	The Boeing Company
Mr. Larry Wood	Federal Aviation Admin.
Mr. J. R. Temple	McDonnell Douglas Corp.
Mr. Orin Nicks	Langley Research Center
Mr. Robert W. Boswinkle	Langley Research Center
Mr. William D. Mace	Langley Research Center
Dr. Thomas Walsh	Langley Research Center
Mr. Eugene Schult	Langley Research Center
Mr. Seymour Salmirs	Langley Research Center
Mr. Leonard Clark	Langley Research Center
Mr. Royce H. Sproull	Langley Research Center
Mr. James R. Hall	Langley Research Center
Mr. Milton Holt	Langley Research Center
Mr. William F. White	Langley Research Center
Mr. Andrew Graham	Langley Research Center
Mr. W. A. Southall	Langley Research Center
Mr. R. T. Taylor	Langley Research Center
Mr. R. J. Tapscott	Langley Research Center
Mr. John F. Garren	Langley Research Center
Mr. Leonard Credeur	Langley Research Center
Mr. Ray V. Hood	Langley Research Center
Mr. Amos Spady	Langley Research Center
Mr. Bruce A. Conway	Langley Research Center
Mr. Richard M. Hueschen	Langley Research Center
Mr. George G. Steinmetz	Langley Research Center
Mr. W. T. Bundick	Langley Research Center
Mr. George Boyles, Jr.	Langley Research Center
Ms. S. C. Chaney	Langley Research Center

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Mr. Kimball Miller	Langley Research Center
Mr. Jacob A. Houck	Langley Research Center
Mr. James E. Dieudonne	Langley Research Center
Mr. Lee H. Person	Langley Research Center
Mr. W. H. Phillips	Langley Research Center
Dr. J. F. Creedon	Langley Research Center
Dr. Charles E. Knox	Langley Research Center

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

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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 experimental 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 optimumization 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 electromechanical 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 J.

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 and 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:

Lee D. Goolsby
Recording Secretary

Concur:

Kenneth E. Hodge
Executive Secretary

TCV PROGRAM OVERVIEW

NASA/TCV ROLE

CONDUCT RESEARCH TO ASSURE AIRBORNE SYSTEMS TECHNOLOGY READINESS FOR IMPROVED LONG HAUL AIRCRAFT OPERATIONS IN FUTURE TERMINAL AREA ENVIRONMENTS.

PLANNING PREMISE:

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

OBJECTIVES	ELEMENTS
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 Flt 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

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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:

I. Terminal area capacity and efficiency.

II. Approach and landing capability in adverse weather.

III. 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.

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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 navigatio 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:

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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 CO'S. (AUTOMATIC SYSTEMS TEST)
- JOINT HUMAN FACTORS EXPERIMENTS: AMES

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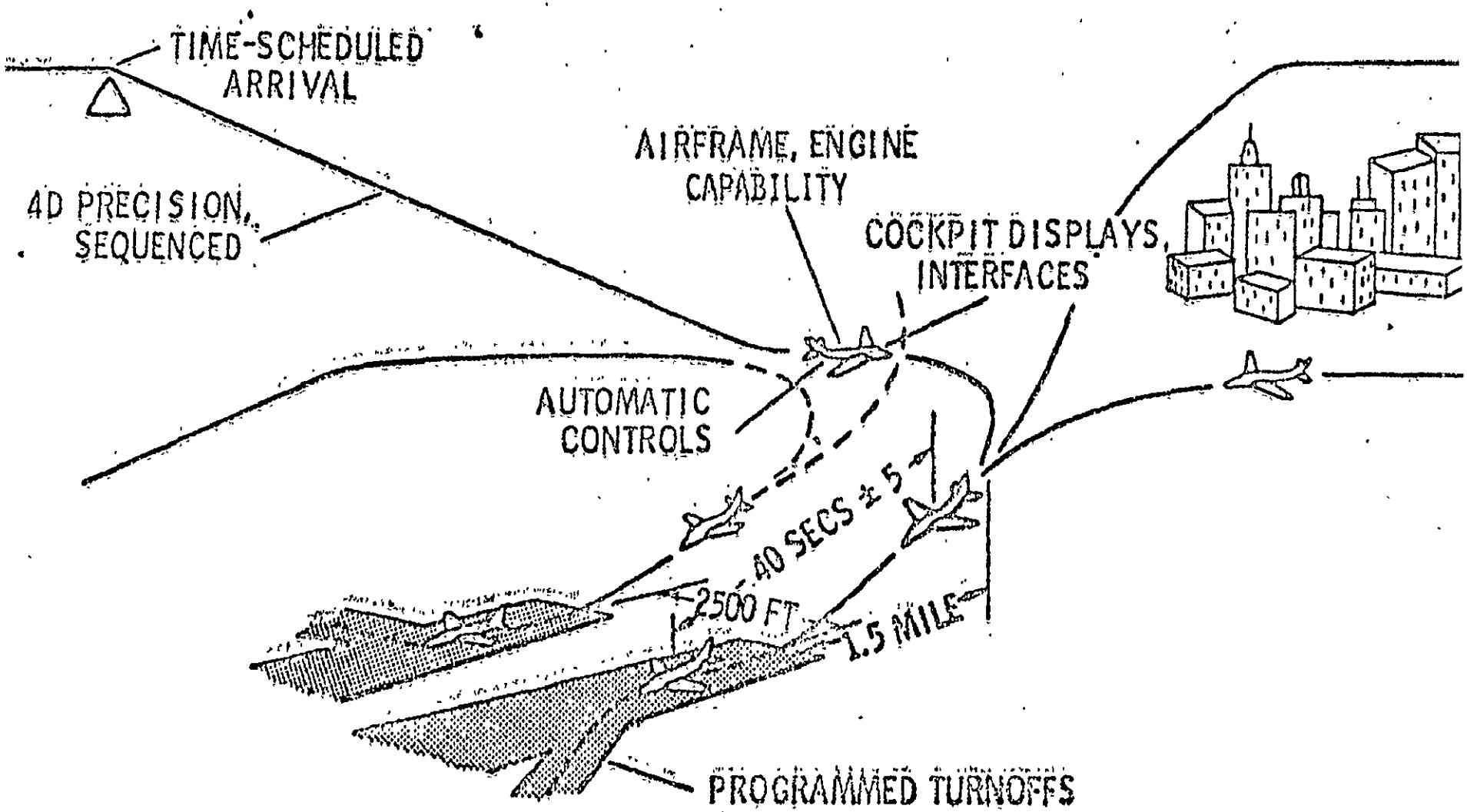
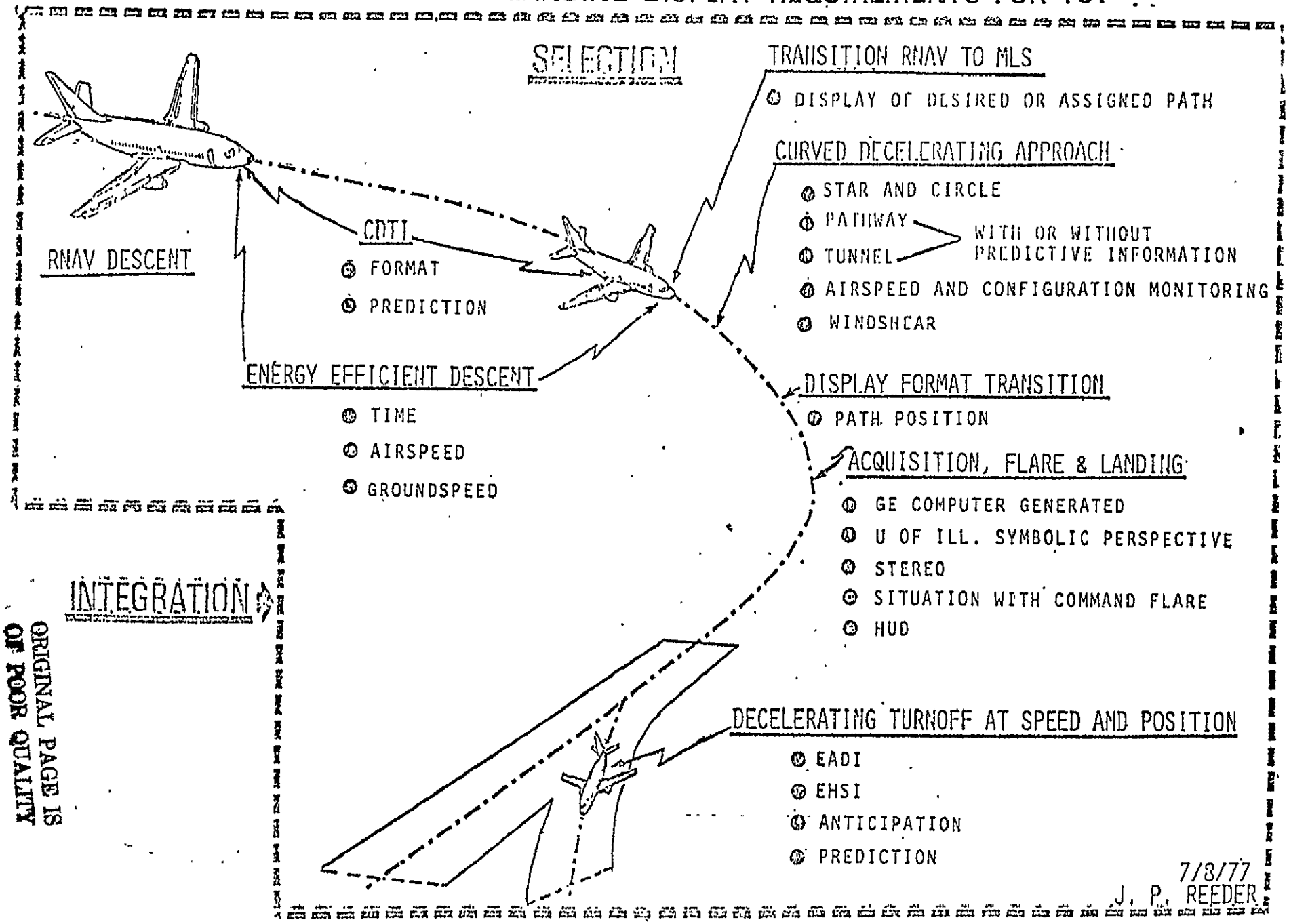
HIGH CAPACITY TERMINAL AREA OPERATIONS IN LOW VISIBILITY UTILIZING RNAV/MLS/DABS



THE CHALLENGE
APPROACH AND LANDING DISPLAY REQUIREMENTS FOR TCV



7/8/77
J. P. REEDER

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PROGRAM ELEMENTS

- 0 TRANSITION TECHNIQUES RNAV/MLS
- COMPLEX APPROACH PATHS (3 AND 4D - DECELERATING)
- ✓ 0 AUTOLAND WITH AUTOTHROTTLE/FLARE
- ✓ 0 METERING AND SPACING CONCEPTS (BENEFITS, A/C IMPACT)
- ✓ 0 SYSTEM SIMPLIFICATION (REDUNDANCY REQUIREMENTS, ETC.)
- ✓ 0 REDUCTION OF PATH ERROR (LATERAL, LONGITUDINAL, VERTICAL)
- ✓ 0 PILOT/CREW INFORMATION REQUIREMENTS
- ✓ 0 DISPLAY INFORMATION ENHANCEMENT
- 0 PILOT/COMPUTER INTERFACE
- ✓ 0 SHEAR DETECTION/DISPLAY/FLIGHT CONTROL
- 0 DETERMINATION OF CURVED-PATH NOISE SENSITIVITY
- 0 ENERGY-EFFICIENT OPERATION
- ✓ 0 HIGH-SPEED RUNWAY OPERATION
- ✓ 0 JOINT FAA/NASA FLIGHT EXPERIMENTS

TCV

ACCOMPLISHMENTS TO DATE

- 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 DEGREES.

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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

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MAJOR MILESTONES*

I. IMPROVE TERMINAL AREA CAPACITY AND EFFICIENCY

II. IMPROVE APPROACH AND LANDING CAPABILITY IN ADVERSE WEATHER

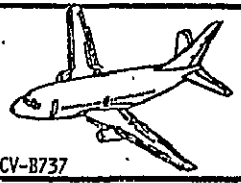
*III. REDUCE NOISE IMPACT AND FUEL CONSERVATIVE OPERATIONS ARE INTEGRATED INTO I AND II.

LANGLEY RESEARCH CENTER

RESPONSIBILITY:

APPROVAL: _____

ACCOMPLISHMENT: _____



TCV-B737

TERMINAL CONFIGURED VEHICLE PROGRAM

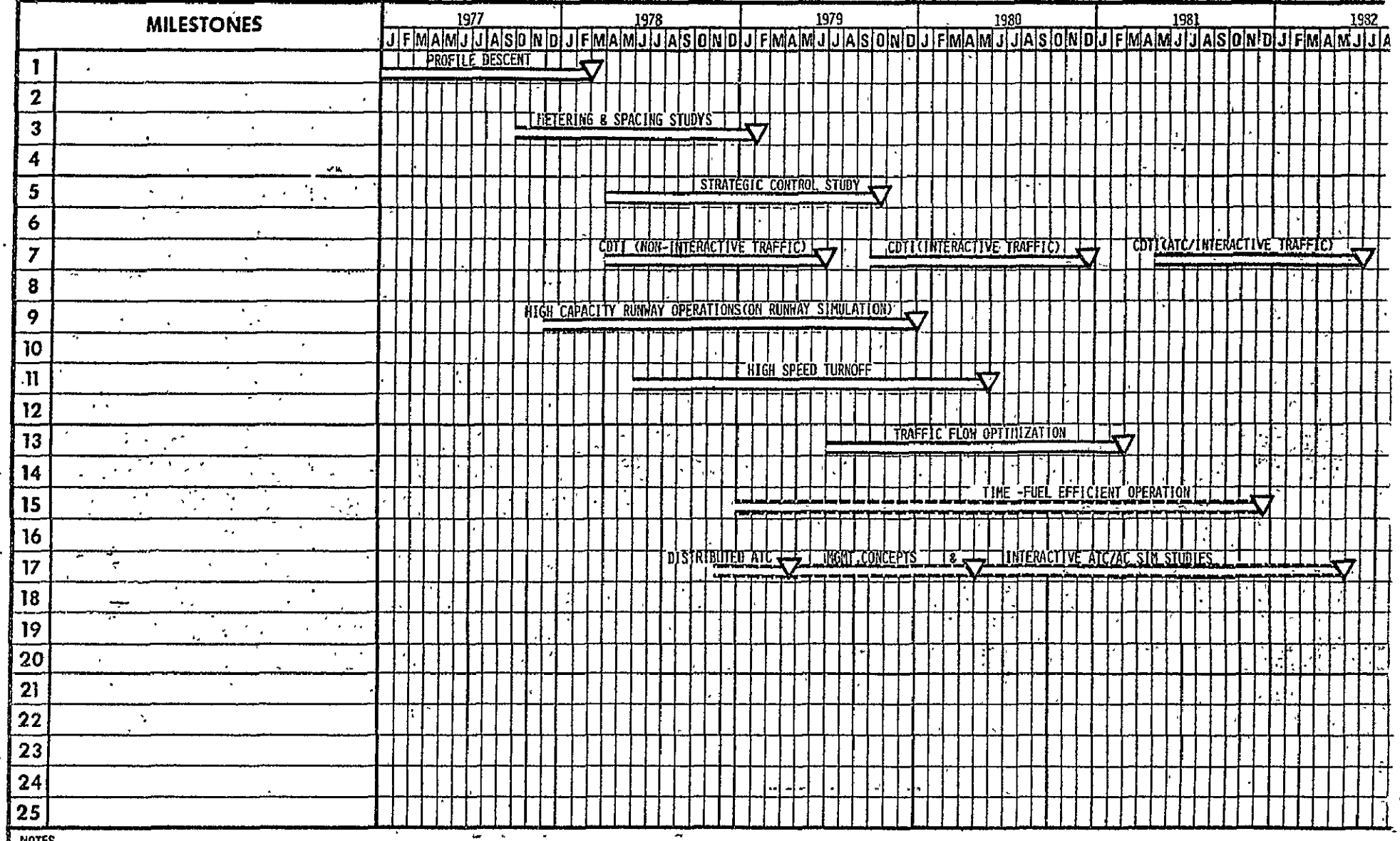
IMPROVE TERMINAL AREA CAPACITY & EFFICIENCY

LEVEL

ORIGINAL SCHEDULE APPROVAL _____ (DATE)

LAST SCHEDULE CHANGE SEPTEMBER 13,1977 (DATE)

STATUS AS OF _____ (DATE)



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(4 YEAR)

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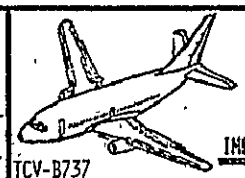
RESPONSIBILITY:

APPROVAL: _____

ACCOMPLISHMENT: _____



TCV-B737

TERMINAL CONFIGURED VEHICLE PROGRAM

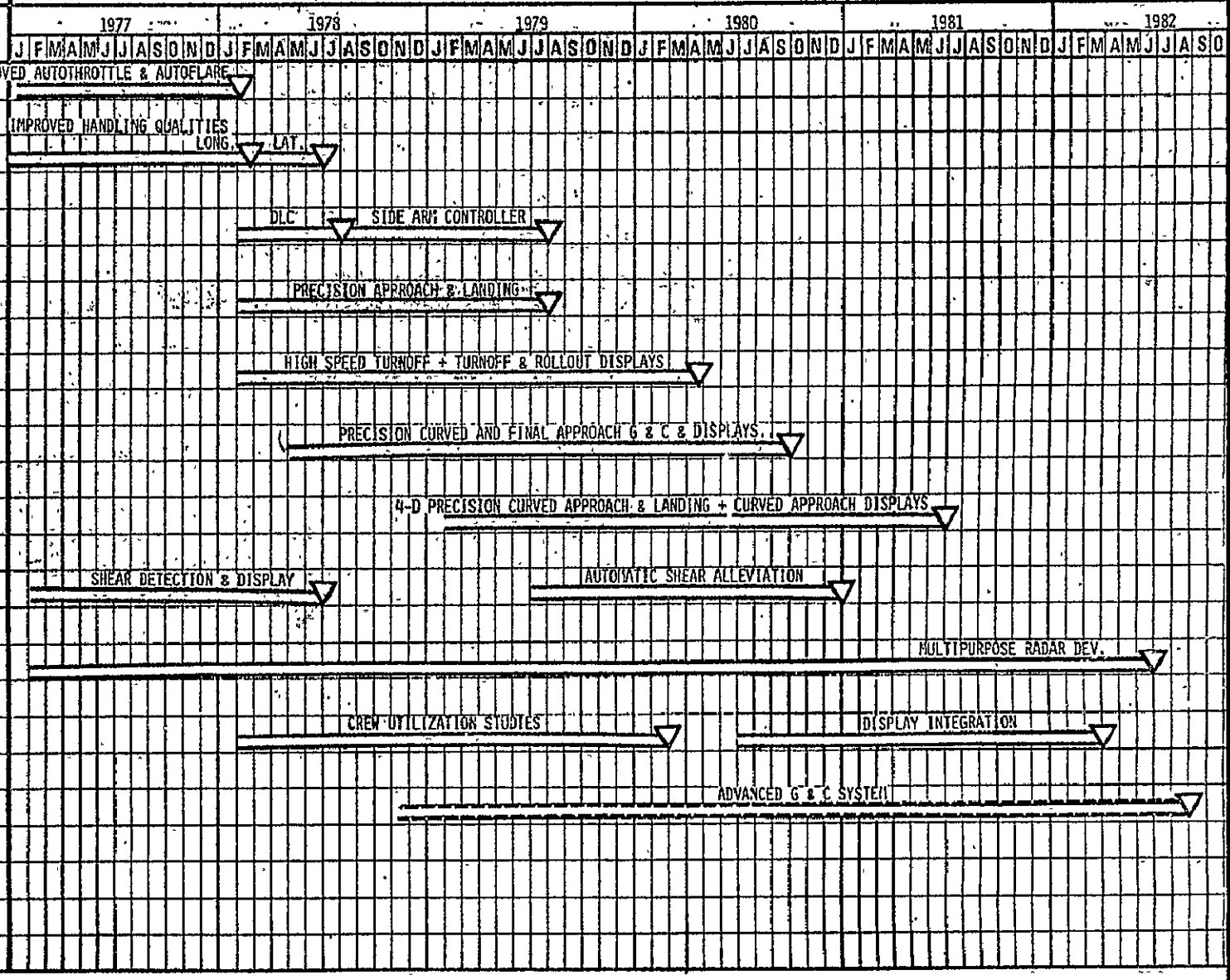
IMPROVE APPROACH & LANDING CAPABILITY IN ADVERSE WEATHER

LEVEL

ORIGINAL SCHEDULE APPROVAL _____ (DATE)

LAST SCHEDULE CHANGE SEPTEMBER 13,1977 (DATE) (INITIAL)

STATUS AS OF _____ (DATE)



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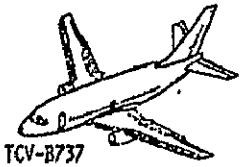
RESPONSIBILITY:

APPROVAL: _____

ACCOMPLISHMENT: _____



TERMINAL CONFIGURED V... DIAGRAM

GUIDANCE & CONTROL

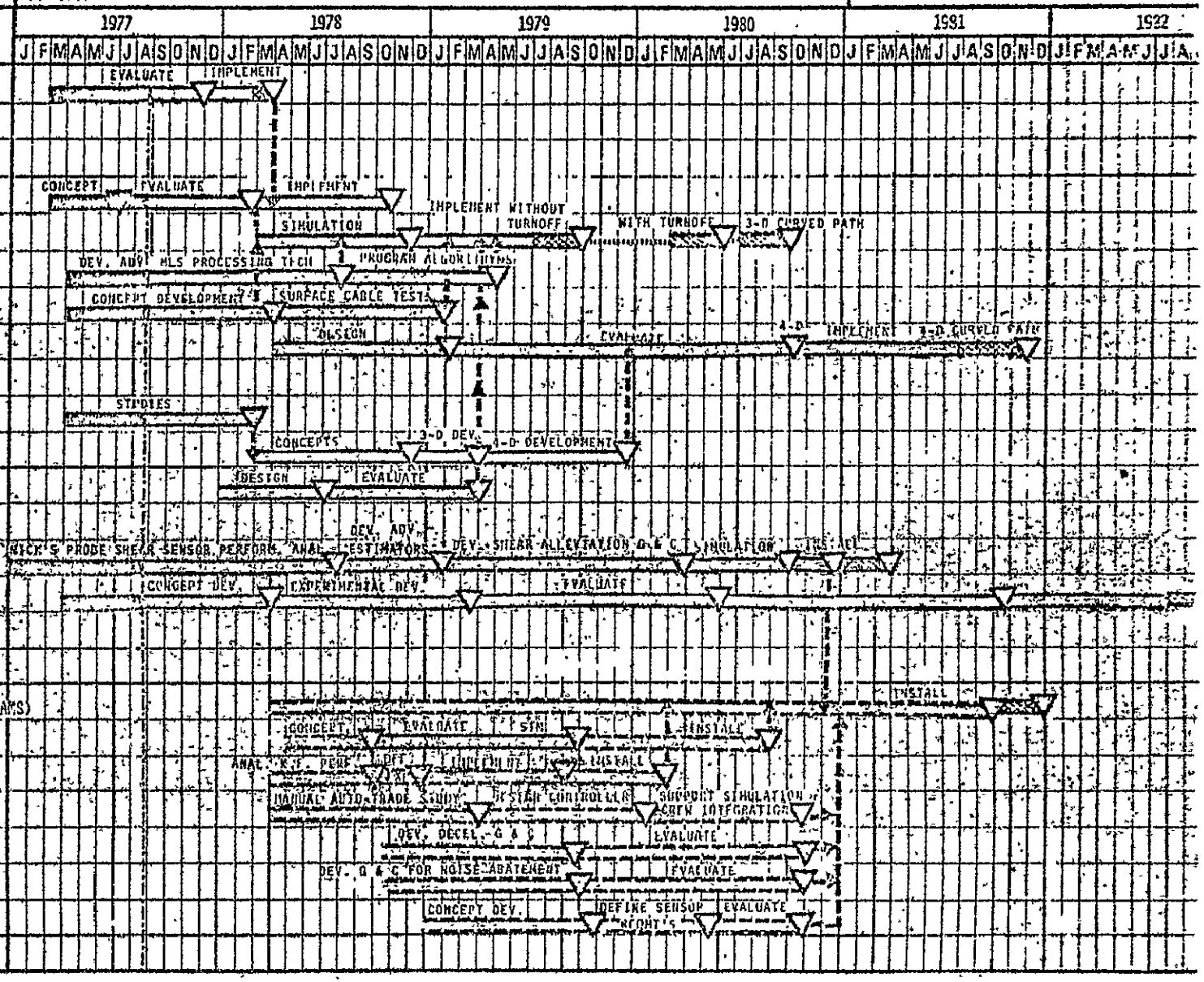
3 LEVEL

ORIGINAL SCHEDULE APPROVAL _____ (DATE)

LAST SCHEDULE CHANGE SEPTEMBER 7, 1977 (DATE)

STATUS AS OF _____ (DATE)

	MILESTONES
1	IMPROVED AUTOFLARE & AUTOTHROTTLE
2	
3	PRECISION APPROACH & LANDING
4	3-D GUIDANCE & CONTROL
5	3-D INTEGRATED GUIDANCE & CONTROL
6	ADVANCED RECEIVER
7	ROLLOUT TURNOFF
8	4-D INTEGRATED GUIDANCE & CONTROL
9	GENERALIZED CURVED-PATH
10	OPTIMIZATION STUDIES
11	CURVED PATH NAVIGATION
12	RNAV TO MLS TRANSITION
13	
14	SHEAR DETECTION & ALLEVIATION
15	MULTIPURPOSE RADAR DEVELOPMENT
16	
17	
18	ADVANCED SYSTEM DEVELOPMENT (AUGMENTED PROGRAMS)
19	ADAPTIVE CONTROLS
20	IMPROVED STATE ESTIMATORS
21	MANUAL/AUTOCONTROL INTERACTION
22	DECELERATING CONTROL SYSTEM
23	NOISE ABATEMENT PATHS
24	ALTERNATIVES/SUPPLEMENTS TO MLS
25	



NOTES

FLIGHT TEST PERIOD

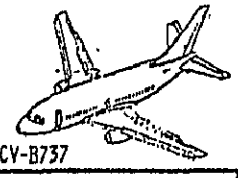
AUGMENTED PROGRAMS

LANGLEY RESEARCH CENTER

RESPONSIBILITY.

APPROVAL _____

ACCOMPLISHMENT: _____



TERMINAL CONFIGURED VEHICLE PROGRAM

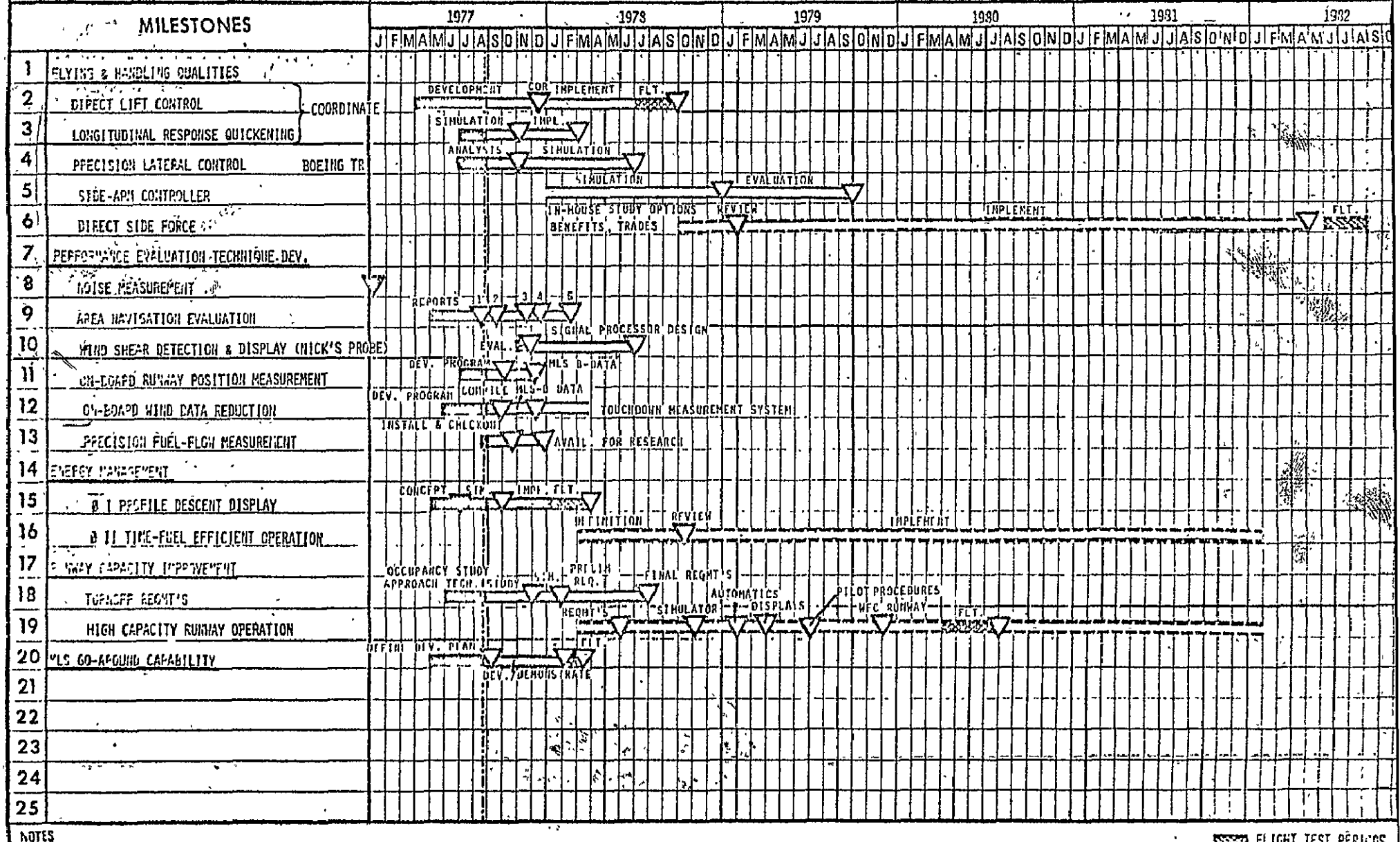
FLIGHT TECHNOLOGY

3 LEVEL

ORIGINAL SCHEDULE APPROVAL _____ (DATE)

LAST SCHEDULE CHANGE AUGUST 25, 1977 (DATE) _____ (INITIALS)

STATUS AS OF _____ (DATE)



NOTES

FLIGHT TEST PERIODS

AUGMENTED PROGRAMS

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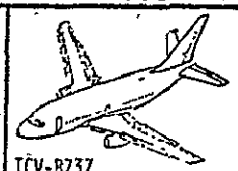
RESPONSIBILITY:

APPROVAL _____

ACCOMPLISHMENT: _____



TCV-B737

TERMINAL CONFIGURED VEHICLE PROGRAM

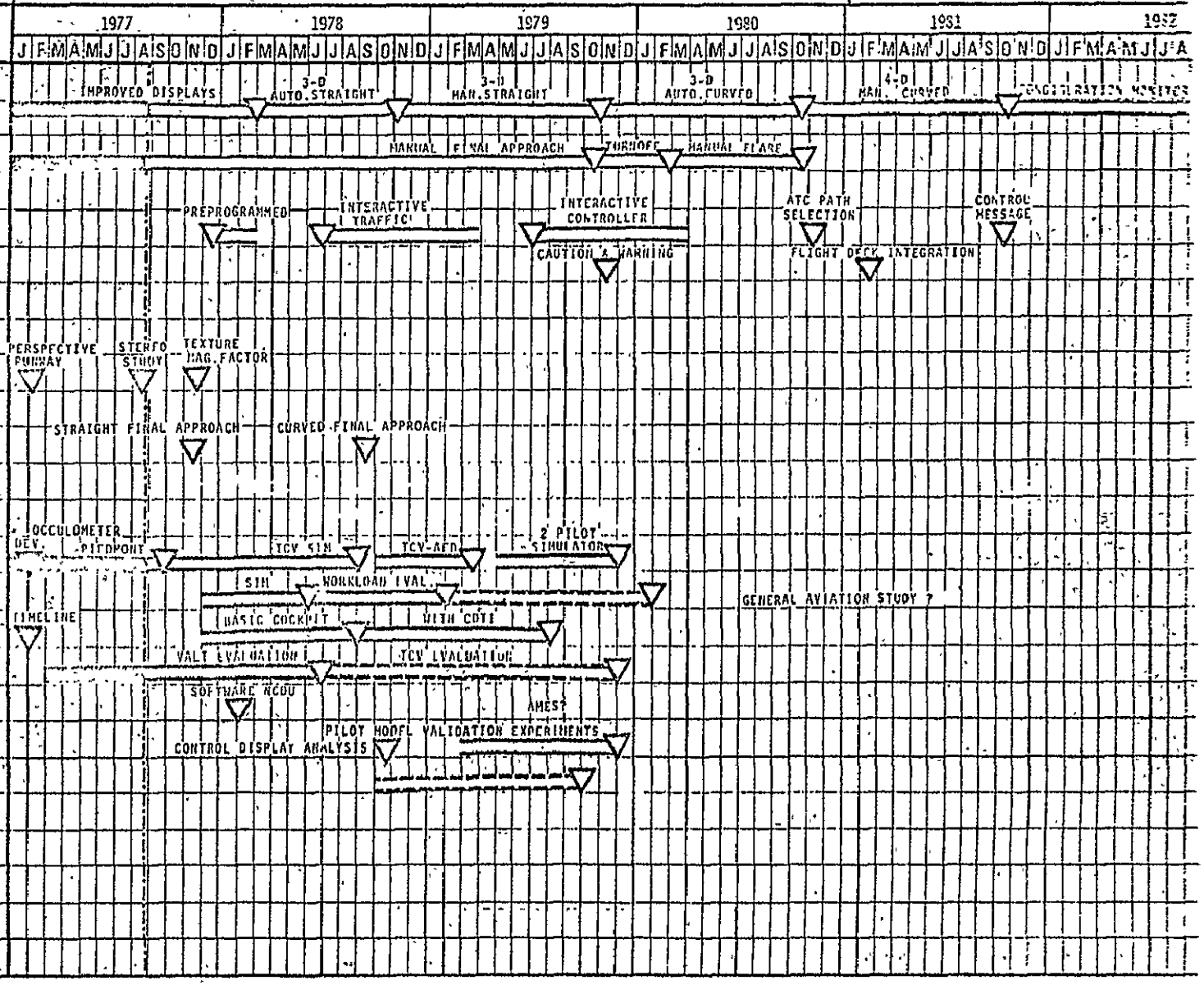
CREW INTEGRATION

3 LEVEL

ORIGINAL SCHEDULE APPROVAL _____ (DATE)

LAST SCHEDULE CHANGE AUGUST 31, 1977 (DATE)

STATUS AS OF _____ (DATE)



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FLIGHT TEST PERIO

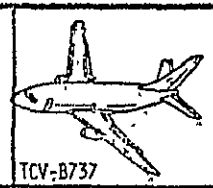
AUGMENTED PROGRAMS

LANGLEY RESEARCH CENTER

RESPONSIBILITY:

APPROVAL: _____

ACCOMPLISHMENT: _____



TCV-B737

TERMINAL CONFIGURED VEHICLE PROGRAM

ATC OPERATIONS ANALYSIS

3 LEVEL

STATUS AS OF SEPTEMBER 1,1977 (DATE)

	MILESTONES	1977	1978	1979	1980	1981	1982	1983
		J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A
1	TAATK SIMULATION		UPDATE ATL MODEL; M & S INTEGRATION; TRAFFIC INTERACTIVE					
2		CASSETTE INTERFACE	FROS	4-D STRATEGIC CONTROL	CONTROLLER INTERACTION			
3								
4	METERING & SPACING STUDIES (FAA REQUEST)	PARAMETRIC STUDY REPORT	PILOT INTERACTION STUDY; IMPL.	FLT.				
5								
6								
7	STRATEGIC CONTROL	DEFINE 4-D S/C ALGORITHM	INCORP. INTO TAATK	SIM.	FLT.			
8			FUEL SENSITIVITY STUDY					
9	TRAFFIC OPTIMIZATION	RUNWAY FLT. PATH OCCUPANC OPT. STUDY	DEFINE EXPMT'S	ANALYSIS; FAST TIME EXPTS.	REAL TIME EXPTS.	IMPL.	FLT.	
10								
11	DISTRIBUTED ATC MANAGEMENT STUDIES							
12	LOCAL FLOW MANAGEMENT	REPORT						
13	PROFILE DESCENT	REPORT						
14	PILOT PARTICIPATION (LITCHFORD)		REPORT					
15								
16	COCKPIT DISPLAY TRAFFIC INFORMATION	PREPROGRAMMED IMPL. FLT.	MONITORED MODE	SHARED MODE	INDEPENDANT MODE			
17								
18								
19								
20								
21				INTERFACES				
22	AIR TRAFFIC CONTROL MILESTONES							
23								
24								
25								

NOTES

FLIGHT TIME

AUGMENTED PROGR

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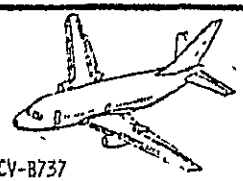
LANGLEY RESEARCH CENTER

RESPONSIBILITY

APPROVAL: _____

ACCOMPLISHMENT: _____



TCV-B737

TERMINAL CONFIGURED VEHICLE PROGRAM

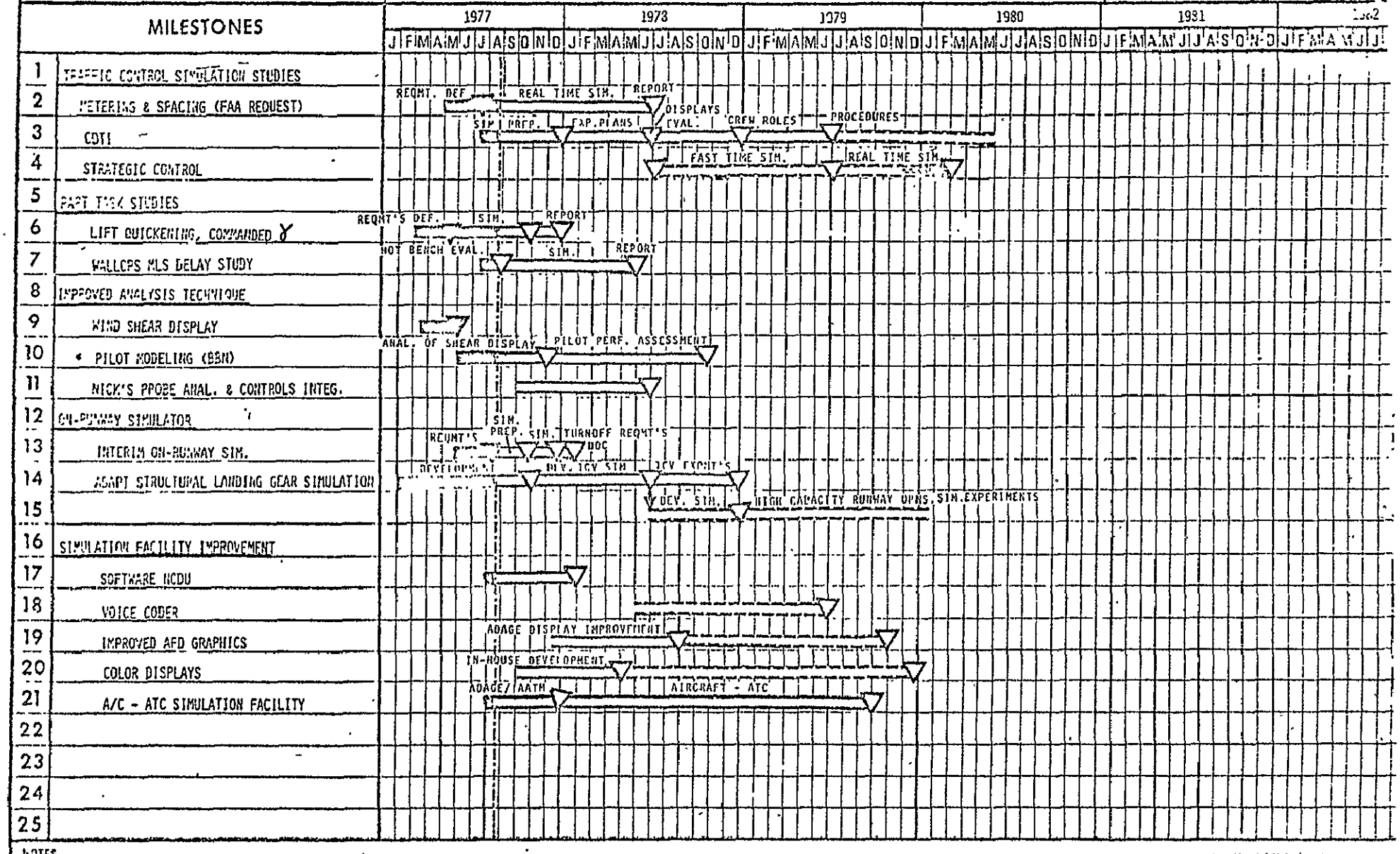
SIMULATION ANALYSIS & SYSTEM STUDIES

3 LEVEL

ORIGINAL SCHEDULE APPROVAL _____ (DATE)

LAST SCHEDULE CHANGE AUGUST 26, 1977 (DATE)

STATUS AS OF _____ (DATE)



NOTES

FLIGHT TIME PERIOD

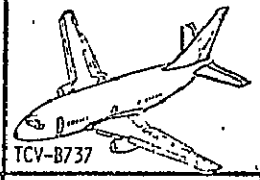
AUGMENTED PROGRAMS

LANGLEY RESEARCH CENTER

RESPONSIBILITY

APPROVAL

ACCOMPLISHMENT



TERMINAL CONFIGURED VEHICLE PROGRAM

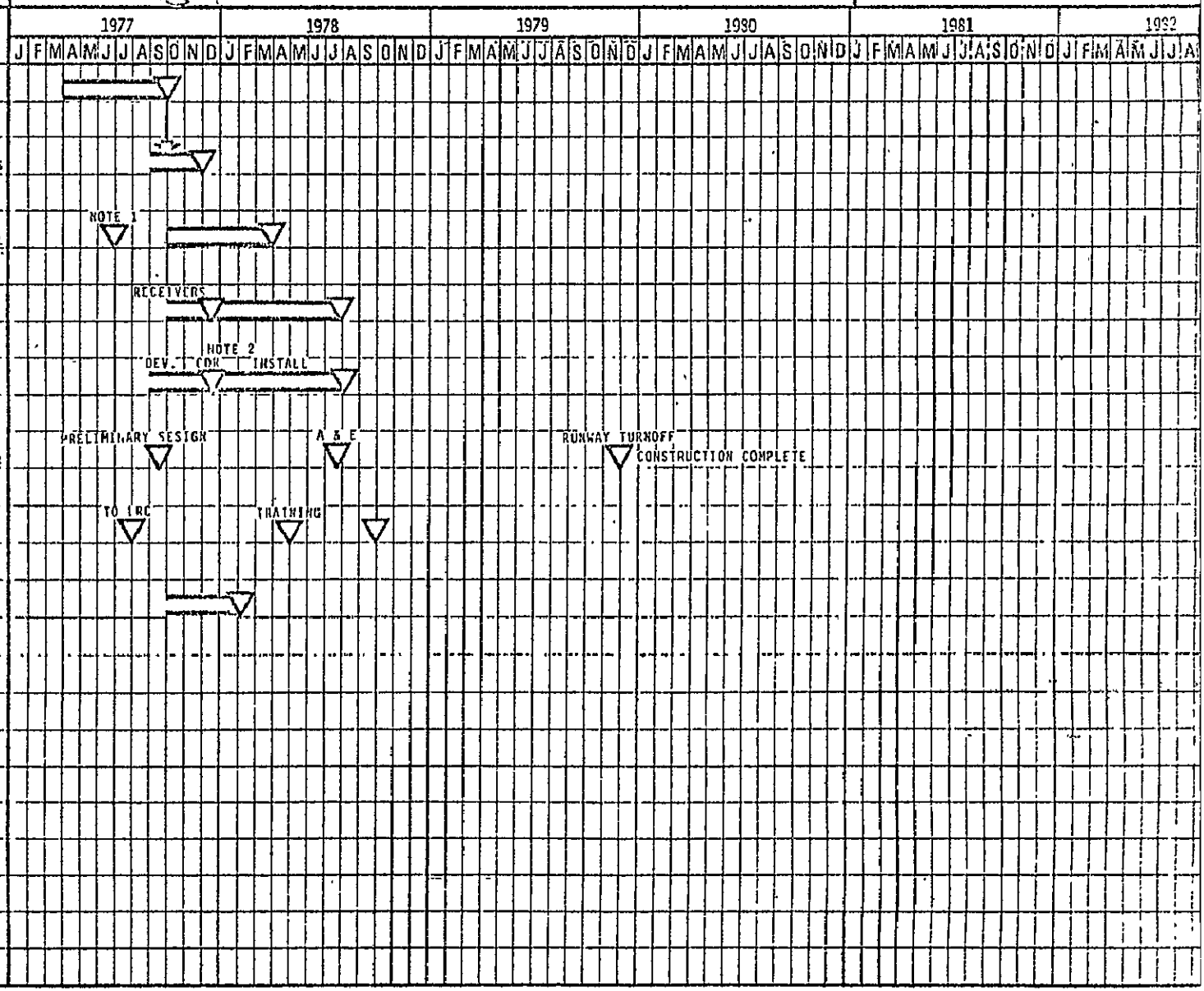
RESEARCH FACILITY DEVELOPMENT

3 LEVEL

ORIGINAL SCHEDULE APPROVAL (DATE)

LAST SCHEDULE CHANGE AUGUST 23, 1977 (DATE)

STATUS AS OF (DATE)



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 (FAA REQUEST)
- FLIGHT TEST VALIDATION OF ANTENNA PATTERN PREDICTIONS
- MLS RECEIVER CONCEPT DEVELOPMENT (AWOP RECOMMENDATION)
- REAL AND SIMULATED MLS AT WALLOPS
  - NEW SOFTWARE CHECKOUT
  - RNAV/MLS TRANSITIONS (VOLUMETRIC COVERAGE)
  - ADVANCED CONTROL LAW DEVELOPMENT
- 1978 TRSB DEMONSTRATION TO ICAO

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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:

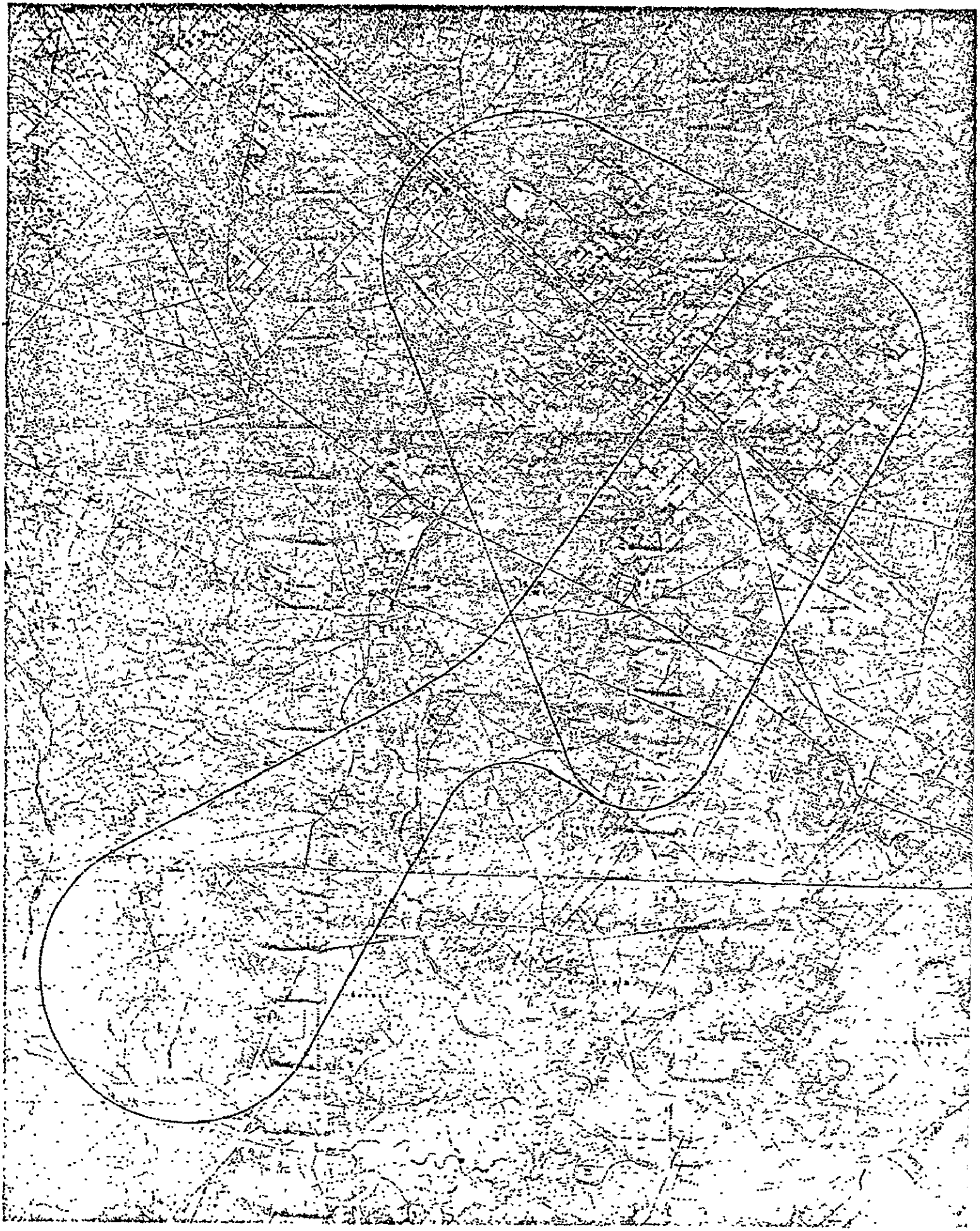
41 APPROACHES (3, 11/2, 1 NAUTICAL MILE FINALS)

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)



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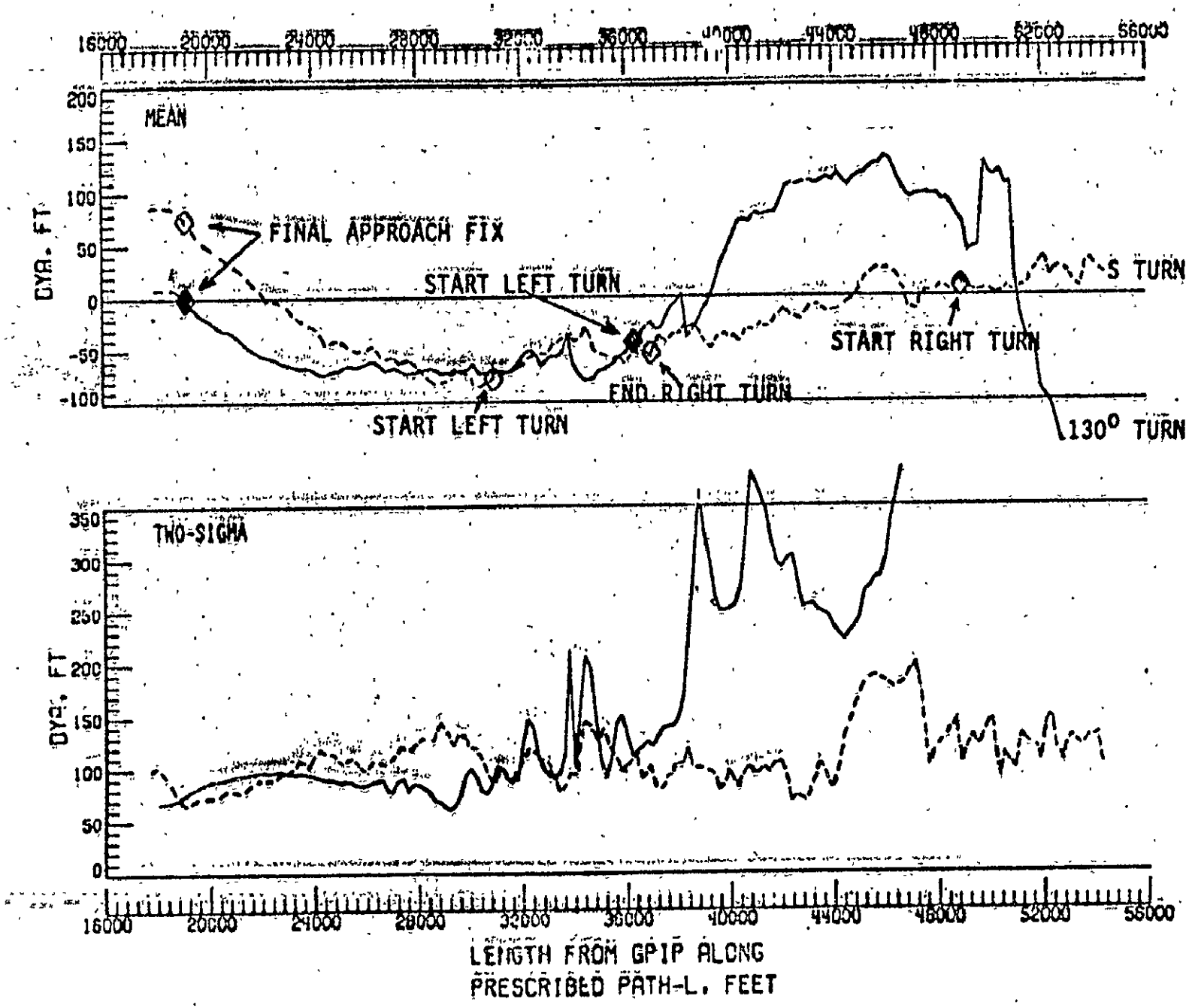
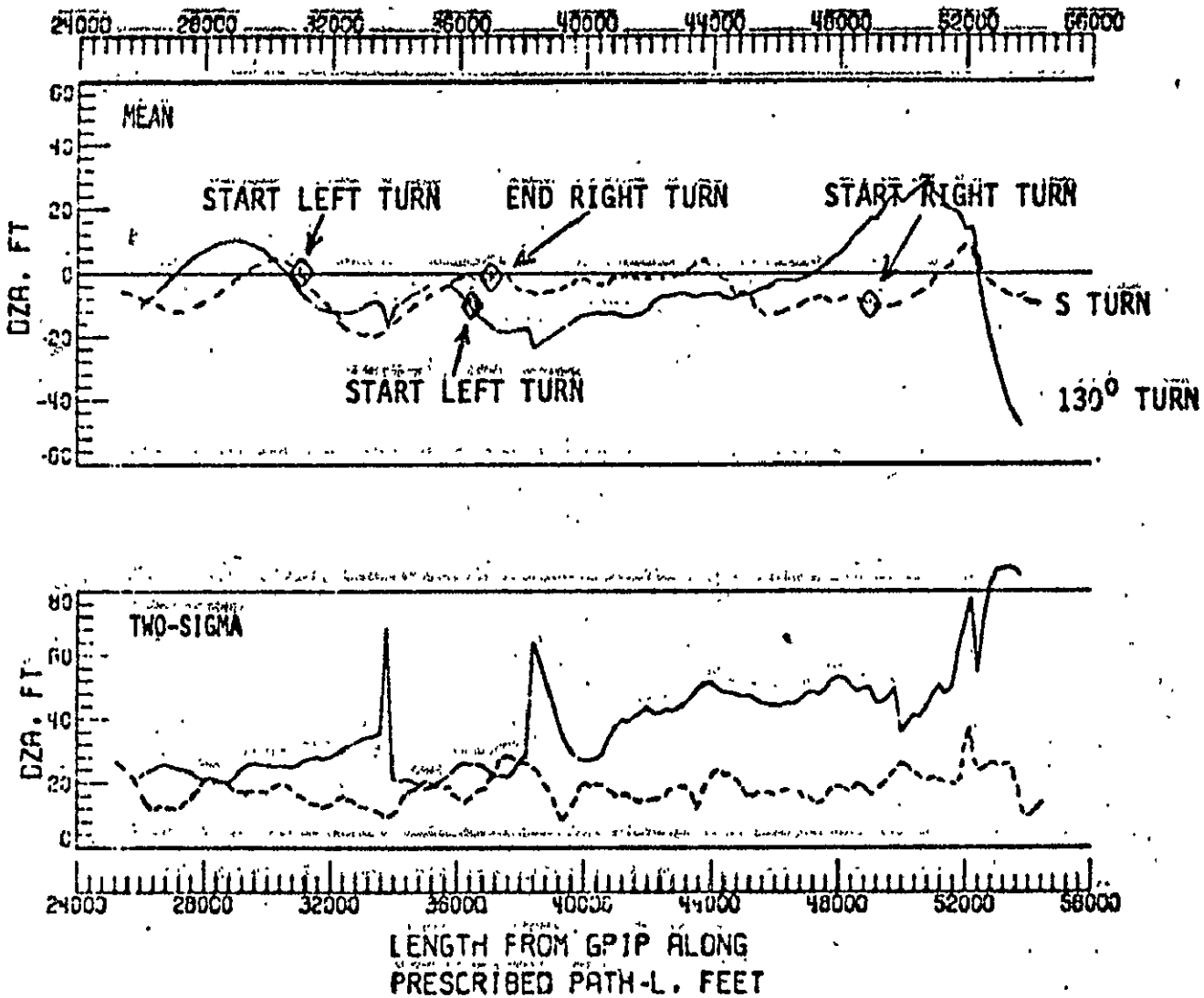


DYA, MEAN AND TWO-SIGMA STATISTICS FOR INITIAL APPROACH



DZA, MEAN AND TWO-SIGMA STATISTICS FOR INITIAL APPROACH

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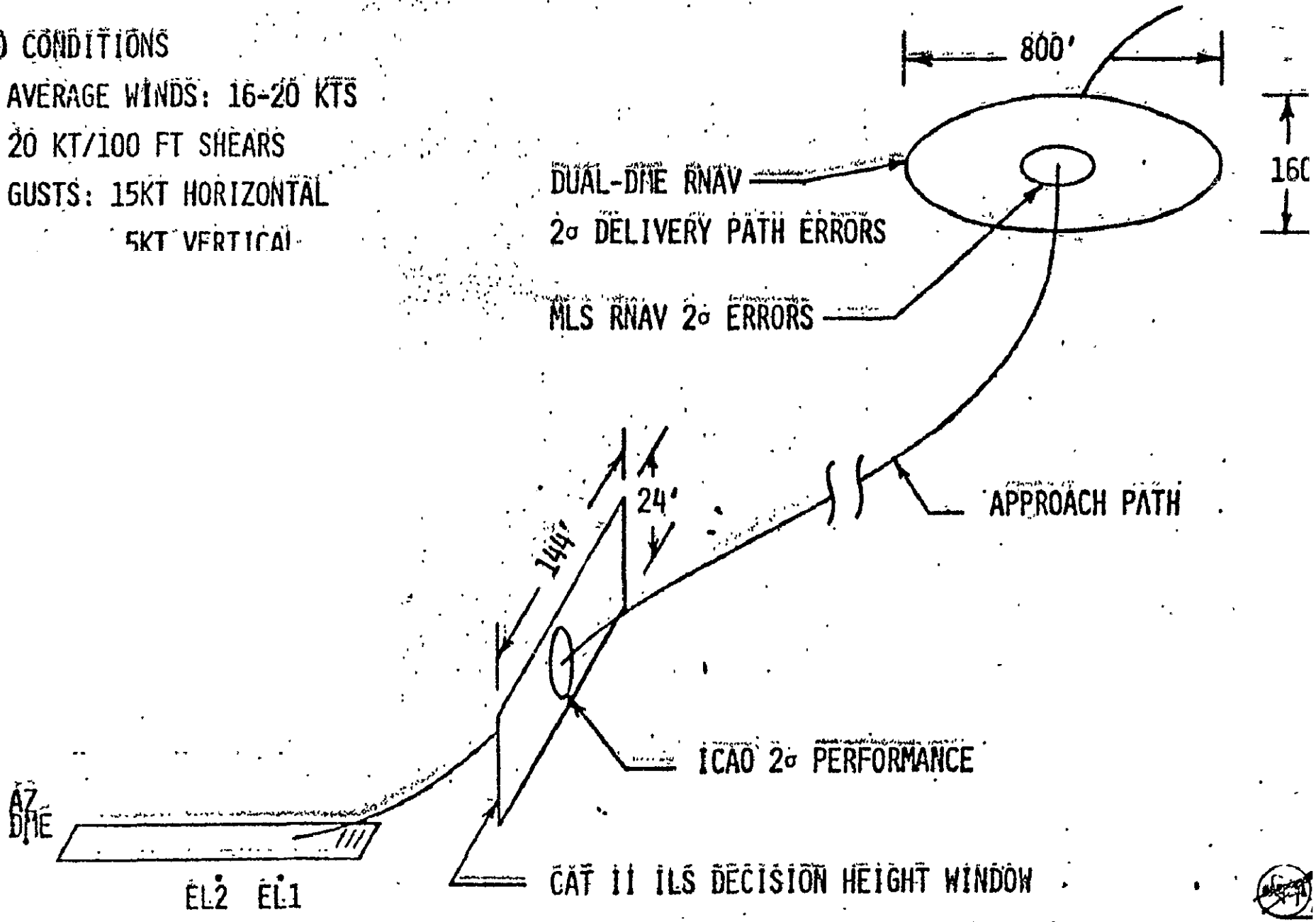
ICAO TRACKING PERFORMANCE

WIND CONDITIONS

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



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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.

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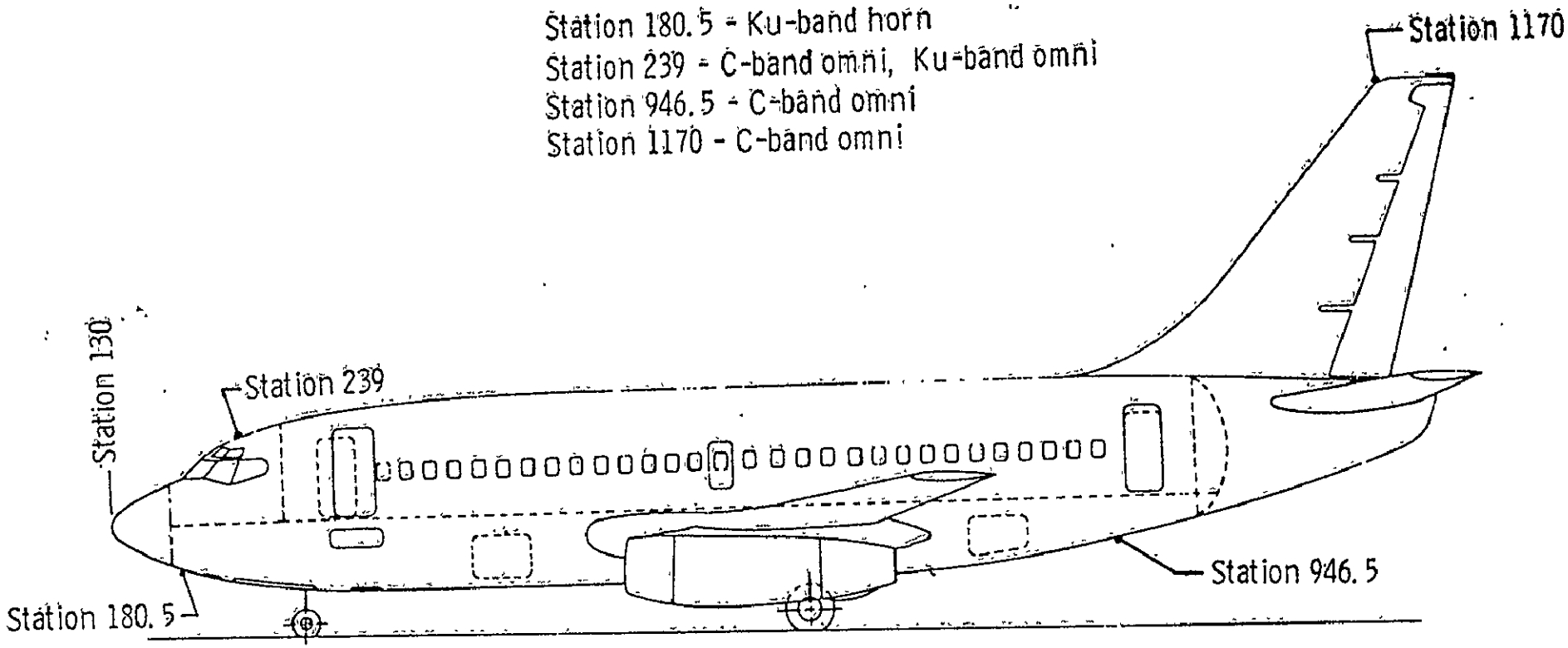

ANTENNA LOCATIONS USED FOR FLIGHT EXPERIMENT

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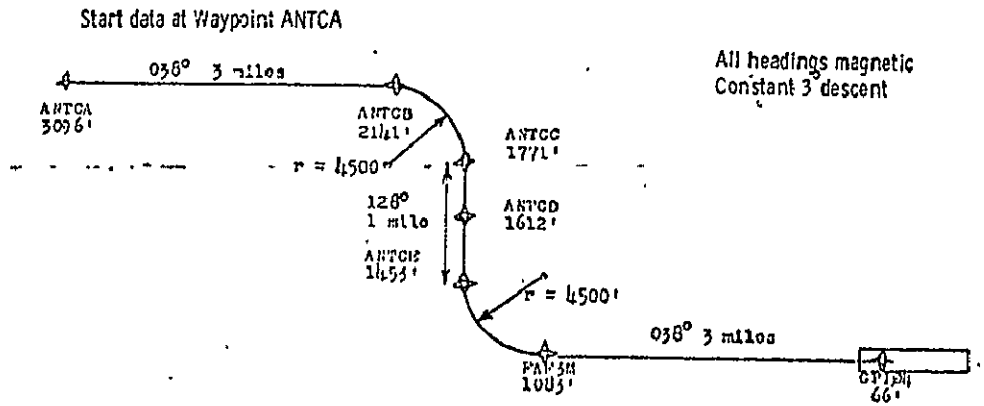
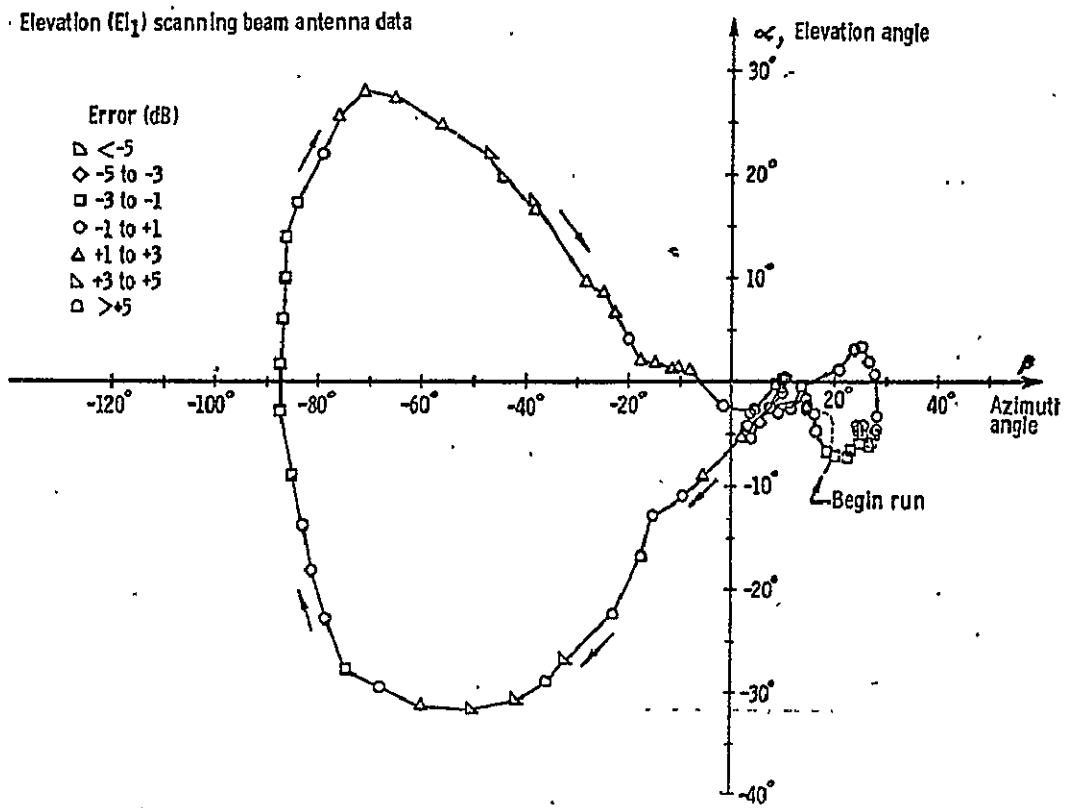


STAR AC049

MLS ANTENNA FLIGHT TEST PROFILE FOR RUN 8.



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

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OPTIMAL MLS RECEIVERS

A HIGH PERFORMANCE RECEIVER HAS BEEN DEMONSTRATED IN SIMULATION:

- o NO MULTIPATH: EQUAL TO OR BETTER THAN CONVENTIONAL RECEIVER
- o 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:

- o VERY CLOSE TRACKING OF SCALLOPING FREQUENCY ($\pm$ 0.4 HZ) REQUIRED TO INSURE ADEQUATE TRACKING OF PHASE DIFFERENCE ($\pm 10^{\circ}$)
- o DIFFICULT ACQUISITION: INITIALIZATION OF 5 OR 6 PARAMETERS REQUIRED, SOME TO HIGH ACCURACIES

RECOMMENDATION:

MODIFY THE DESIGN TO ELIMINATE

PHASE DIFFERENCE, β

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

CON

- SOME LOSS IN PERFORMANCE RELATIVE TO OPTIMAL RECEIVER

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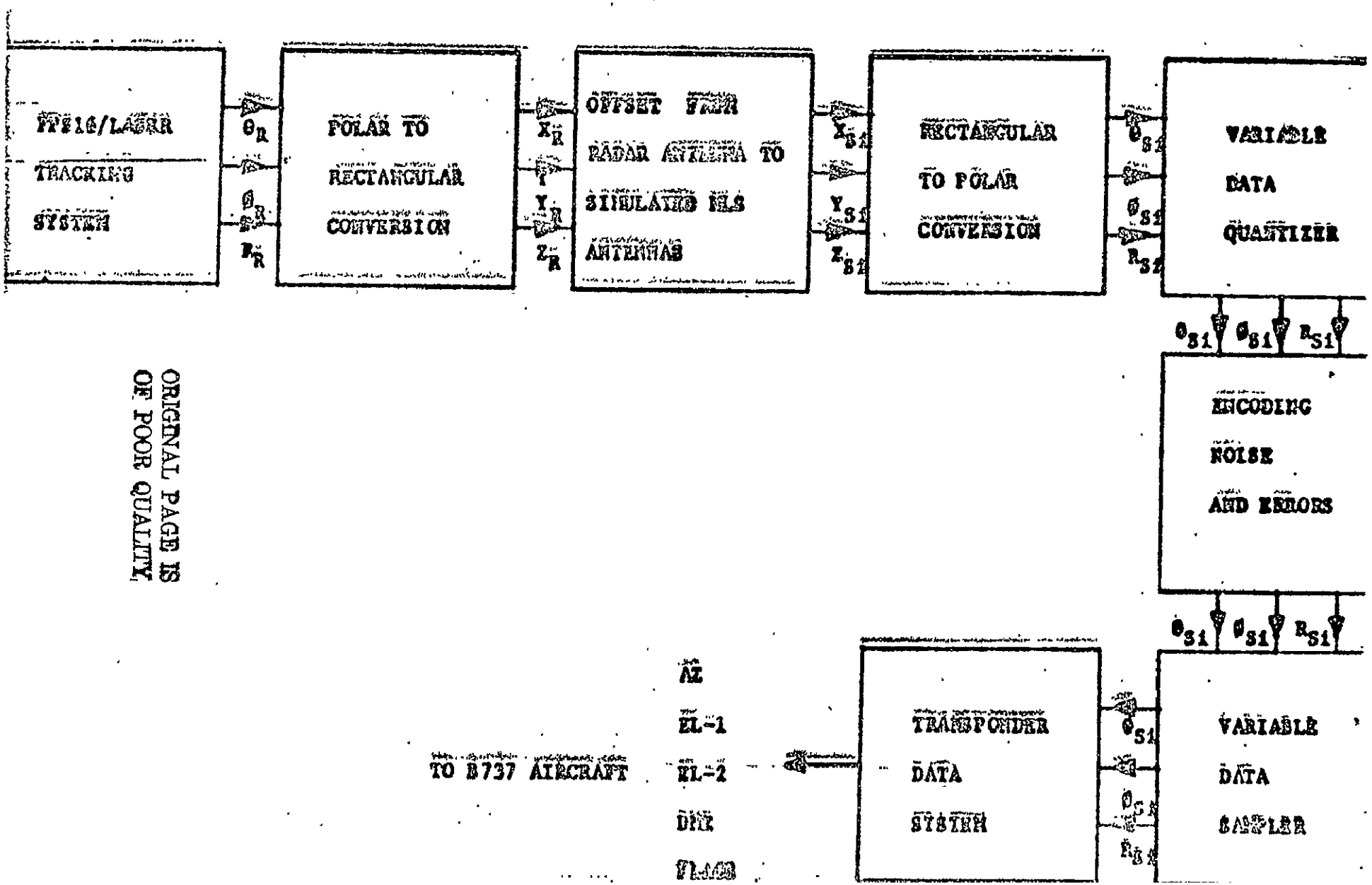
DATA FLOW FOR SIMULATED MLS



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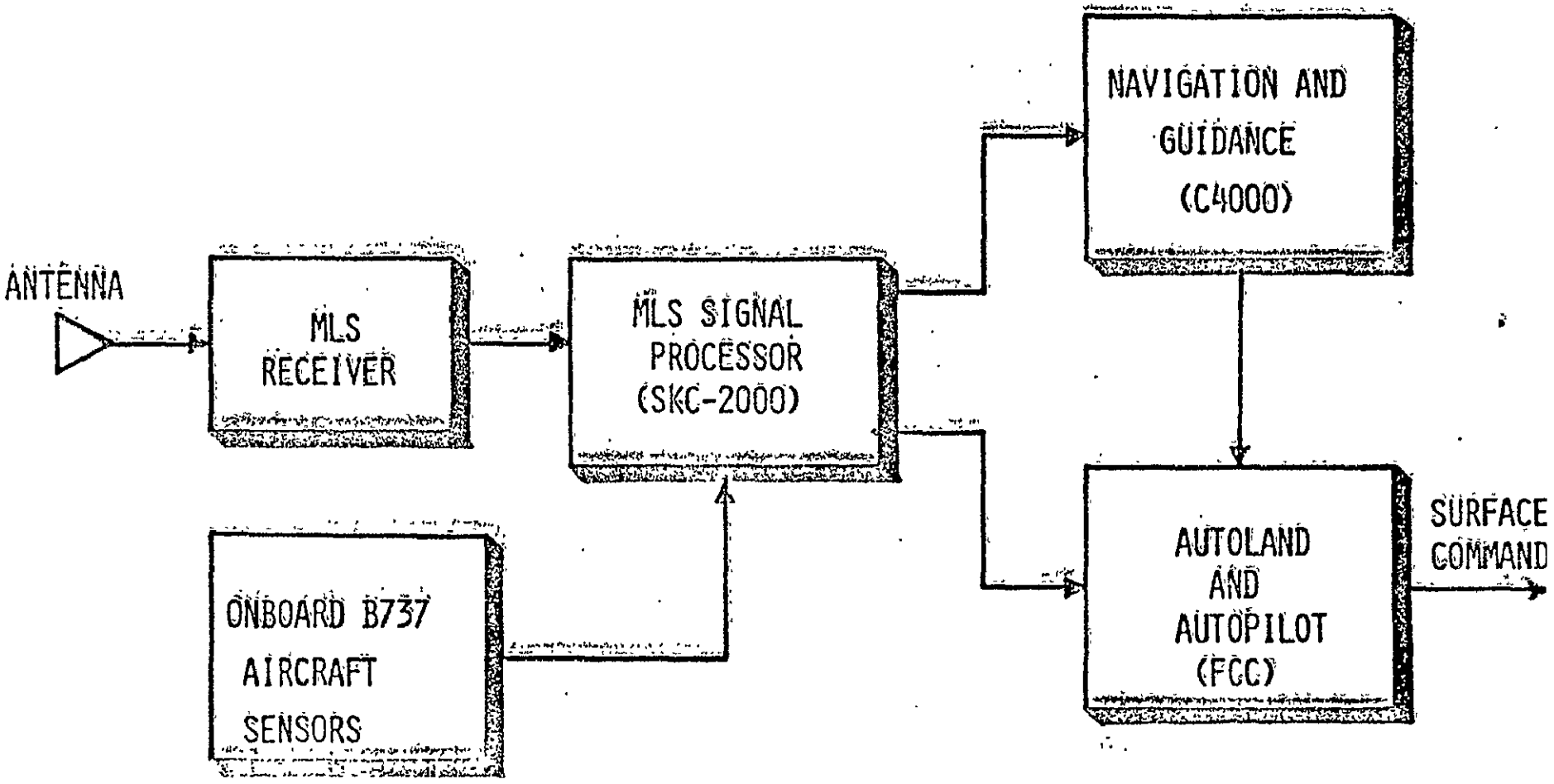
ONBOARD ELEMENTS FOR ICAO NAVIGATION, GUIDANCE AND CONTROL SYSTEM



RNAV/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

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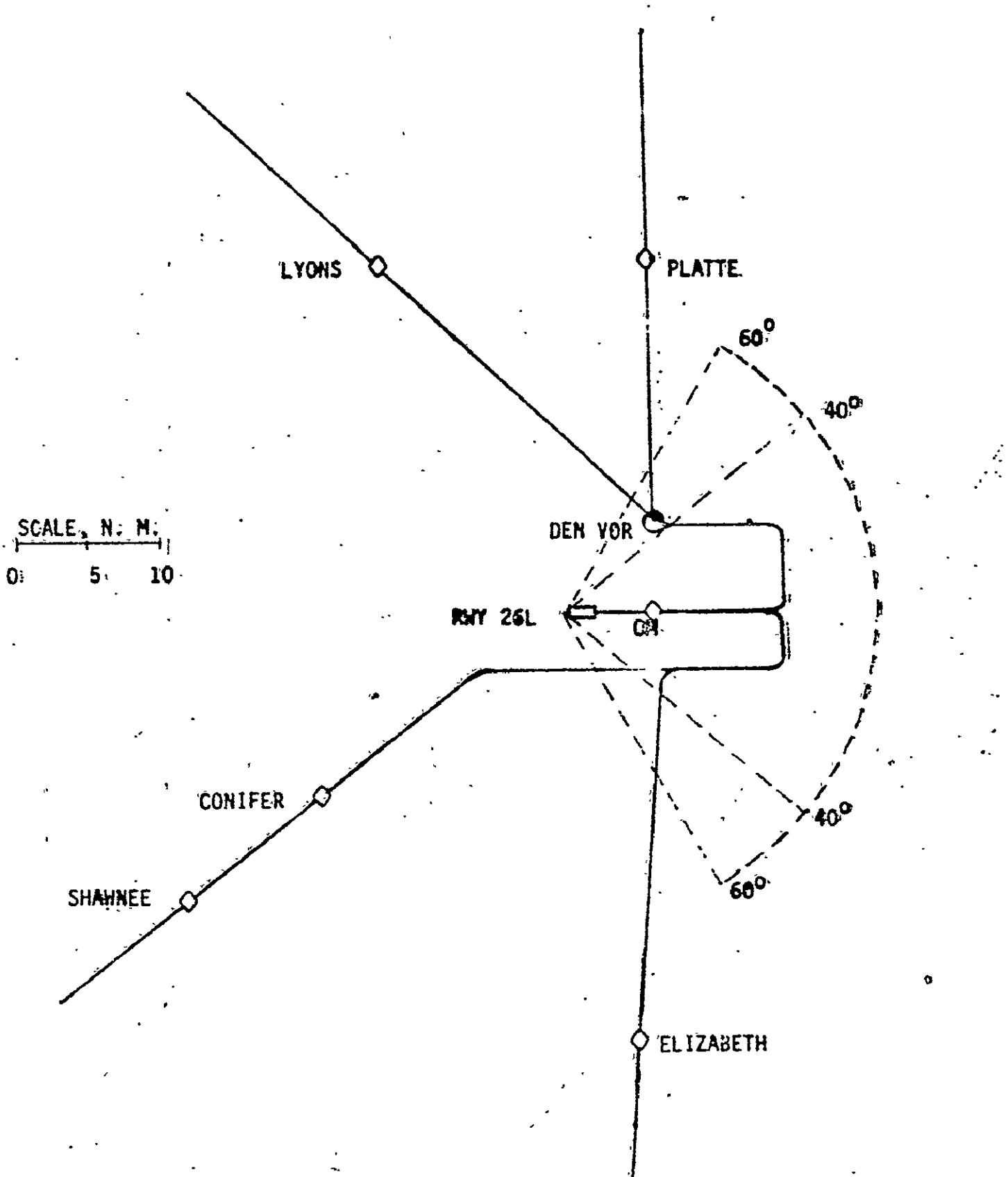
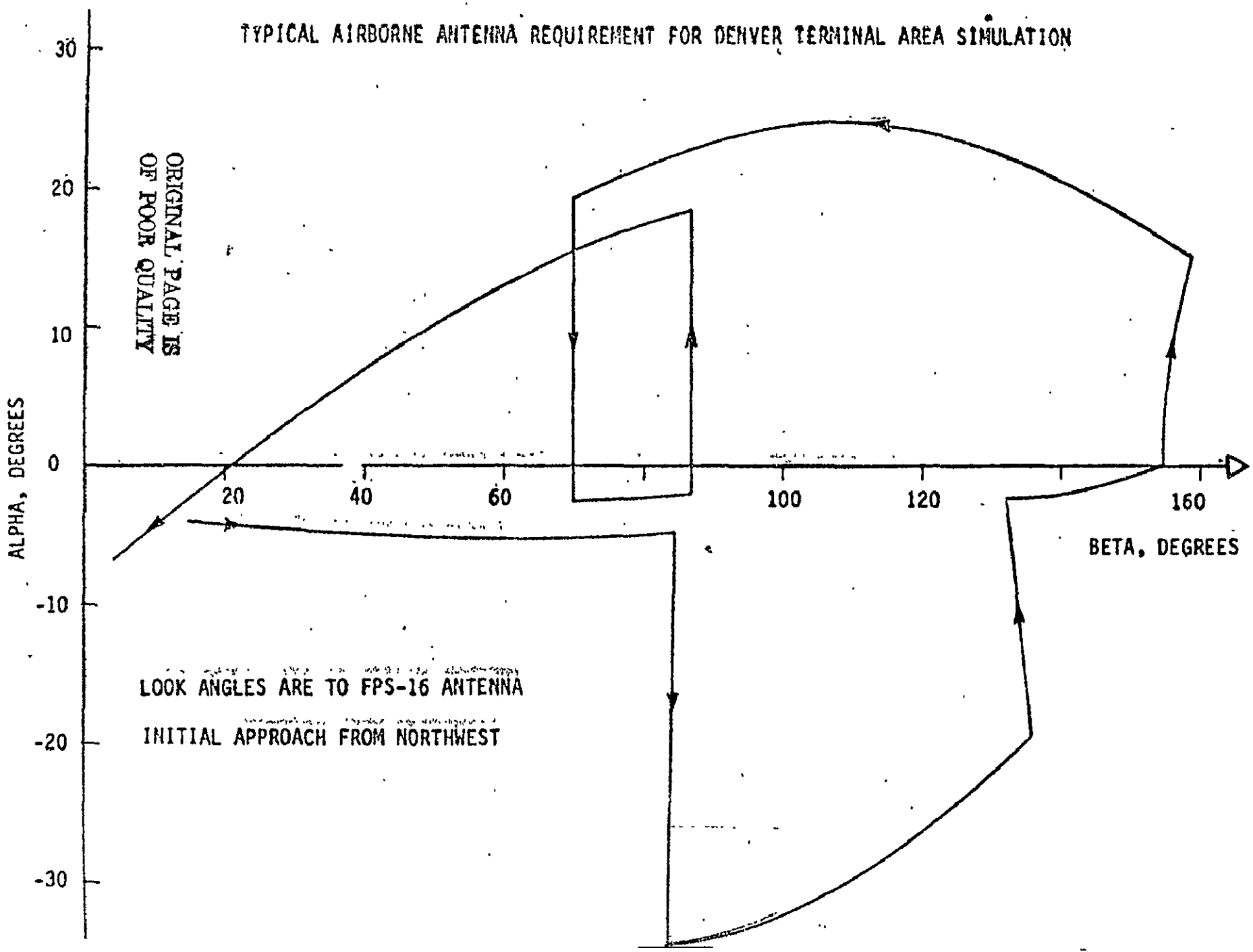


DENVER TERMINAL AREA MODEL USED IN ANTENNA REQUIREMENTS STUDY

NASA LANGLEY RESEARCH CENTER


TYPICAL AIRBORNE ANTENNA REQUIREMENT FOR DENVER TERMINAL AREA SIMULATION
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ALPHA, DEGREES
30
20
10
0
-10
-20
-30
20
40
60
100
120
160
BETA, DEGREES
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

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PROPOSED TRSB DEMONSTRATION TO O.A.S. MEETING

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

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

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WHOLE WORD COMPUTER SYSTEM STATUS

(WWCS)

WHOLE WORD COMPUTER SYSTEM STATUS
(WWCS)

* COMPUTER SYSTEM COMPARISON
* INTERFACE WITH GUIDANCE AND CONTROL SYSTEM
* SUMMARY OF FLIGHT CONTROL COMPUTER STATUS
* FLIGHT CONTROL COMPUTER SYSTEM

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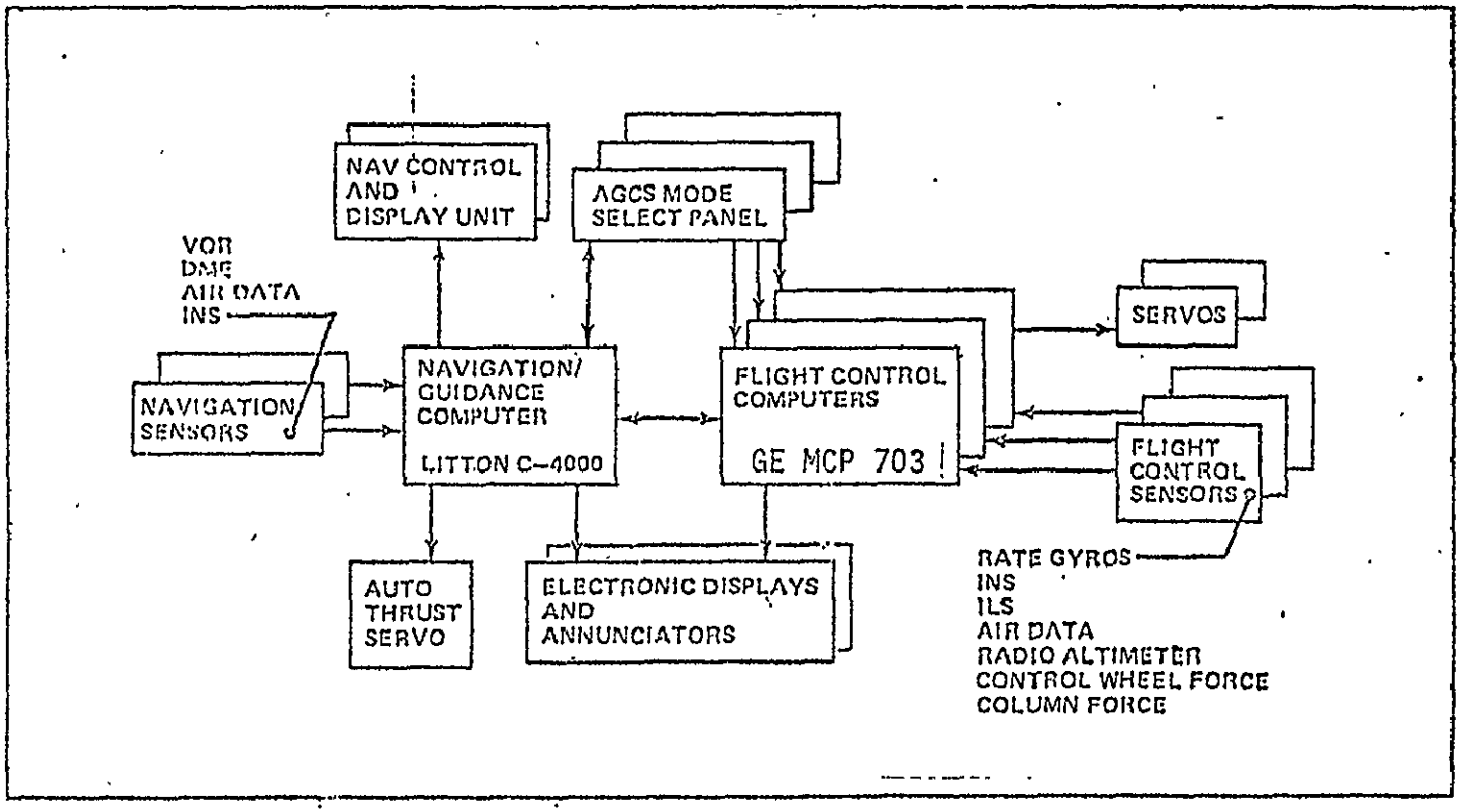
FLIGHT CONTROL COMPUTER CHARACTERISTICS

OLD	NEW
* GE ICP-723	* GE MCP-703 (WWCS)
* DIGITAL VARIABLE INCREMENT	* DIGITAL GENERAL PURPOSE
* SPECIAL PURPOSE	* EXTERNAL MEMORY FOR EXPANSION
* NO EXPANSION CAPABILITY	* PROVEN DESIGN
* DIFFICULT TO PROGRAM	
* SOME FUNCTIONS INEFFICIENT (LOGICAL, DISCRETE)	

FLIGHT CONTROL COMPUTER CHARACTERISTICS

	ICP-723	MCP-703 (WWCS)
TYPE	DIGITAL VARIABLE INCREMENT	DIGITAL GENERAL PURPOSE
WORD LENGTH	16 BITS	16 BITS
MEMORY	4K x 18 BIT CORE	32K x 18 BIT CORE
TIMING	48 μSEC./ALGORITHM	2 μSEC./INSTRUCTION
	6.144 MSEC/ITERATION	6.144 MSEC/MINOR FRAME
COMPUTA-TIONAL CAPABILITY	256 ALGORITHMS (128/ITERATION)	LIMITED ONLY BY MEMORY, SIZE AND TIMING
INPUTS	64 SERIAL	64 SERIAL
	32 DISCRETE	45 DISCRETE
		36 ANALOG
OUTPUTS	64 SERIAL	8 SERIAL
	32 DISCRETE	18 DISCRETE
		15 ANALOG

FLIGHT CONTROL SYSTEM BLOCK DIAGRAM



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FLIGHT CONTROL PALLET
(EASILY CONFIGURATION)

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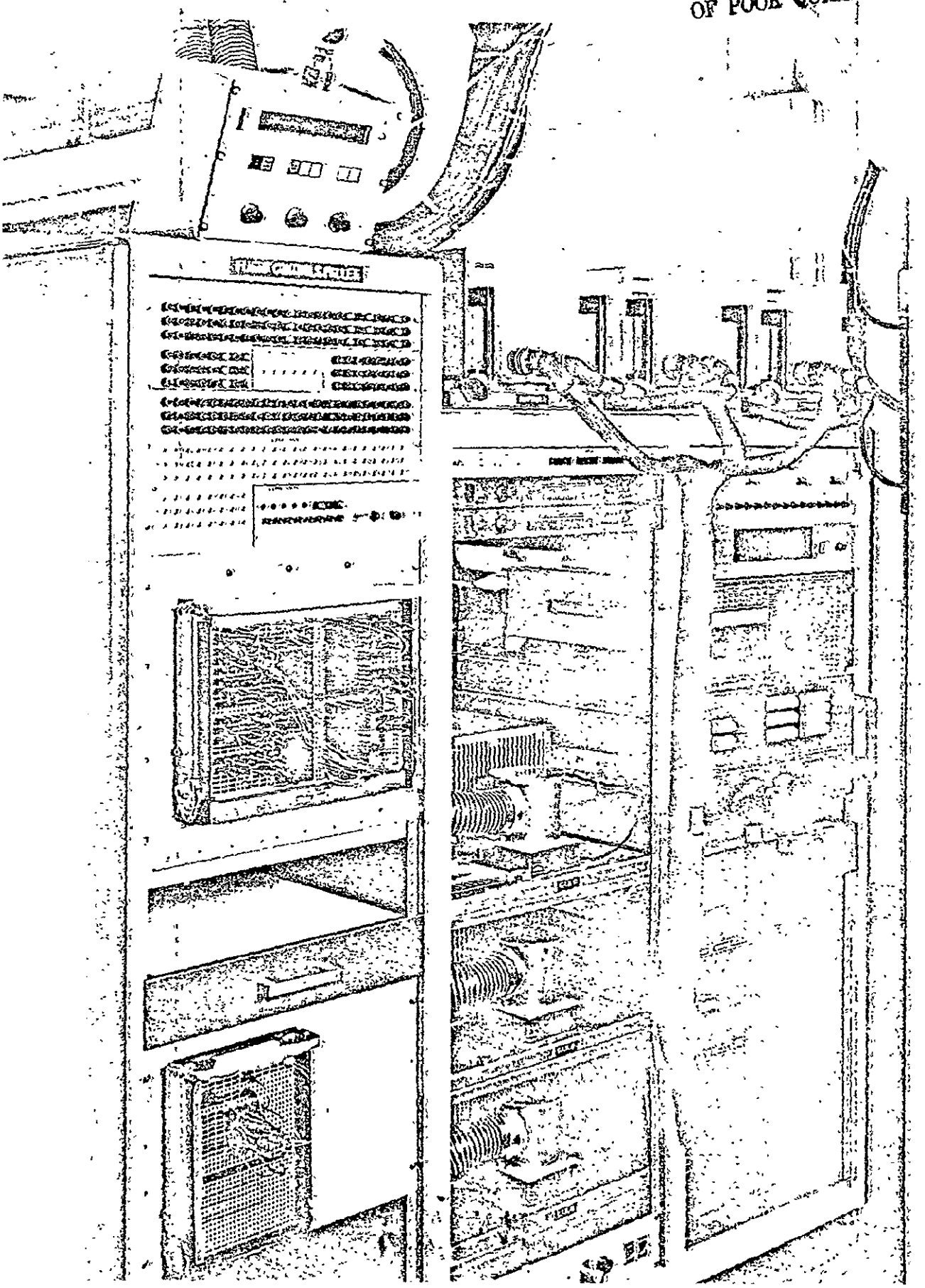

NASA
L-77-4847

OPERATIONAL STATUS OF FLIGHT CONTROL COMPUTER
(WHCS)

CAPABILITIES	HARDWARE	SOFTWARE	TESTING
2D, 3D GUIDANCE, MANUAL CWS, AND ILS AUTO LAND	OPERATIONAL	OPERATIONAL	30 RESEARCH FLIGHTS
SIMULATED	DESIGN AND FABRICATION COMPLETE	DESIGN AND CODING COMPLETE	SIMPLEX SYSTEM TESTS COMPLETE EASILY TESTS IN PROGRESS
MLS	RECEIVER INTERFACE	ADDITIONAL CAPABILITIES UNDER DEVELOPMENT	NONE

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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

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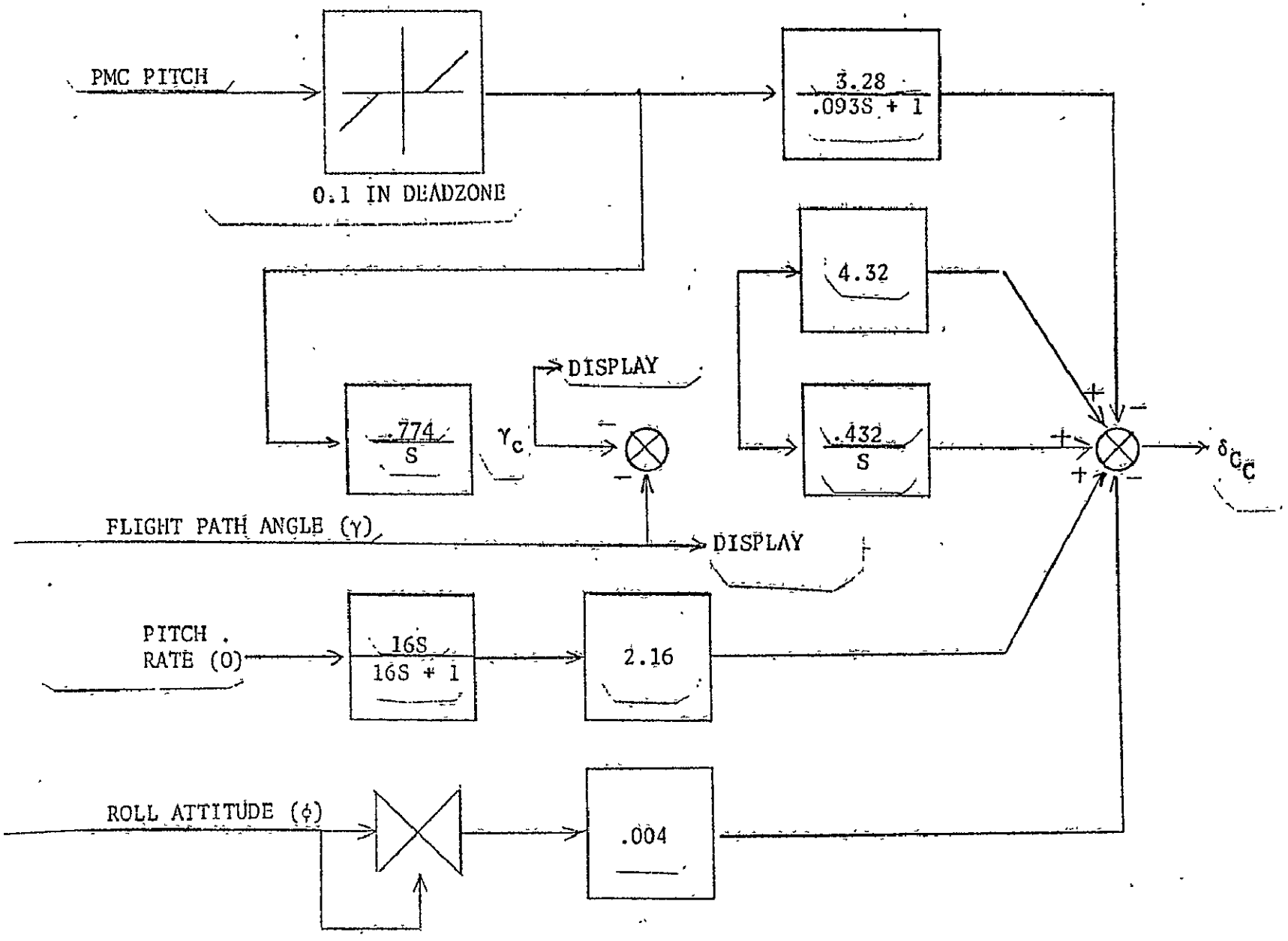
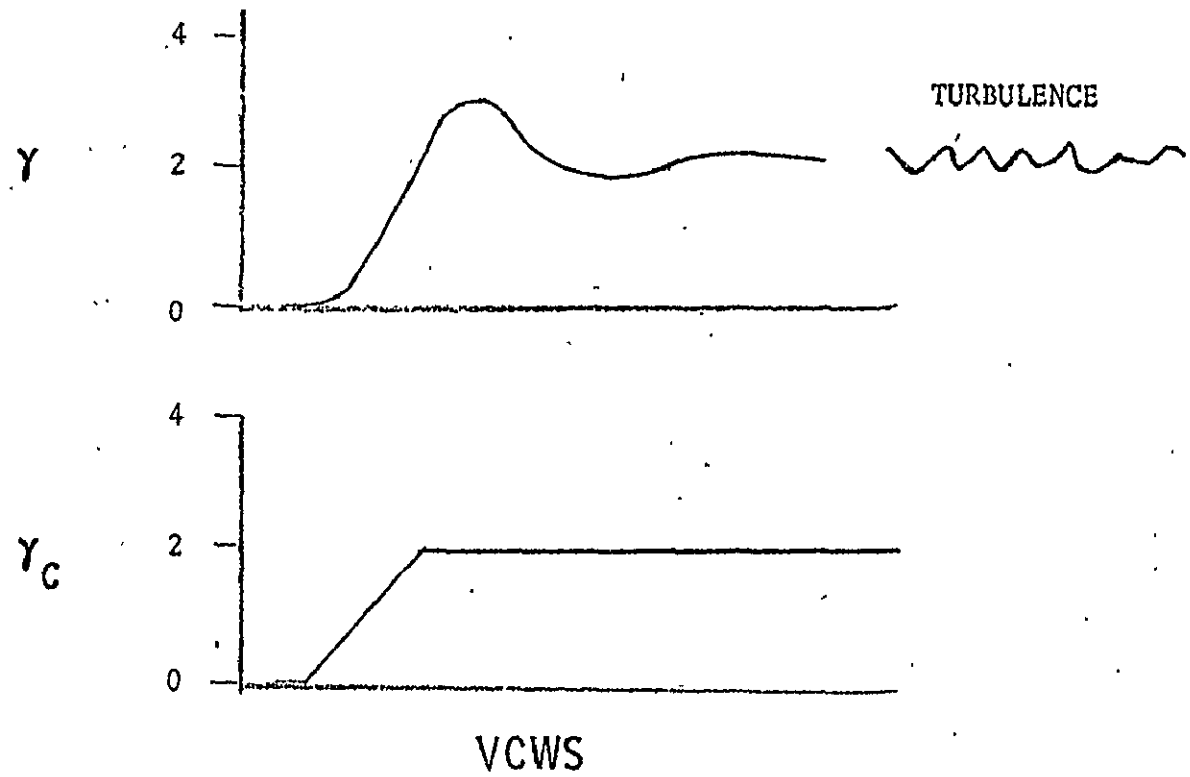


VELOCITY CWS CONTROL LAW -

SYSTEM RESPONSE TO A STEP CONTROL INPUT



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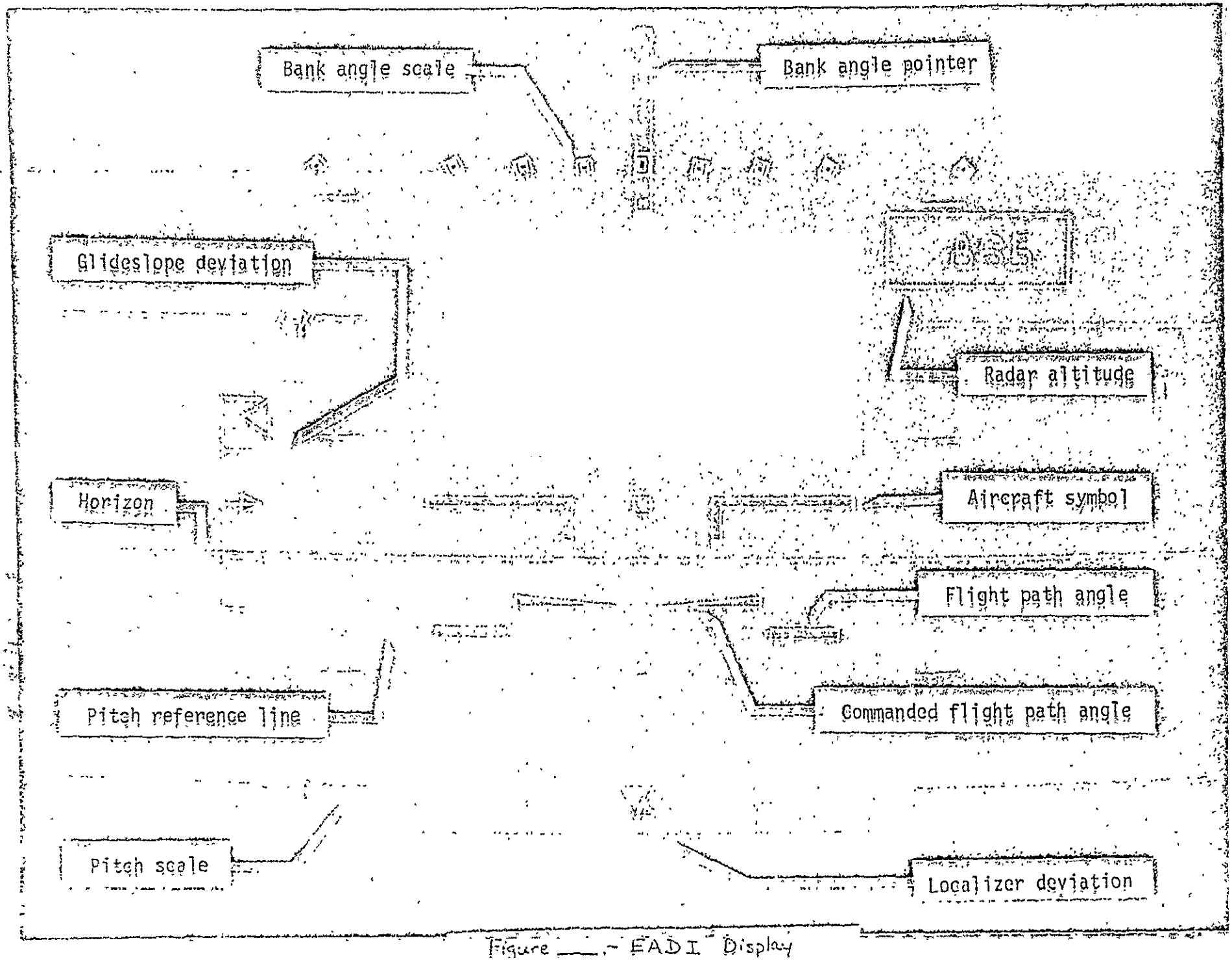
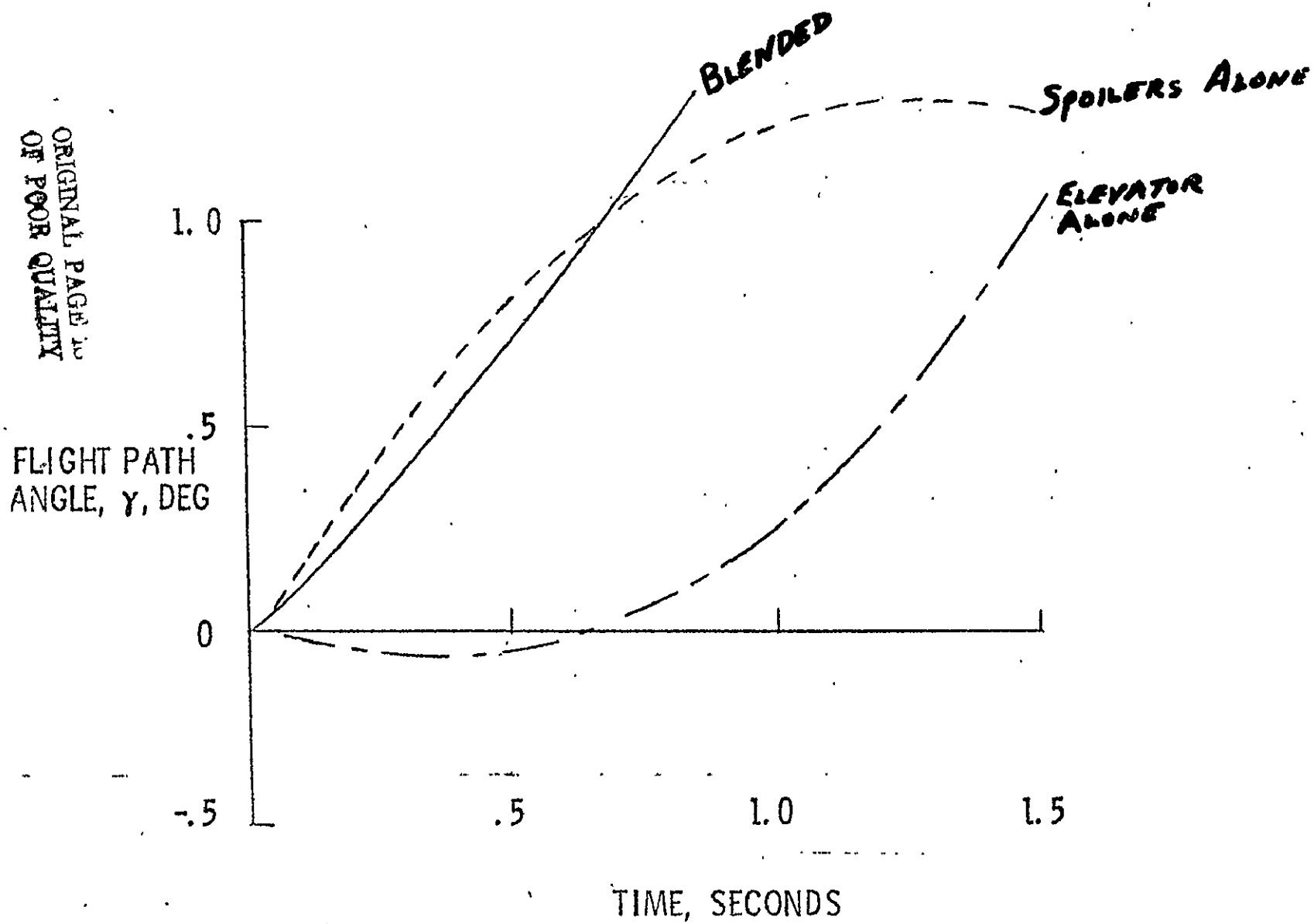


Figure ___ - EADI Display

FLIGHT PATH ANGLE RESPONSE TO STEP CONTROL INPUTS



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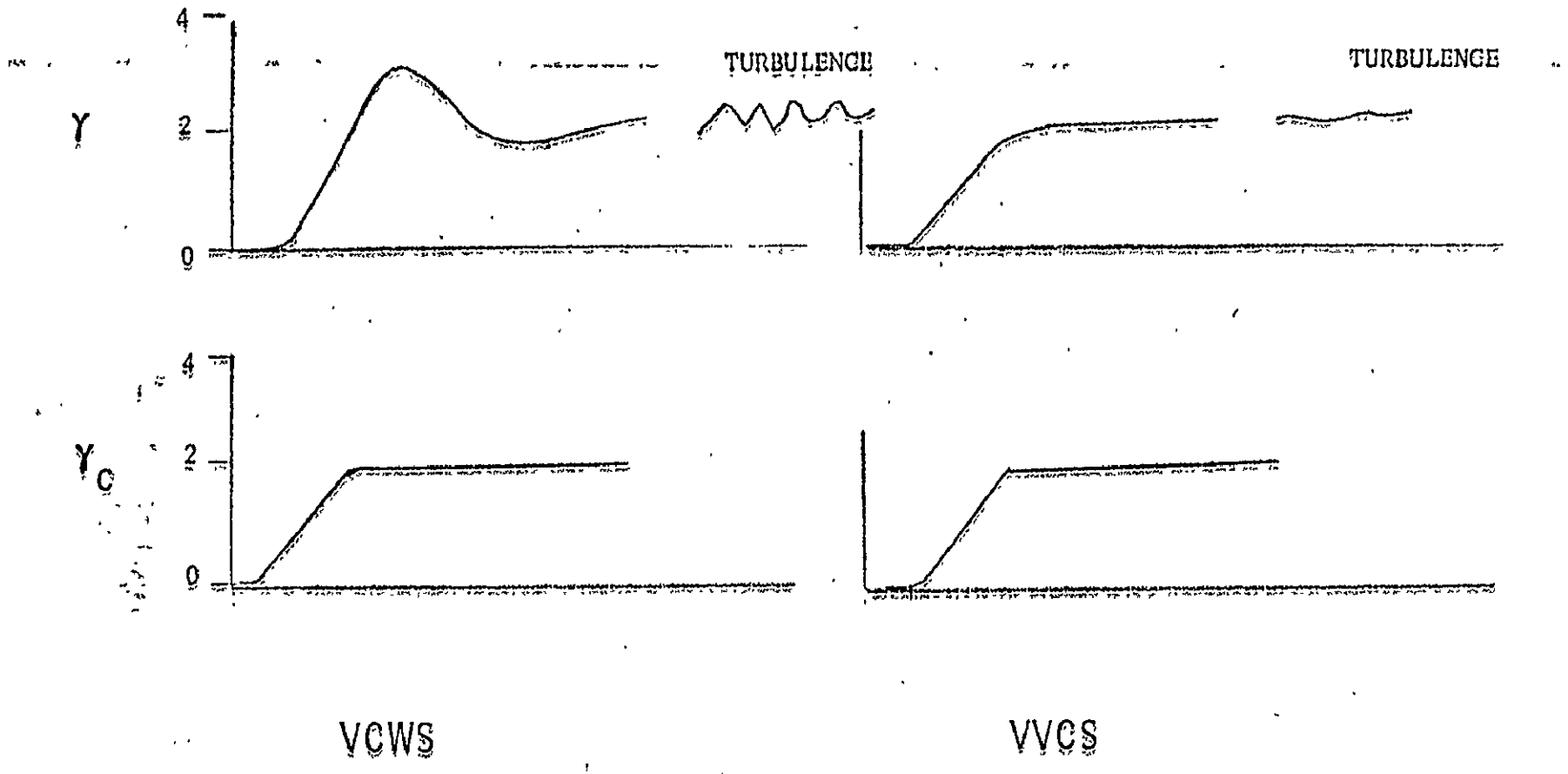
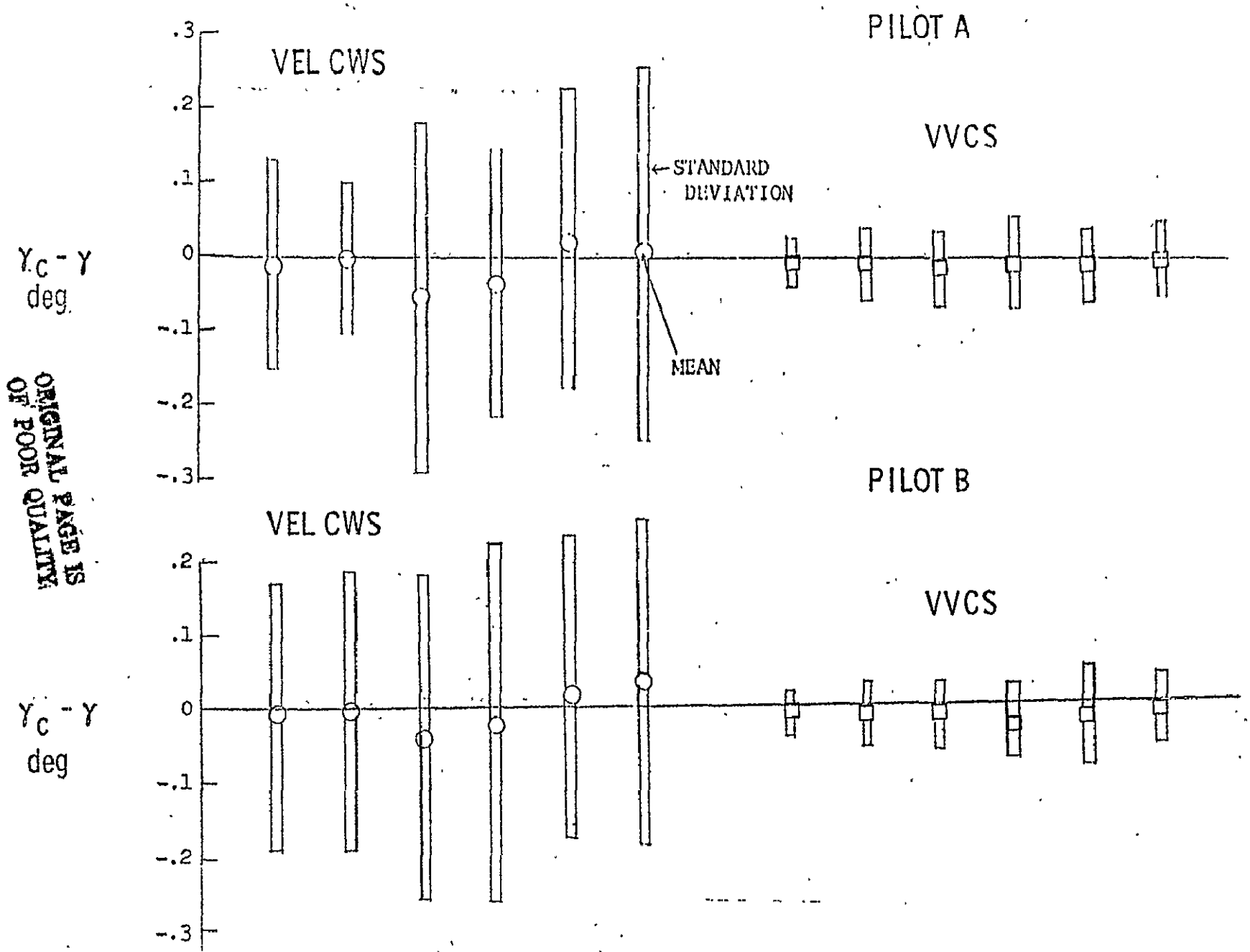


COMPARISON OF SYSTEM RESPONSE TO STEP CONTROL INPUT



RESULTS OF 6 ILS GLIDESLOPE TRACKING TASKS

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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

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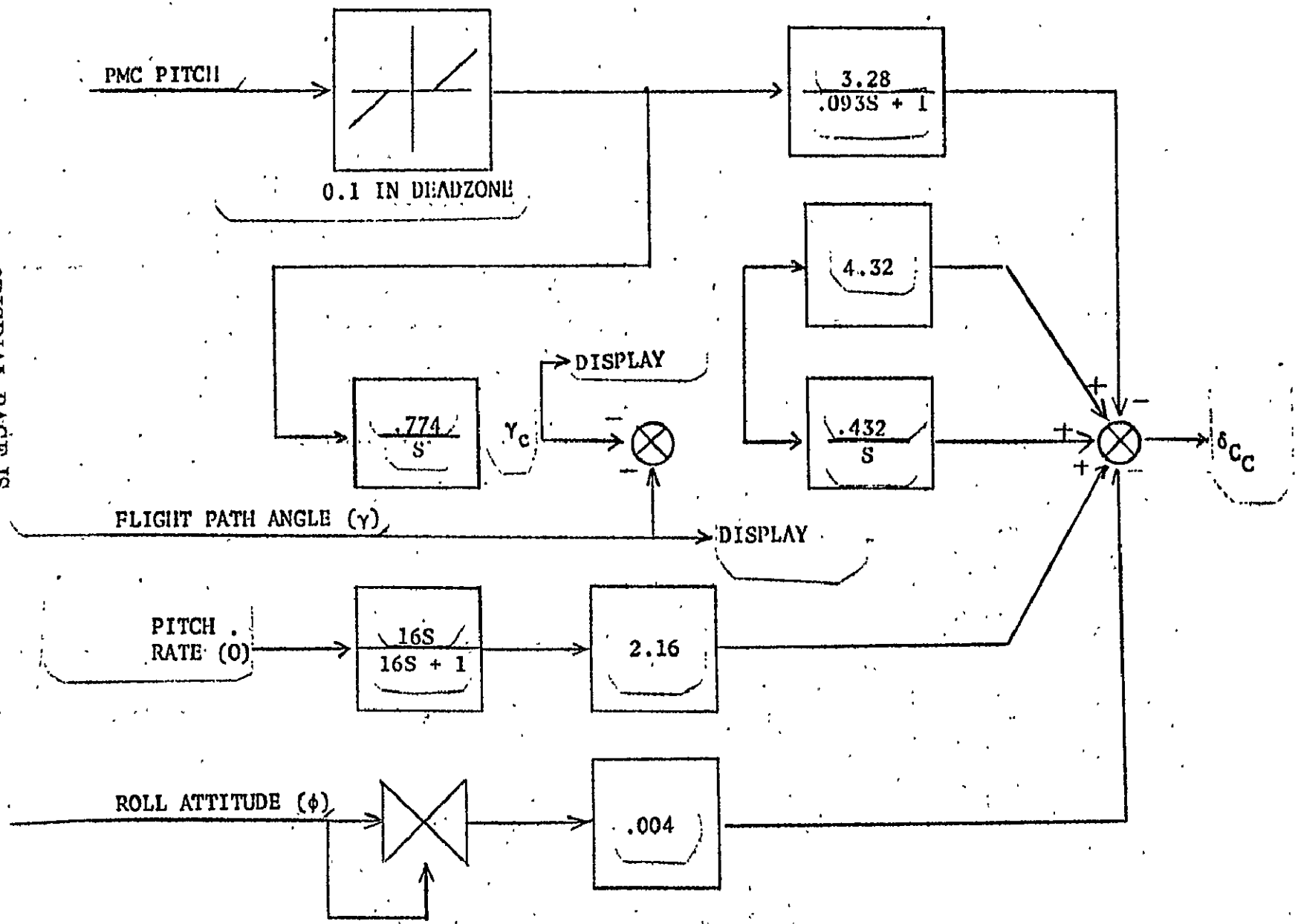
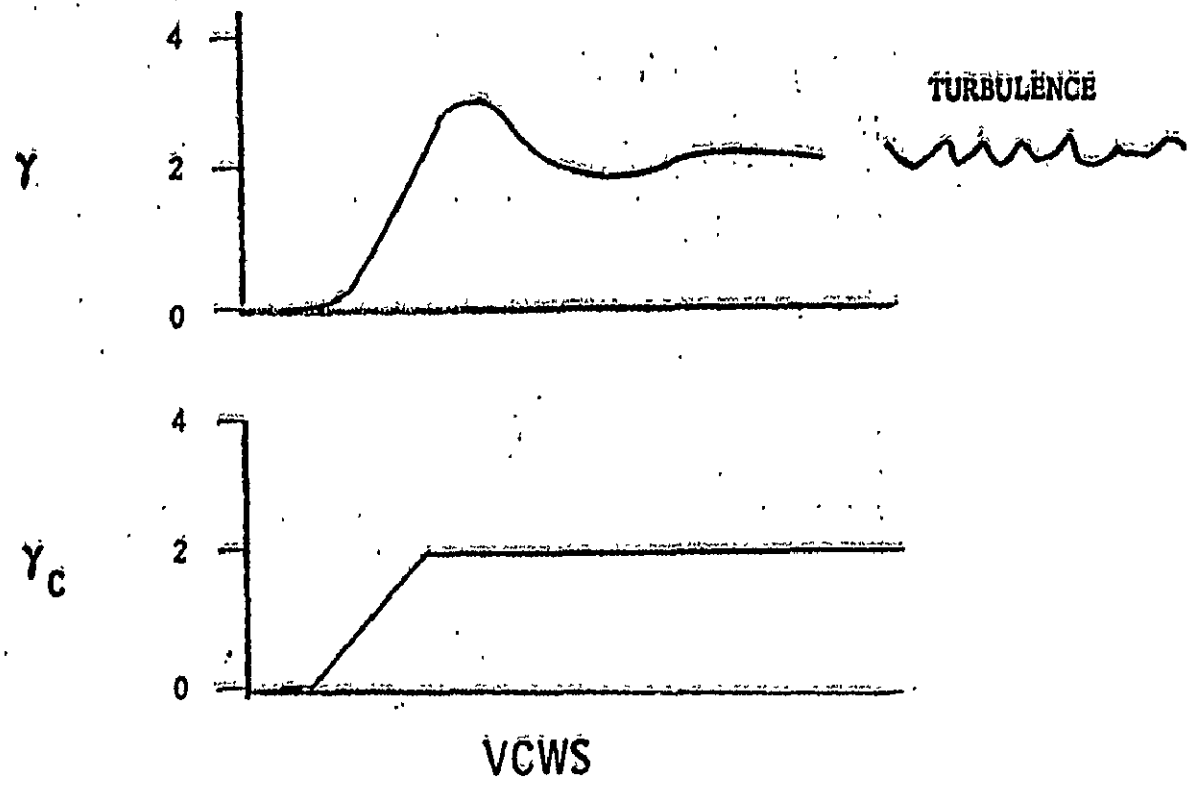


VELOCITY CWS CONTROL LAW

SYSTEM RESPONSE TO A STEP CONTROL INPUT



NASA
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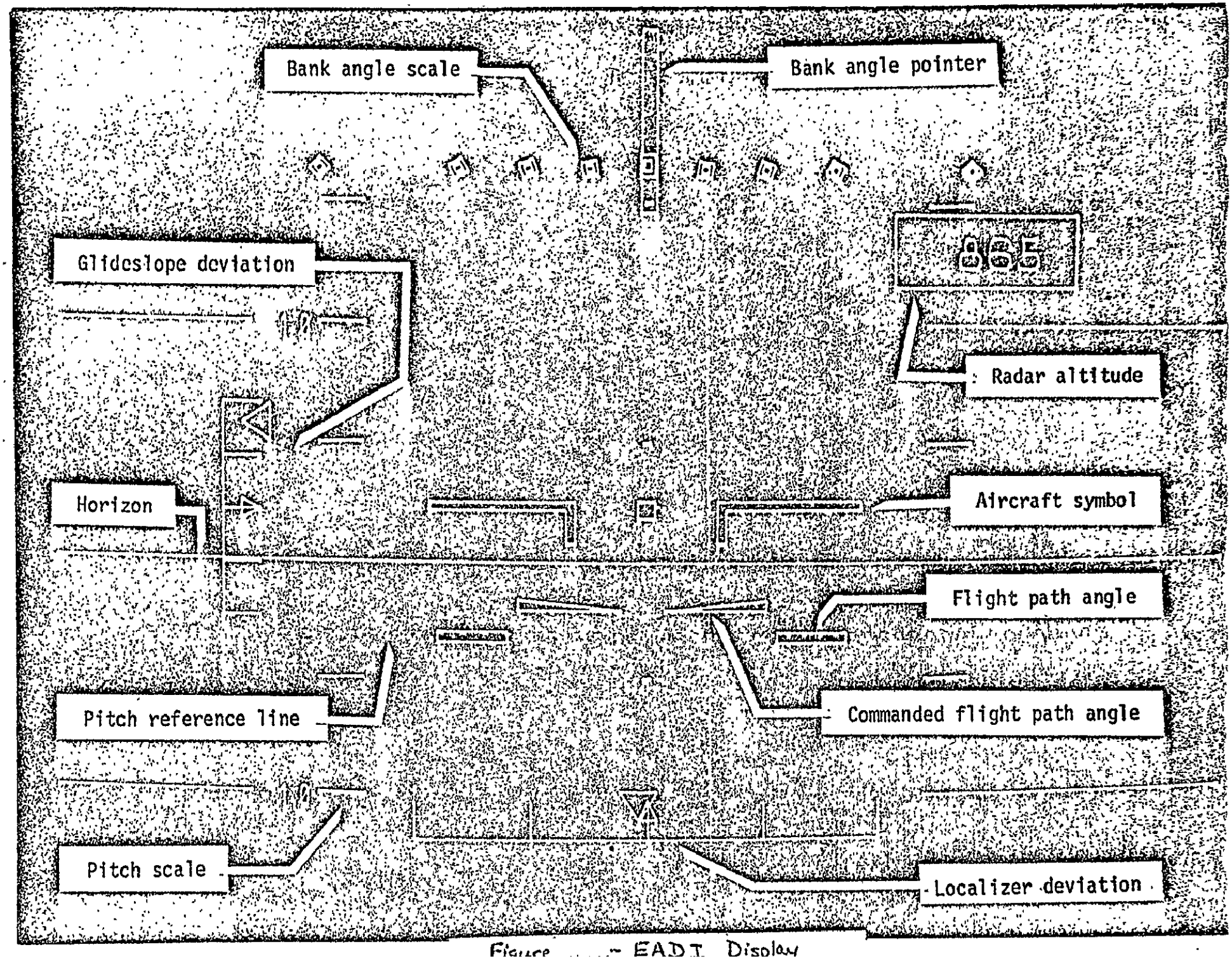

Figure ... - EADI Display

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AUTOFLARE LAW IMPROVEMENT

RTAC PRESENTATION
9/14/77

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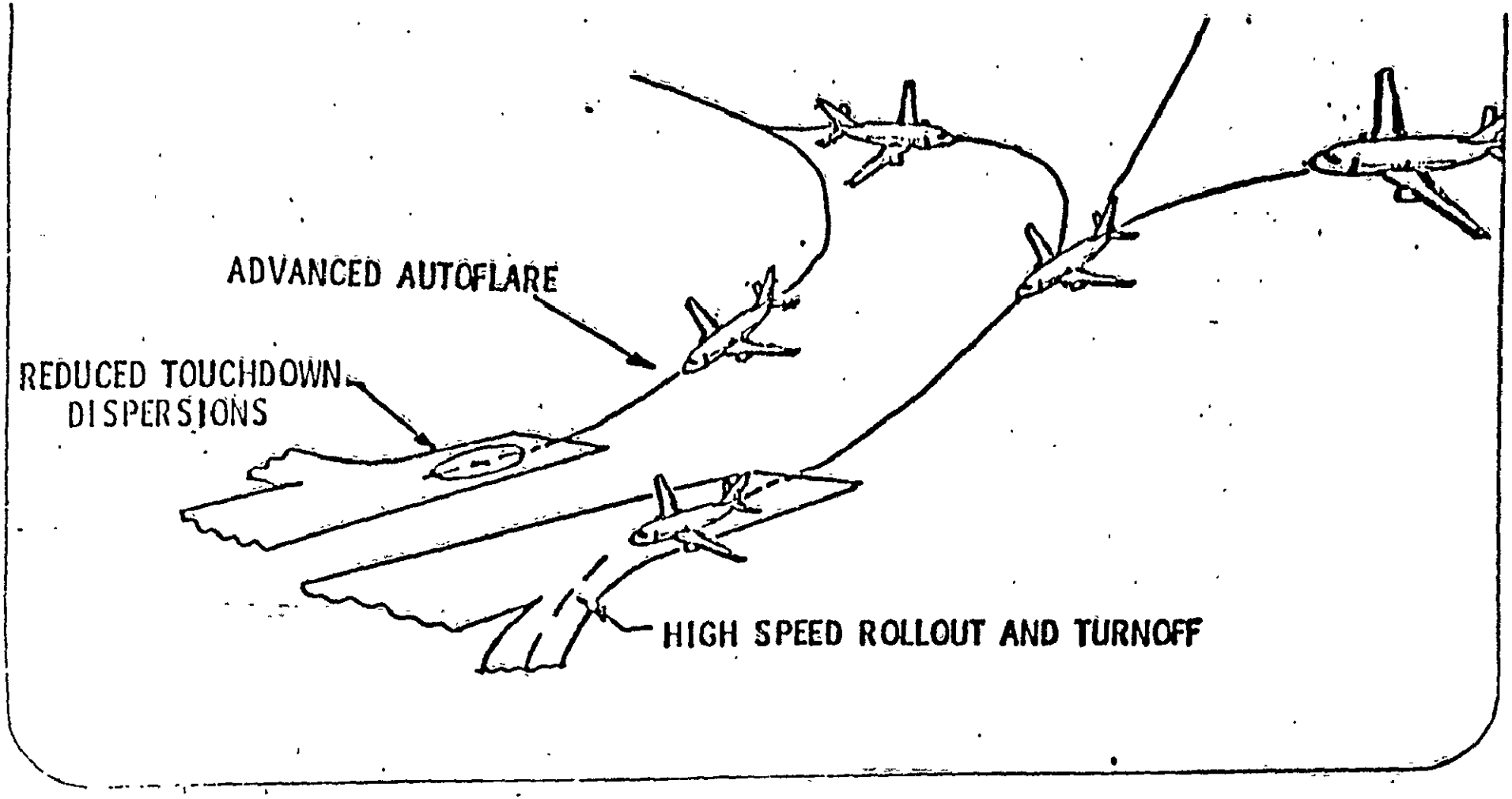
AUTOFLARE LAW IMPROVEMENT

OBJECTIVE - REDUCE TOUCHDOWN DISPERSIONS TO PROVIDE INCREASED TERMINAL AREA CAPACITY



AUTOFLARE LAW IMPROVEMENT

- EXISTING AUTOFLARE
  - DESCRIPTION
  - PERFORMANCE
- AUTOFLARE MODIFICATIONS
  - CONCEPTS CONSIDERED
  - PRELIMINARY SIMULATION RESULTS
- ADVANCED DESIGN
  - DESIGN GOALS
  - SIMULATION PERFORMANCE

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TCV B-737 AUTOFLARE

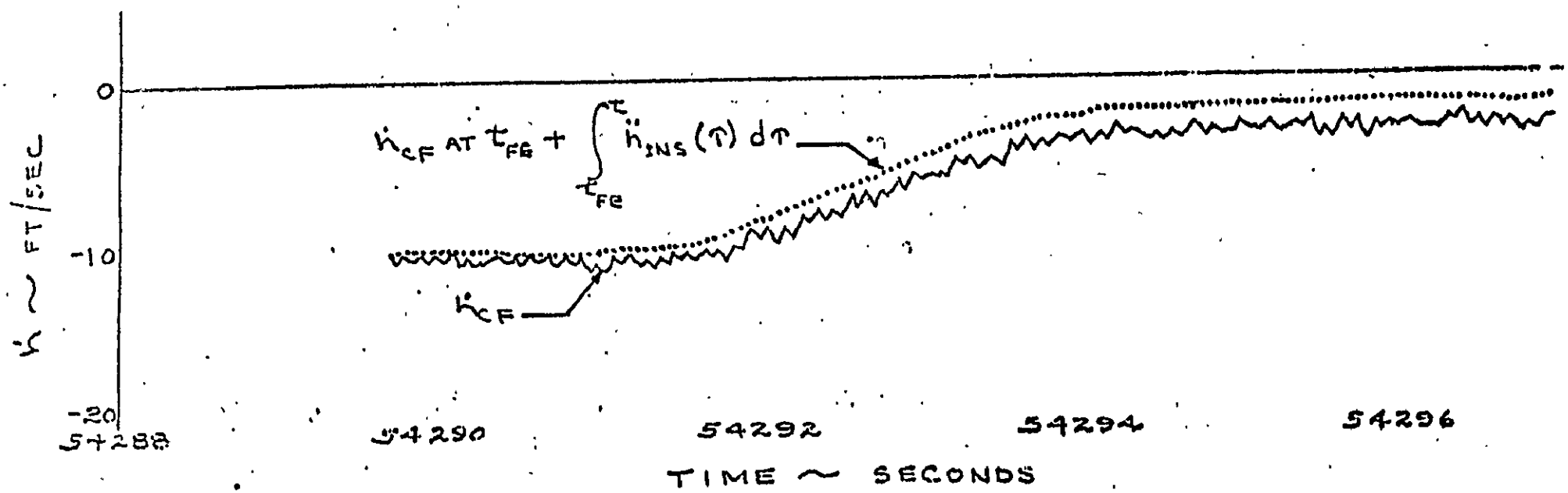
ALGORITHM $\delta_e = \text{RAMP} + K(s)\,[\underbrace{\dot{H} + \tau\,(H + H_B)}_{F(H)}] + \text{DAMPING TERMS}$

FLARE INITIATION	$F(H) < 0$
EXPONENTIAL PATH	$H = (H + H_B)\,e^{-tT} - H_B$
THROTTLE COMMAND	RETARDED TO IDLE AT FIXED RATE

FACTORS CONTRIBUTING TO TOUCHDOWN DISPERSION INCLUDE:

- WIND CONDITIONS
- ERRORS IN FILTERED $\dot{H}$
- VARIATIONS IN THROTTLE SETTING

⋮



COMPARISON OF $\dot{h}_{CF}$ AND $\dot{h}$ DERIVED FROM $\ddot{h}_{INS}$

FLIGHT 117 RUN B2

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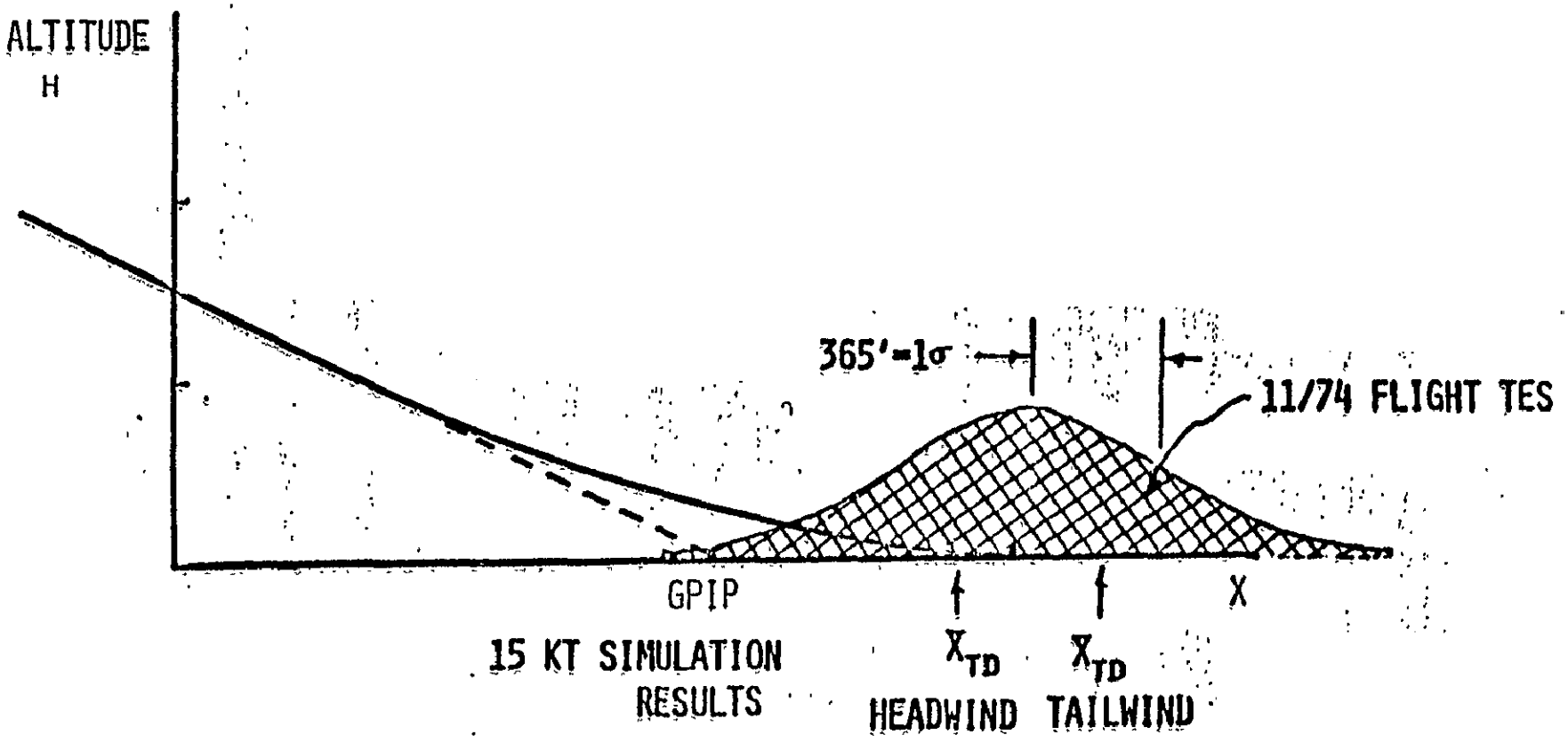
ALTITUDE
H
365'=1σ
11/74 FLIGHT TES
GPIP
X
15 KT SIMULATION
RESULTS
X_{TD}
HEADWIND
X_{TD}
TAILWIND

AUTOFLARE MODIFICATIONS

H_B MODIFICATION

$$H = (H_O + H_B)\, e^{-tT} - H_B$$

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

T MODIFICATION

INITIATE FLARE AT CONSTANT H

MODIFY T TO FIX X_{TD}

$$T = \frac{T_O V_G}{V_{GO}} \longrightarrow H = (H_O + H_B)\, e^{-\frac{T_O X}{V_{GO}}} - H_B$$

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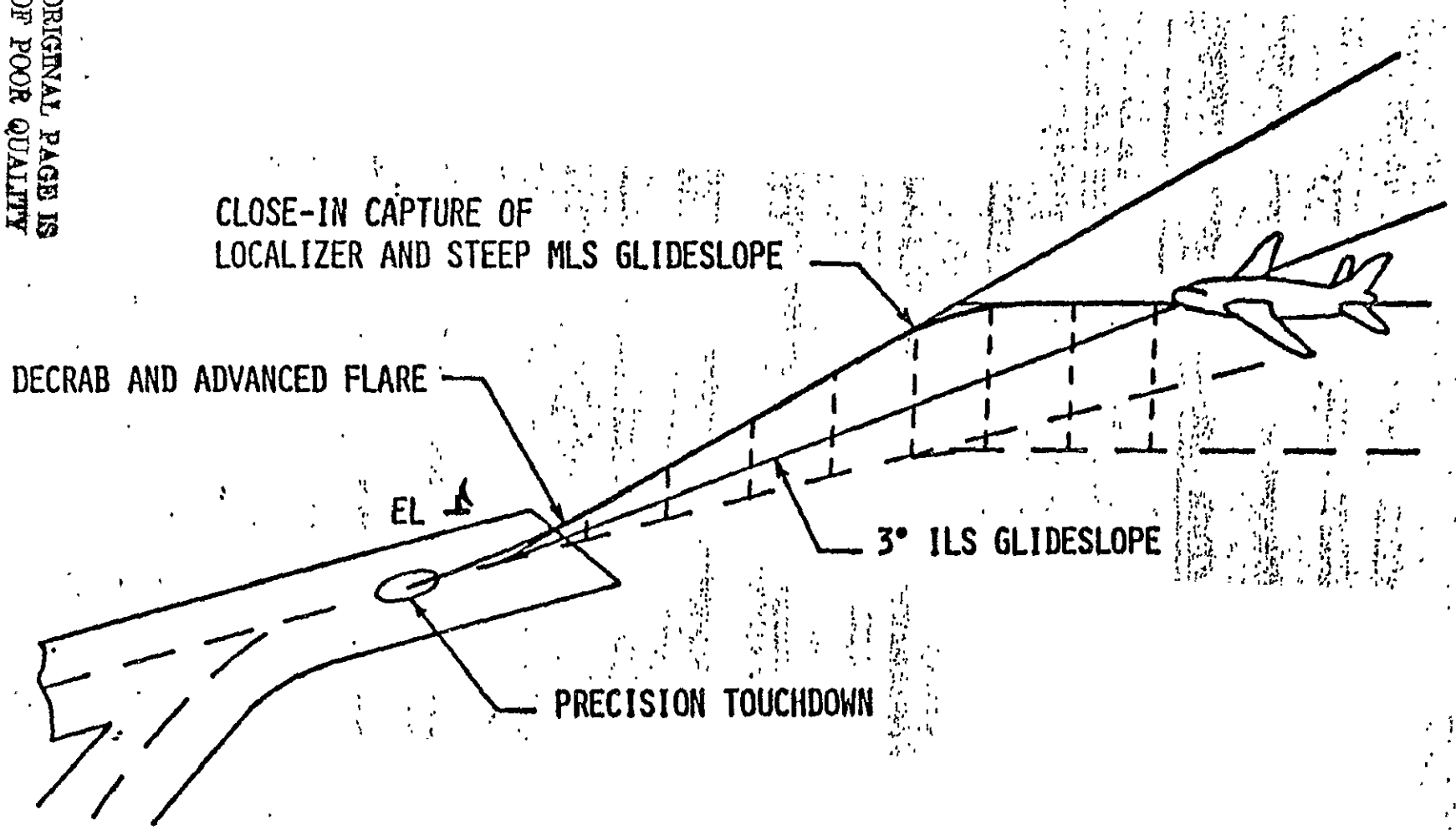
MODIFIED AUTOFLARE PERFORMANCE

(PRELIMINARY SIMULATION RESULTS)

(MEAN TOUCHDOWN POINT FROM GPIP IN FT)

	15 KT HEADWIND	15 KT TAILWIND
TCV B-737	634	1024
H_B MODIFICATION	649	574
T MODIFICATION CONSTANT H_O	564	569

ADVANCED DIGITAL AUTOLAND CONTROL LAWS



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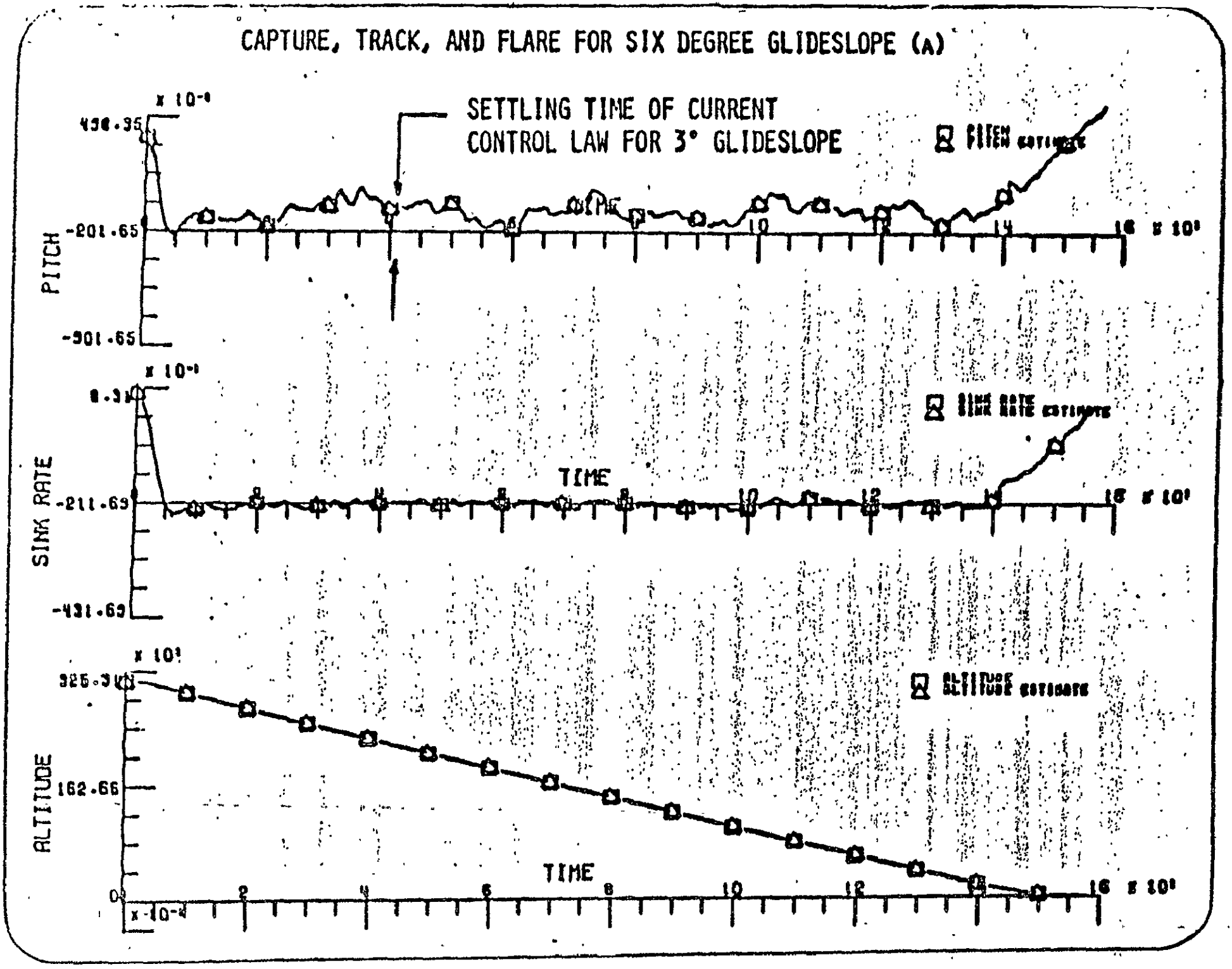
ADVANCED DIGITAL CONTROL SYSTEM

- 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)



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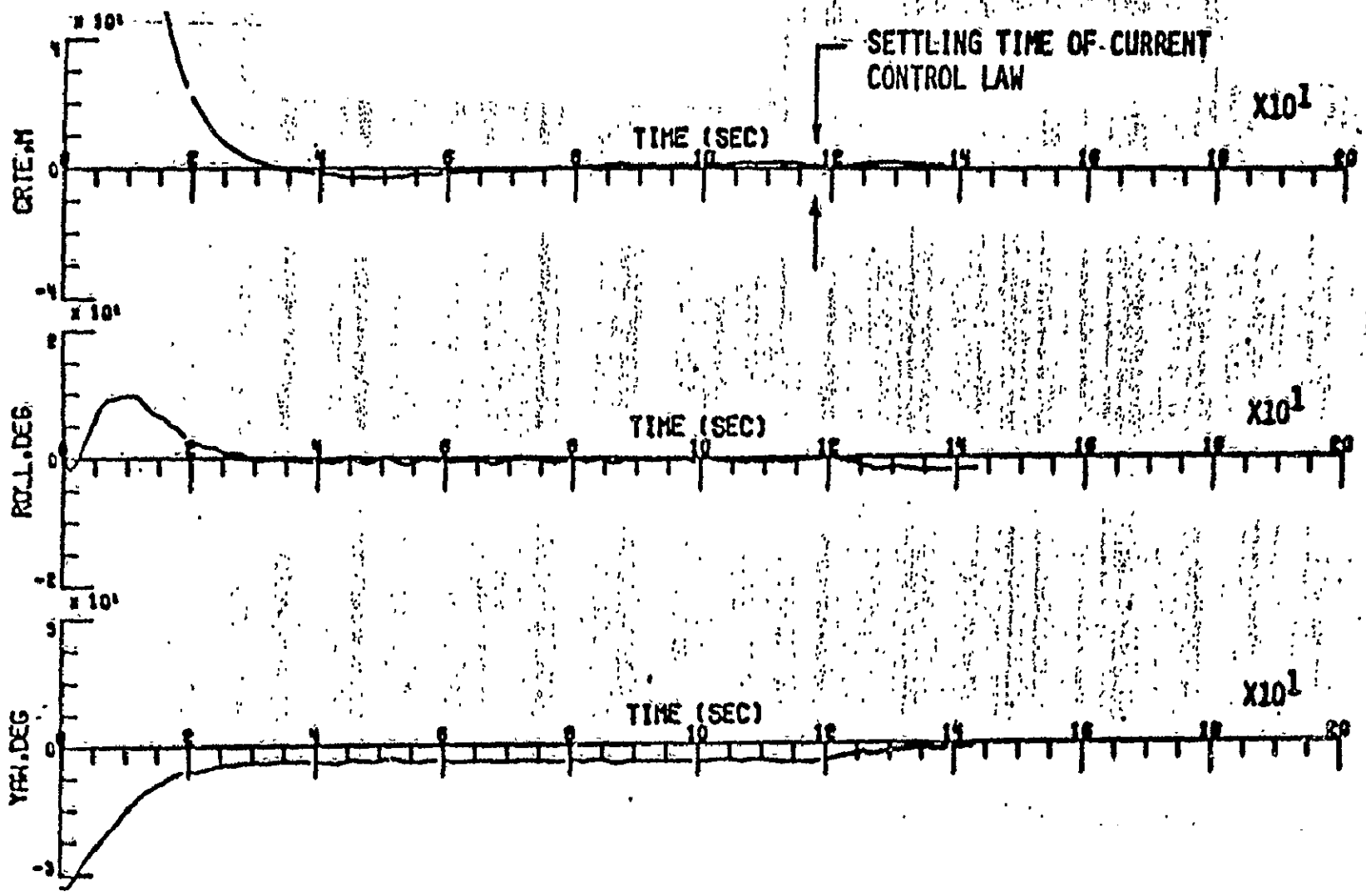
CAPTURE, TRACK, AND DECRAB OF LOCALIZER PATH



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

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HIGH SPEED TURNOFF ANALYSIS

RESEARCH OBJECTIVES

- DETERMINE THE EFFECTS OF TURNOFF SPEED AND TOUCH DOWN DISPERSION ON SINGLE RUNWAY LANDING CAPACITY

- DESIGN A HIGH SPEED TURNOFF FOR THE WALLOPS FLIGHT CENTER RESEARCH RUNWAY

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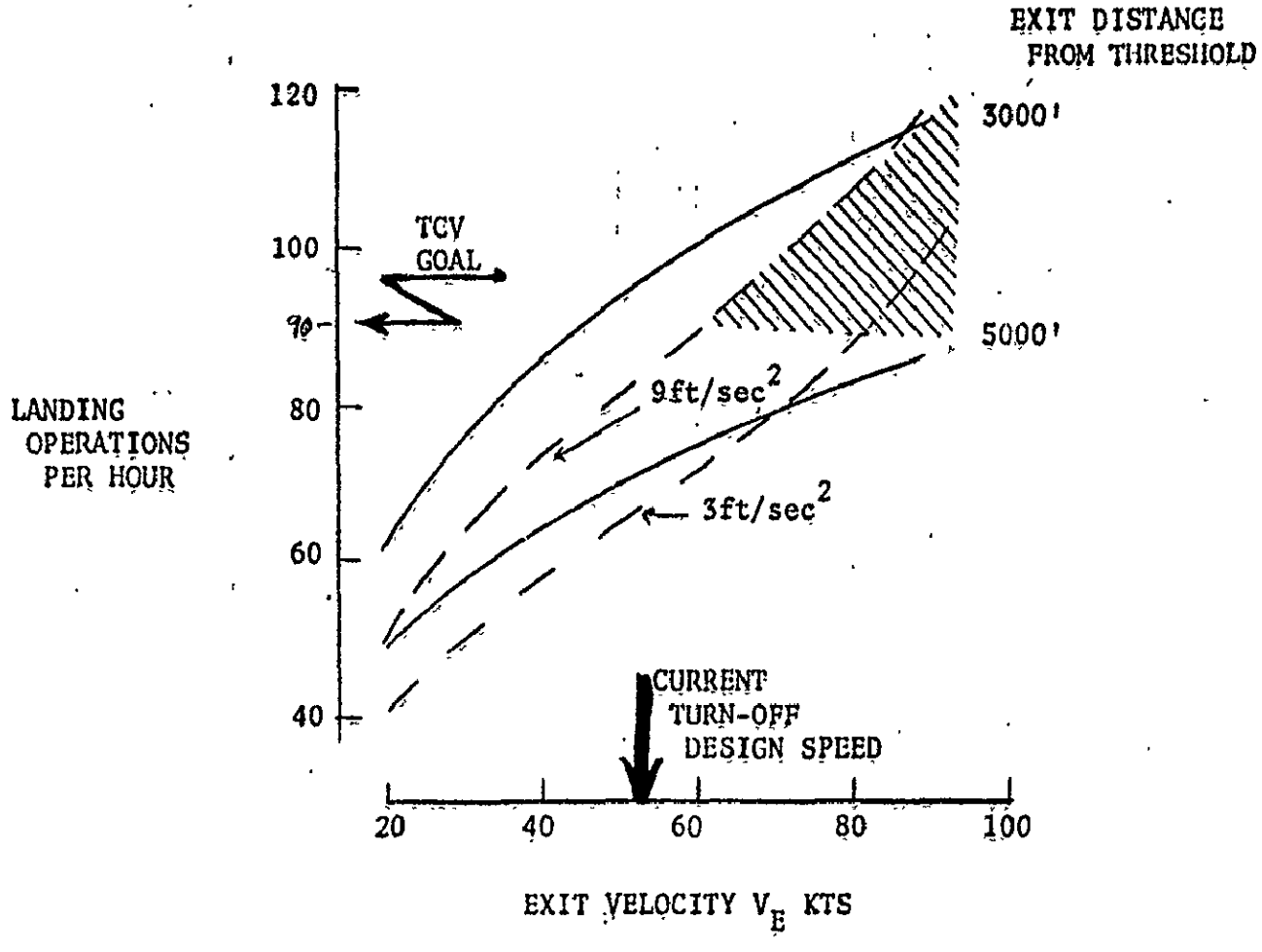
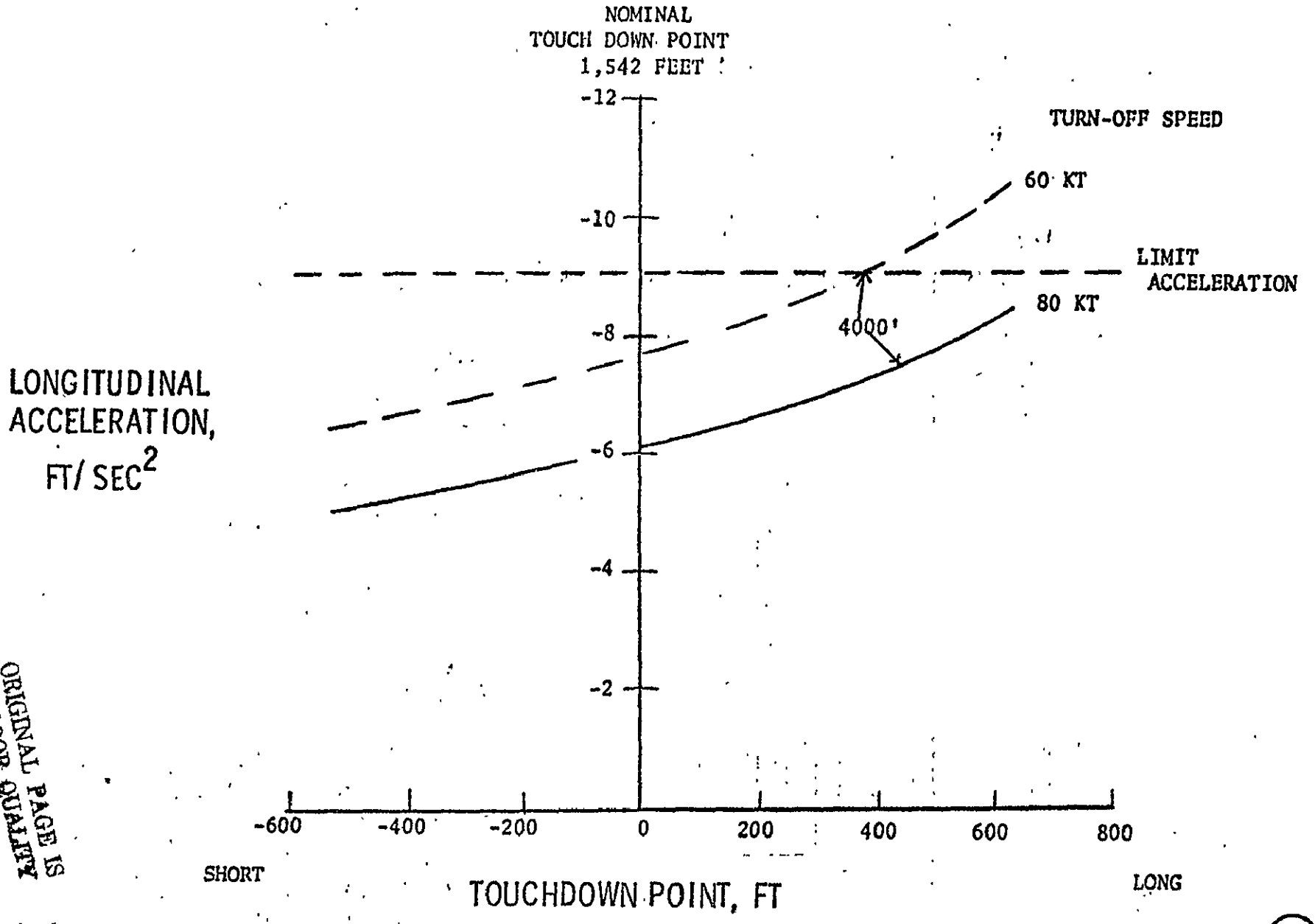
AIRCRAFT LANDING RATE VERSUS EXIT VELOCITY



REQUIRED ACCELERATION VS TOUCHDOWN POINT $V_A = 140$



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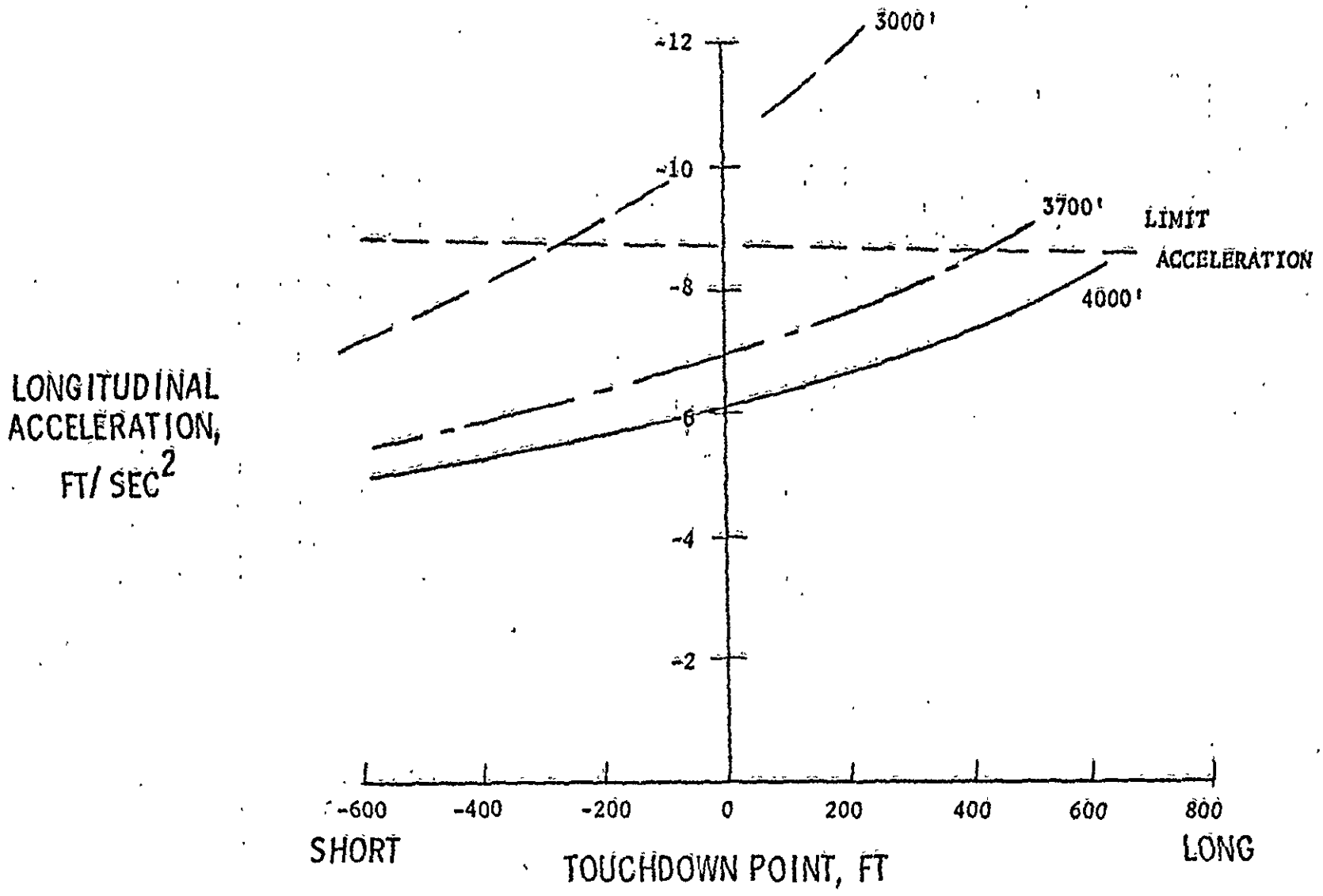
REQUIRED ACCELERATION VS TOUCHDOWN POINT FOR TWO TURNOFF DISTANCES $V_A = 140$

$V_E = 80$



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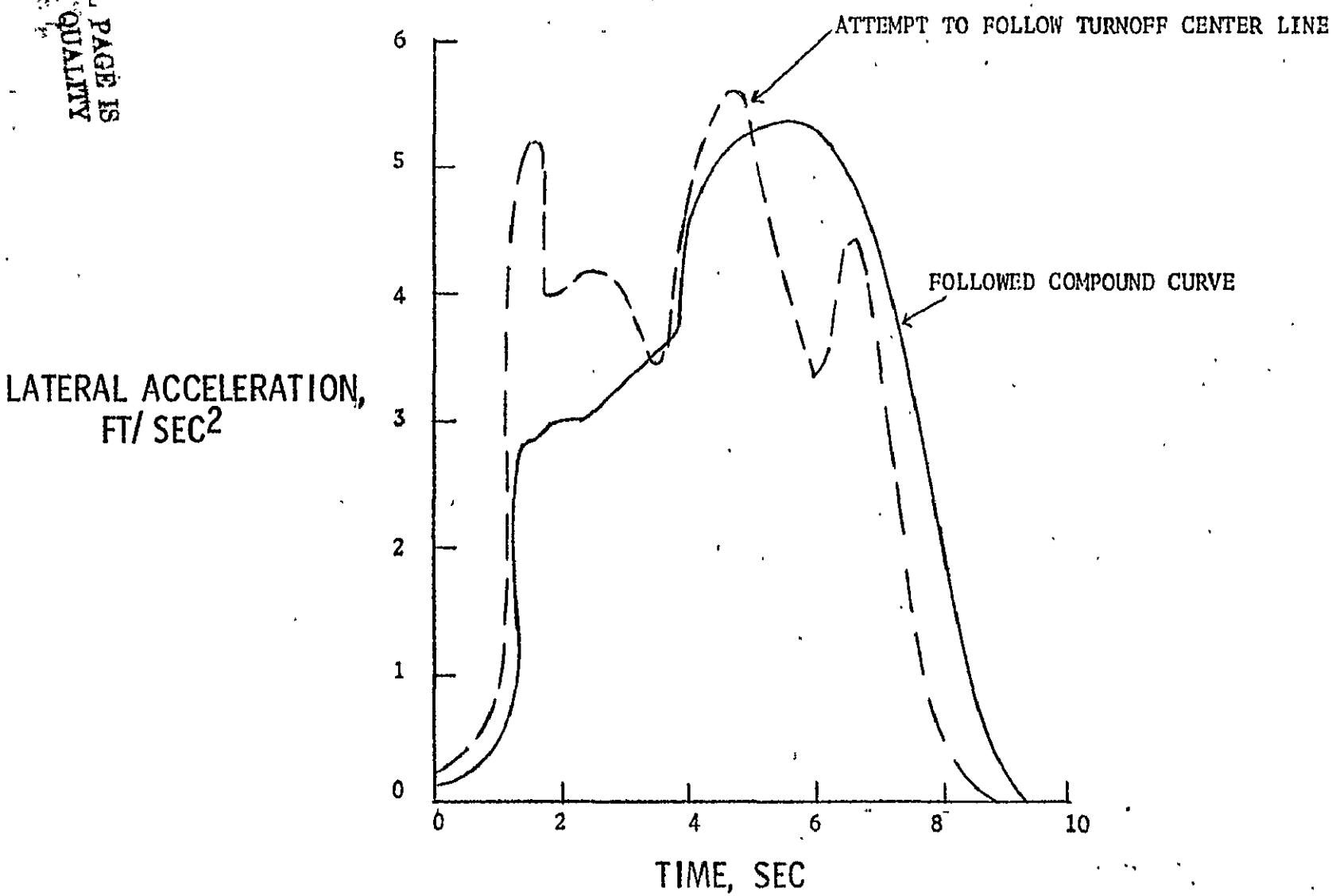
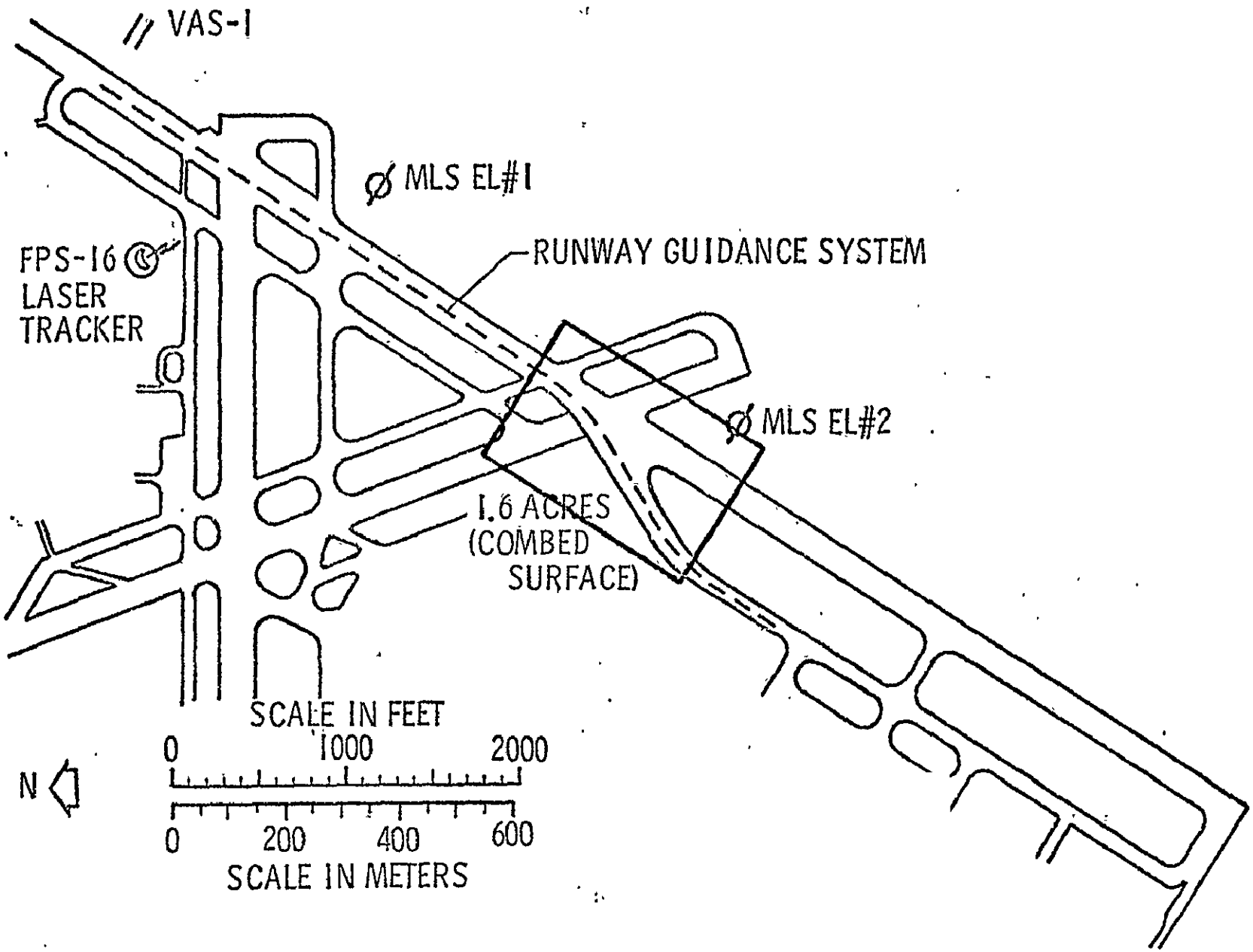
LATERAL ACCELERATION VS TIME

MANUAL TURNOFF $V_E = 75$ KT

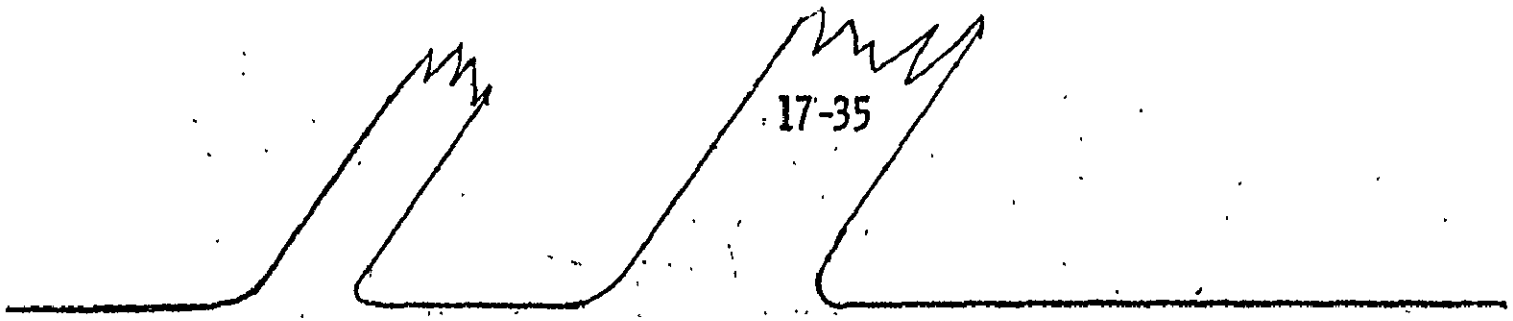
COLUMBIA, S.C



CONSTRUCTION OF HIGH SPEED RUNWAY TURNOFF
WALLOPS FLIGHT CENTER

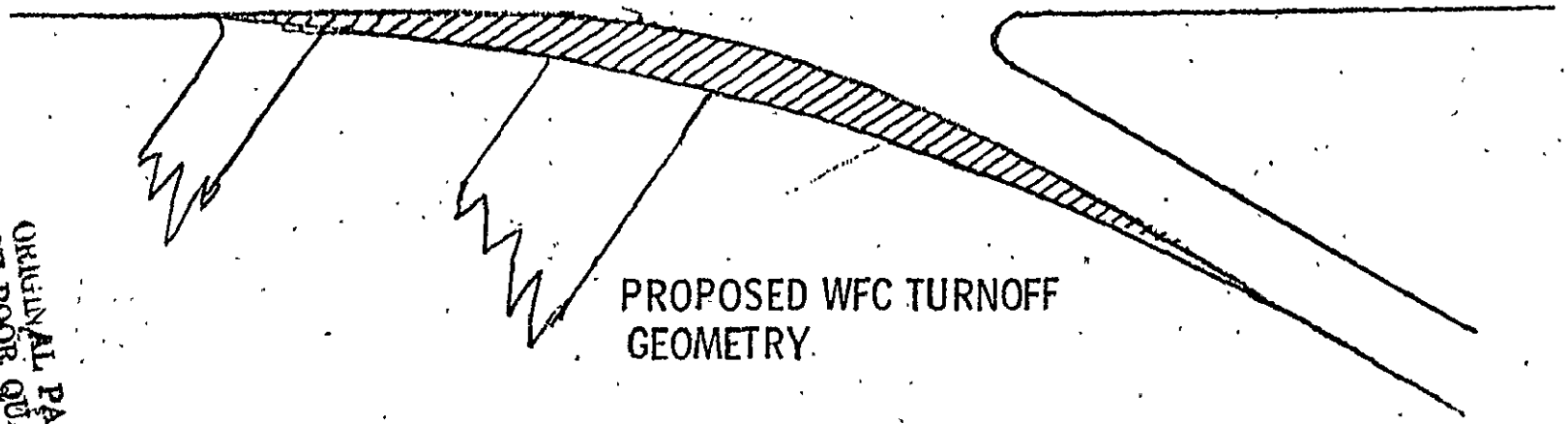


WALLOPS FLIGHT CENTER



ST'D TURNOFF GEOMETRY

22-04



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PILOTED GROUND SIMULATOR STUDIES

- SIMULATOR MODEL VERIFICATION
- TURN-OFF DESIGN STUDIES
- GUIDANCE, CONTROL, AND DISPLAY STUDIES

APPENDIX G

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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

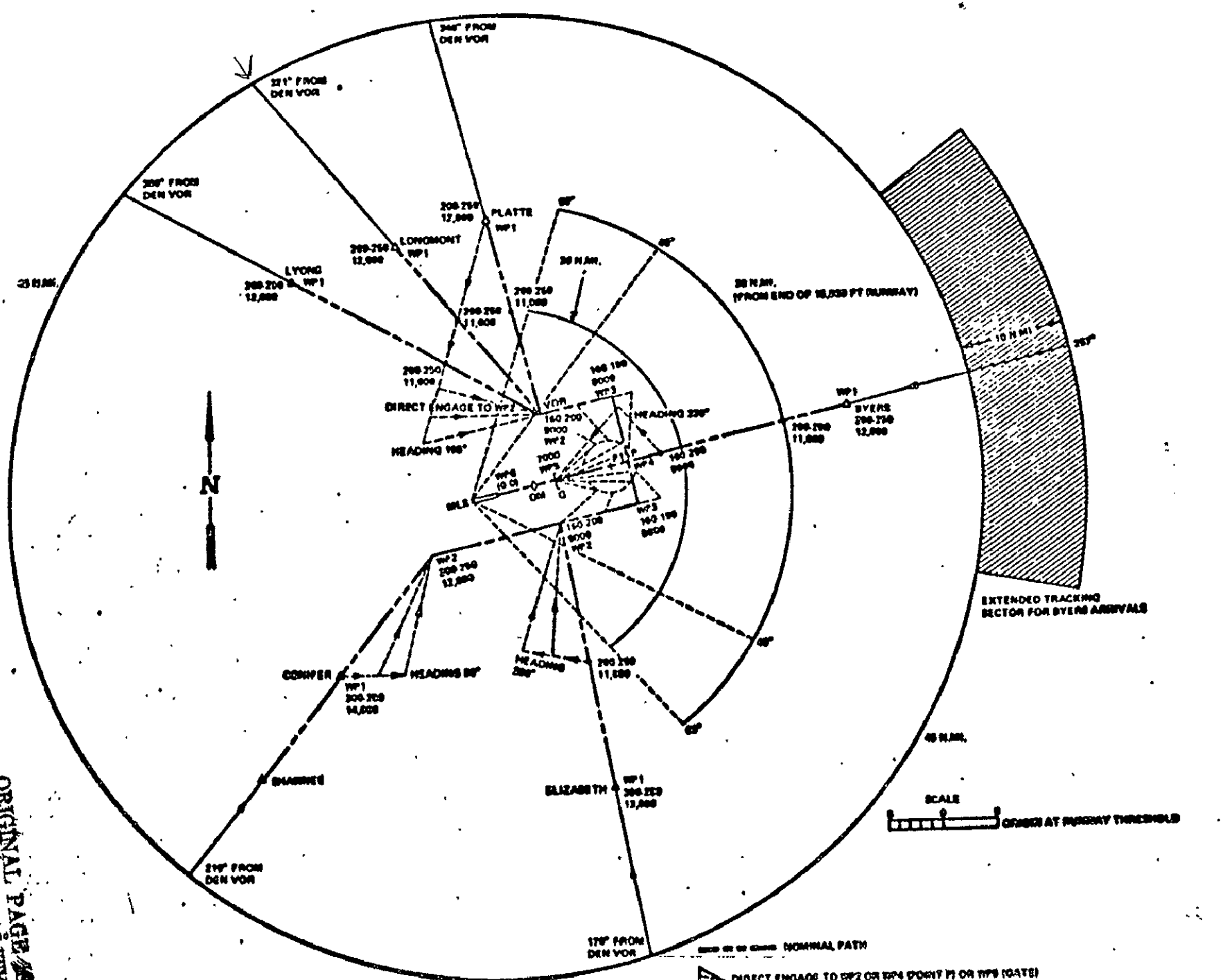
- VOR/DME AND ILS
- VOR/DME AND ±40° MLS
- VOR/DME AND ±60° MLS

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)



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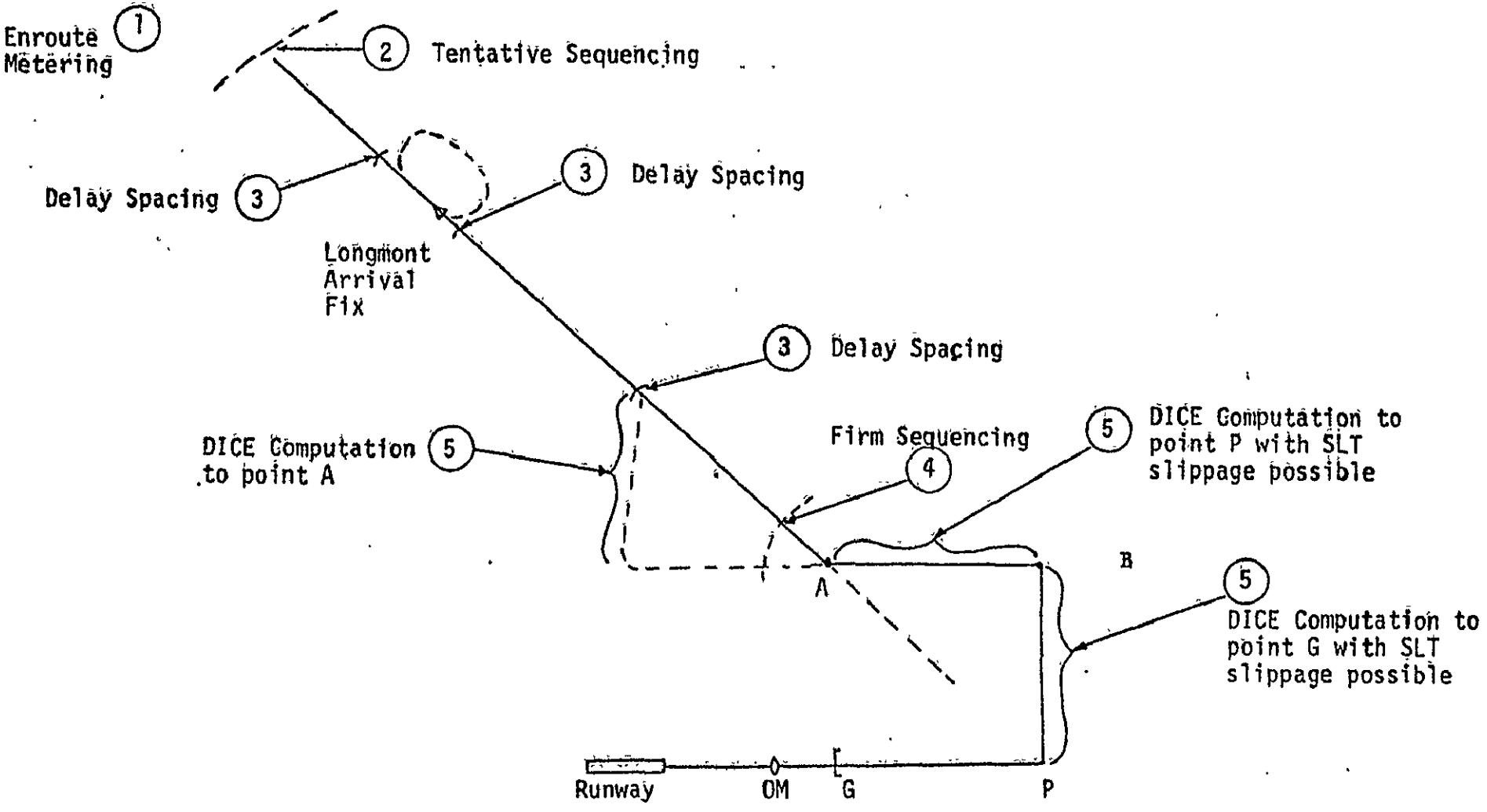
Enroute Metering
1
2
Tentative Sequencing
Delay Spacing
3
3
Delay Spacing
Longmont Arrival Fix
3
Delay Spacing
DICE Computation to point A
5
Firm Sequencing
4
5
DICE Computation to point P with SLT slippage possible
A
B
5
DICE Computation to point G with SLT slippage possible
Runway
OM
G
P

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

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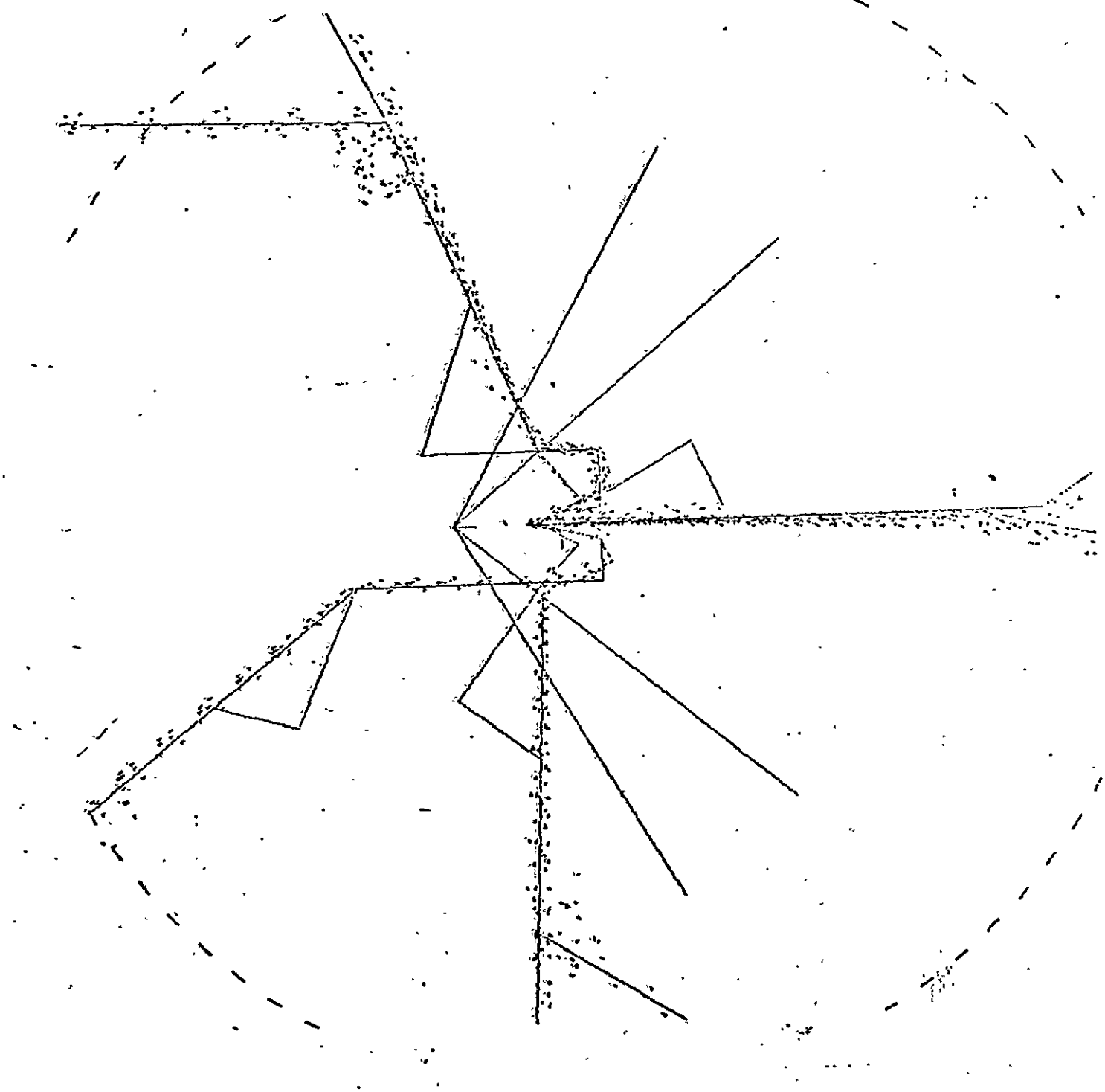
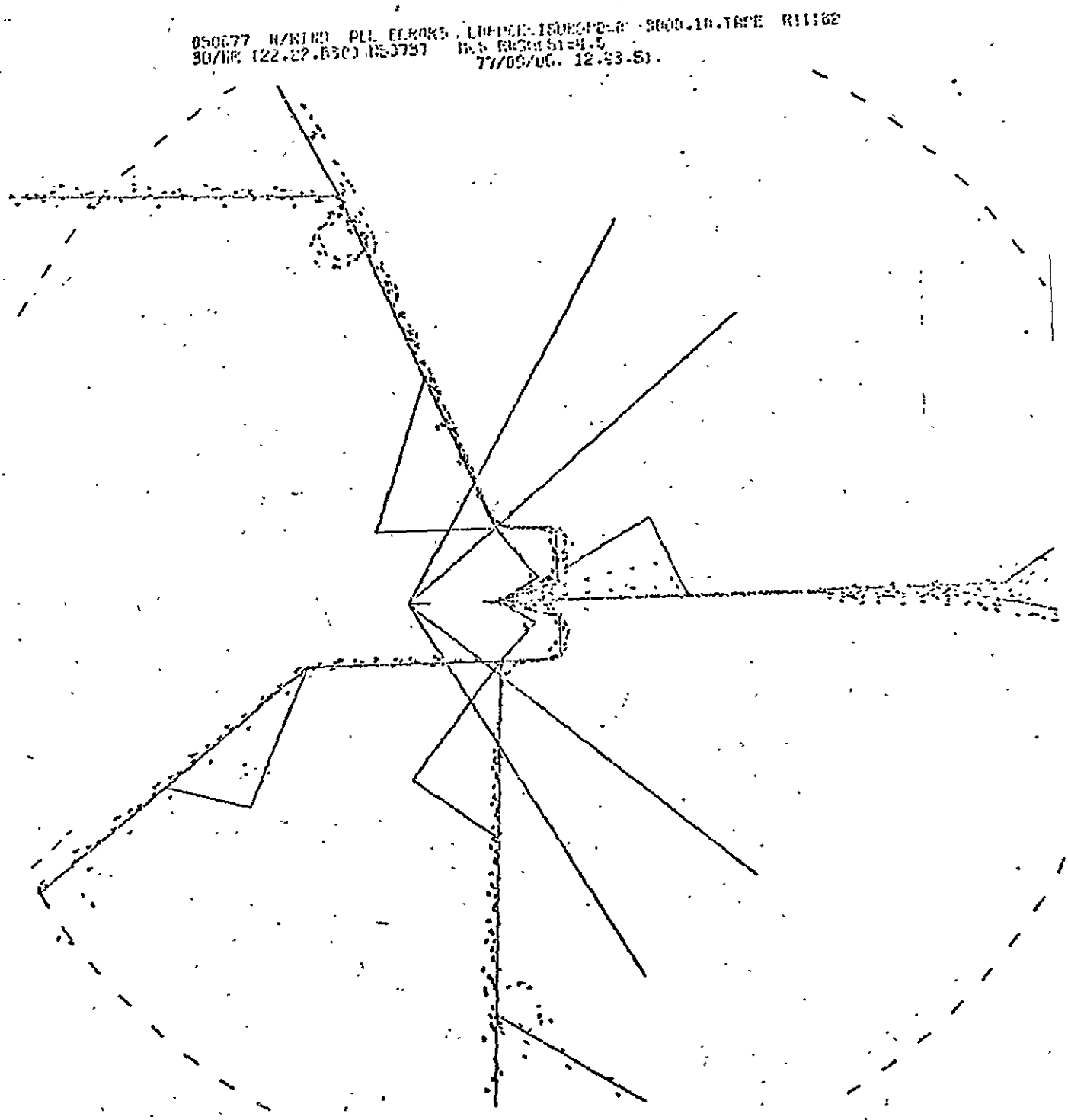

090277 N/WIND ALL ERRORS LDRACK=ISURSPD=0 3000.10.TAPE RIIIA2
30/HR (22,22,630) N50731
77/09/02. 16.56.46.



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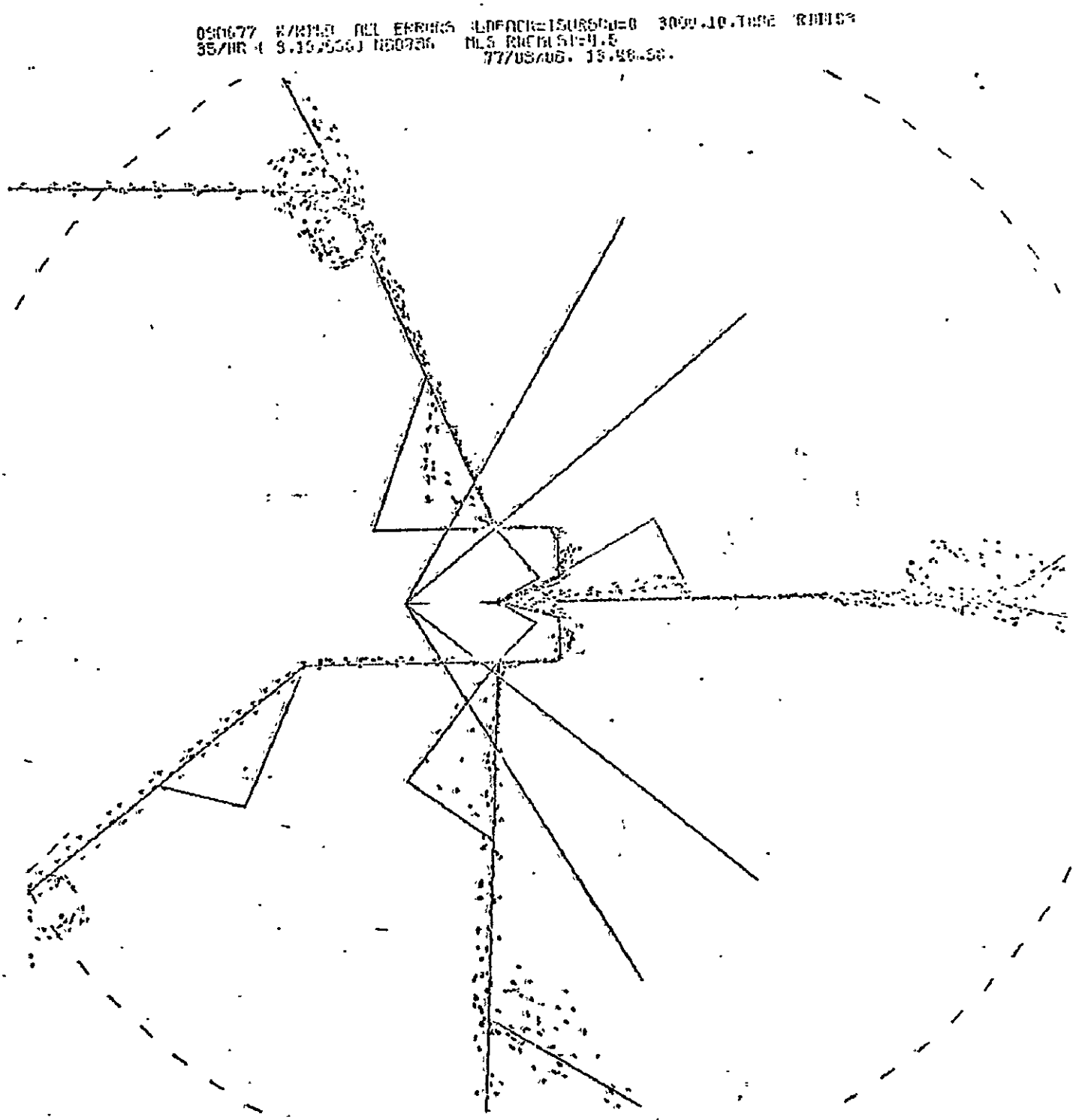
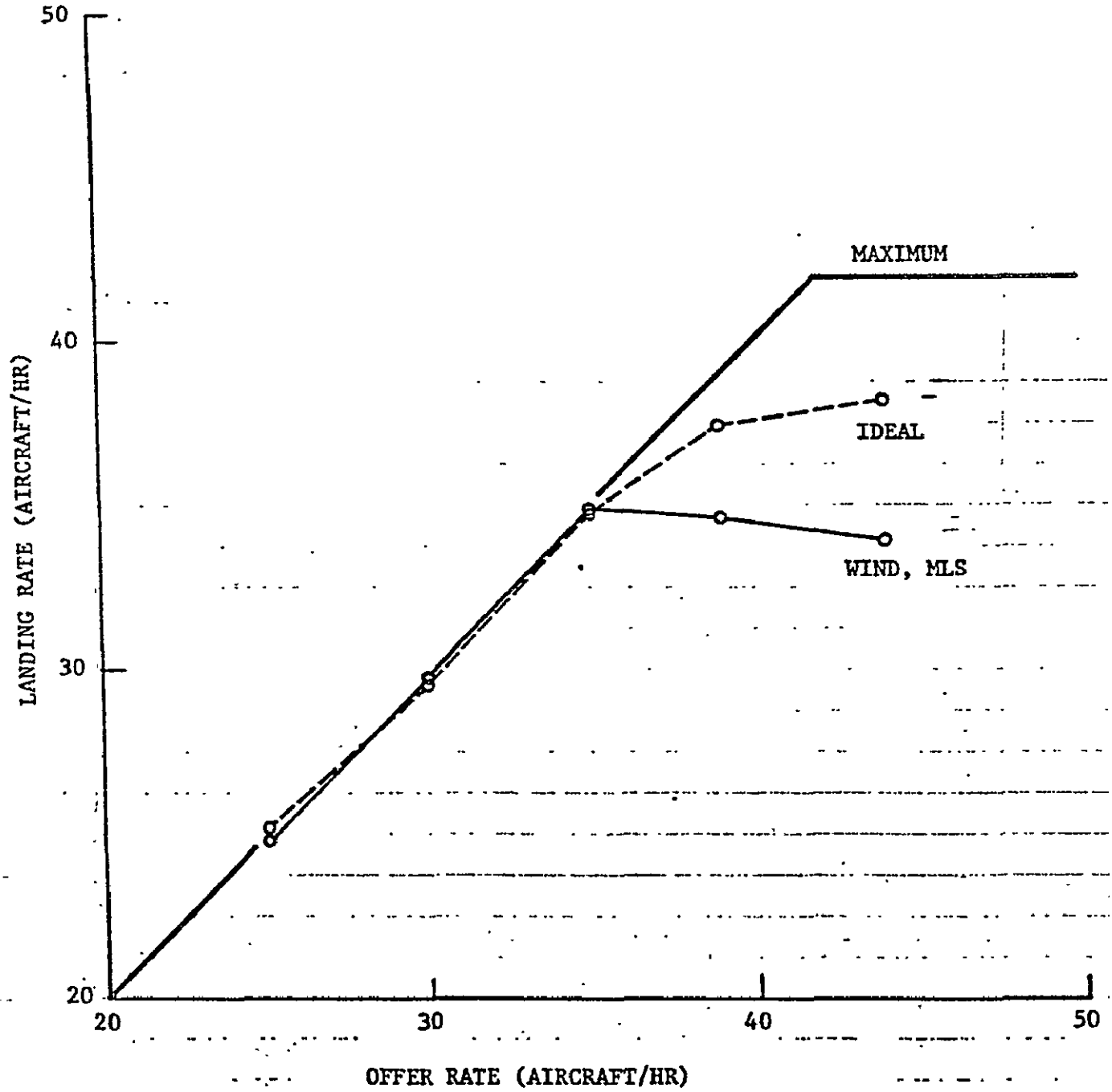

ALL ERRORS
MLS RNEMLST=4.5
77/08/08. 13.48.58.



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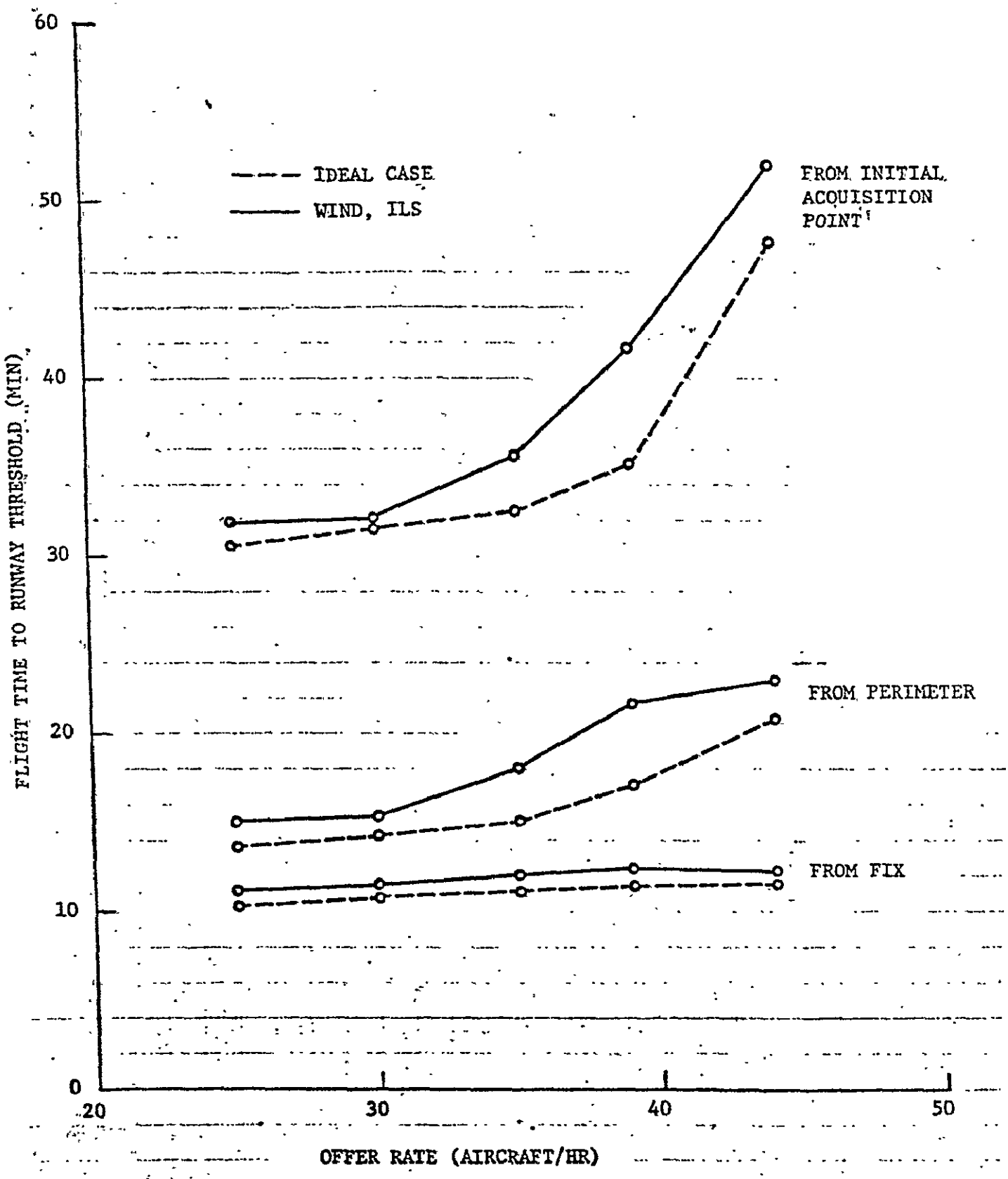
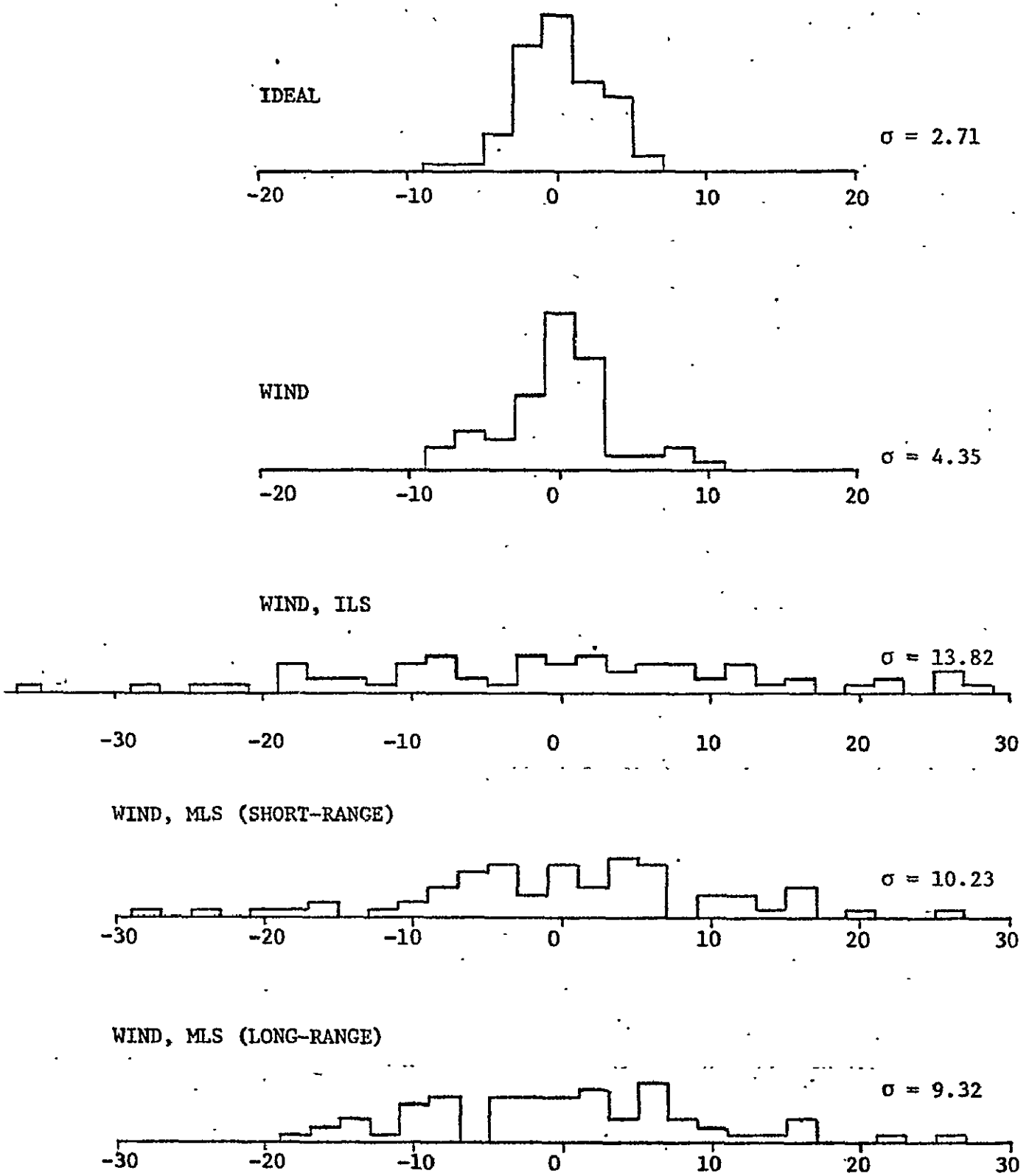

IDEAL CASE
WIND, ILS
FROM INITIAL ACQUISITION POINT
FROM PERIMETER
FROM FIX
FLIGHT TIME TO RUNWAY THRESHOLD (MIN)
OFFER RATE (AIRCRAFT/HR)
0
10
20
30
40
50
60
20
30
40
50

INTER-ARRIVAL TIME ERRORS (SEC.)



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VTOL
(VTOL APPROACH AND LANDING TECHNOLOGY)

OBJECTIVE

SCOPE

RESULTS

RESEARCH SYSTEMS

SCHEDULE

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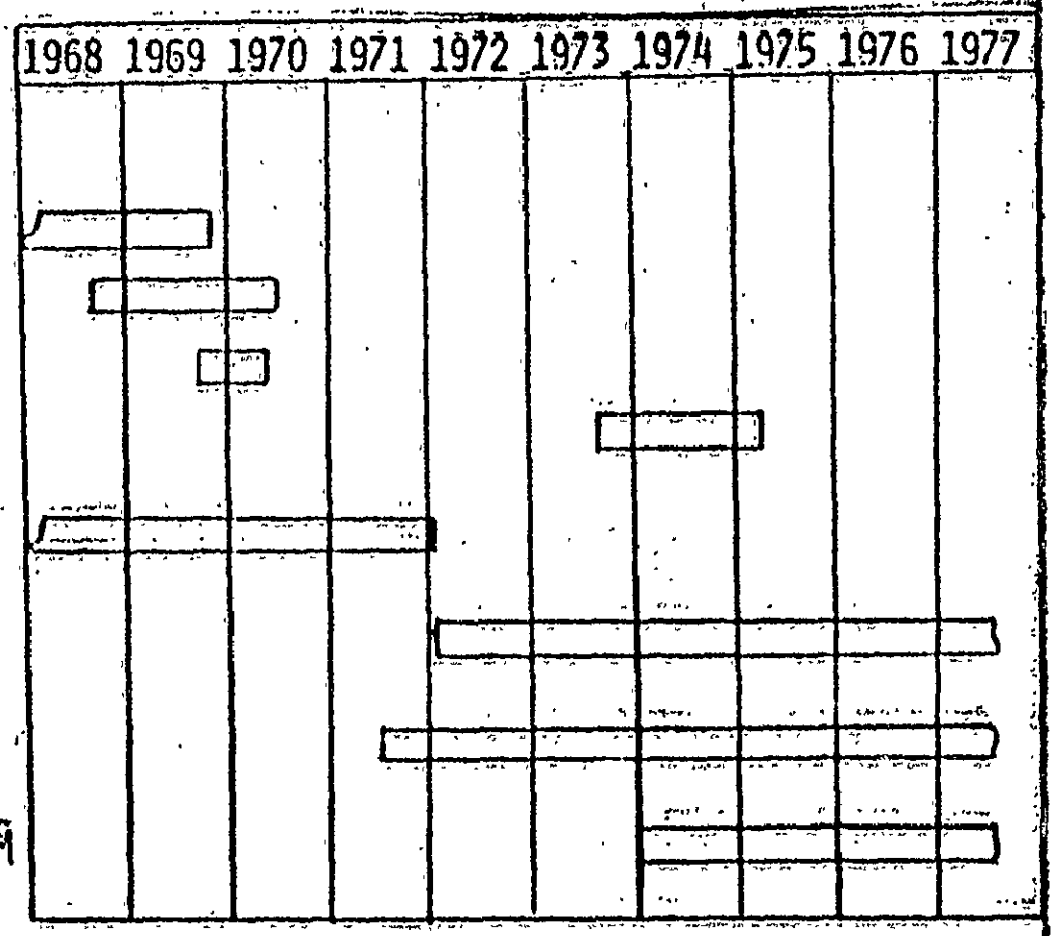
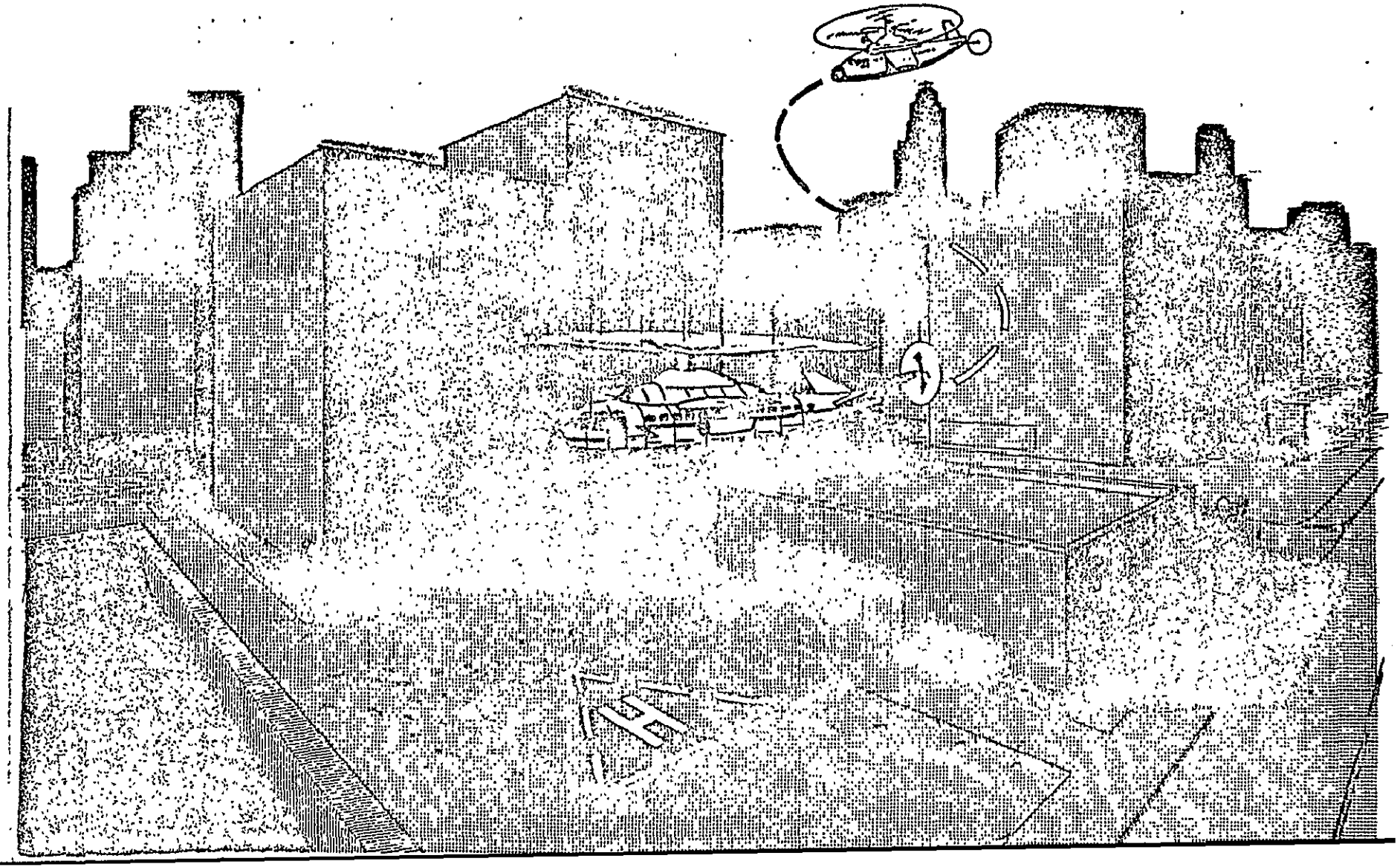
SUMMARY OF RECENT LRC IFR RELATED RESEARCH



- VTOL TERMINAL-AREA OPERATIONS STUDIES:
  - P. 1127 (VECTORED THRUST)
  - XC-142 (TILT WING)
  - DO-31 (MIXED PROPULSION)
  - X-22 TASK III (TILT DUCT)
- IFR FLIGHT CONTROL AND GUIDANCE (CH-46)
- VALT INTEGRATED SYSTEMS STUDIES (CH-47)
- "REAL WORLD" DSIPLAY STUDIES (SH-3A)
- TERMINAL CONFIGURED VEHICLE (TCV) PROGRAM

GARREN

TYPICAL ALL-WEATHER OPERATION OF FUTURE ROTORCRAFT



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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

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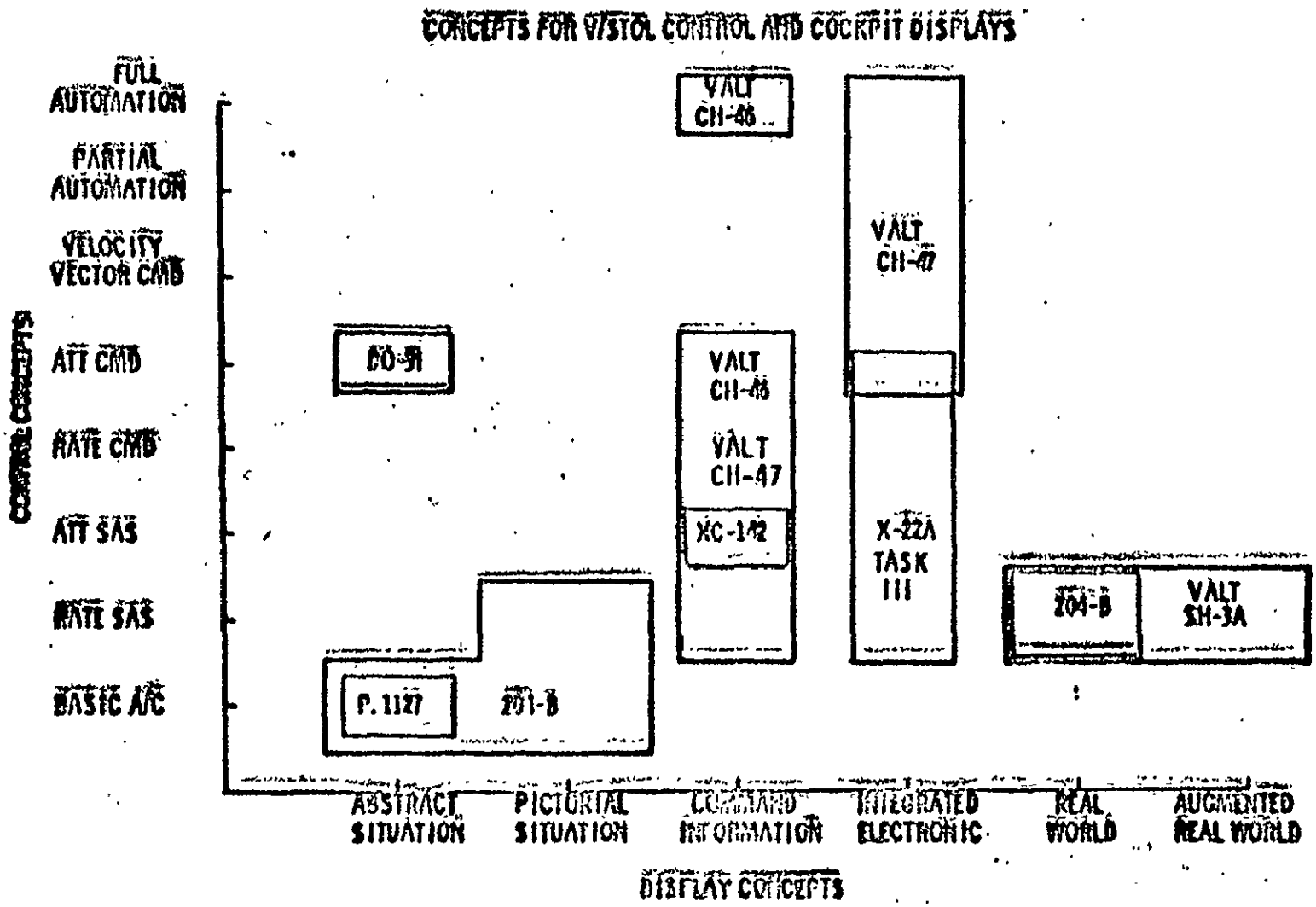
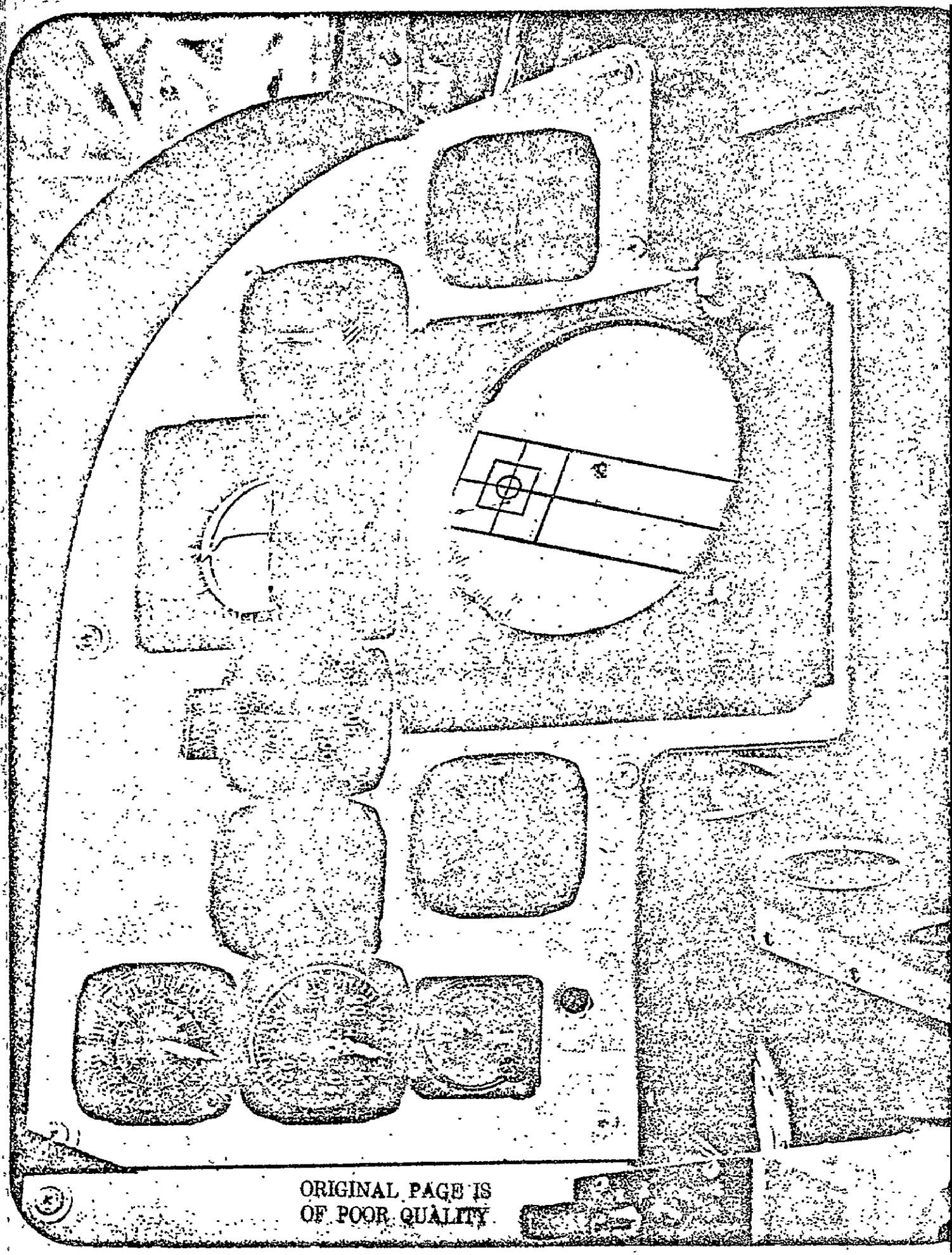

CONCEPTS FOR V/STOL CONTROL AND COCKPIT DISPLAYS
CONTROL CONCEPTS
FULL AUTOMATION
PARTIAL AUTOMATION
VELOCITY VECTOR CMD
ATT CMD
RATE CMD
ATT SAS
RATE SAS
BASIC A/C
DO-31
P. 1127
201-B
VALT CH-46
VALT CH-46
VALT CH-47
XC-142
VALT CH-47
X-22A TASK III
204-B
VALT SH-3A
ABSTRACT SITUATION
PICTORIAL SITUATION
COMMAND INFORMATION
INTEGRATED ELECTRONIC
REAL WORLD
AUGMENTED REAL WORLD
DISPLAY CONCEPTS



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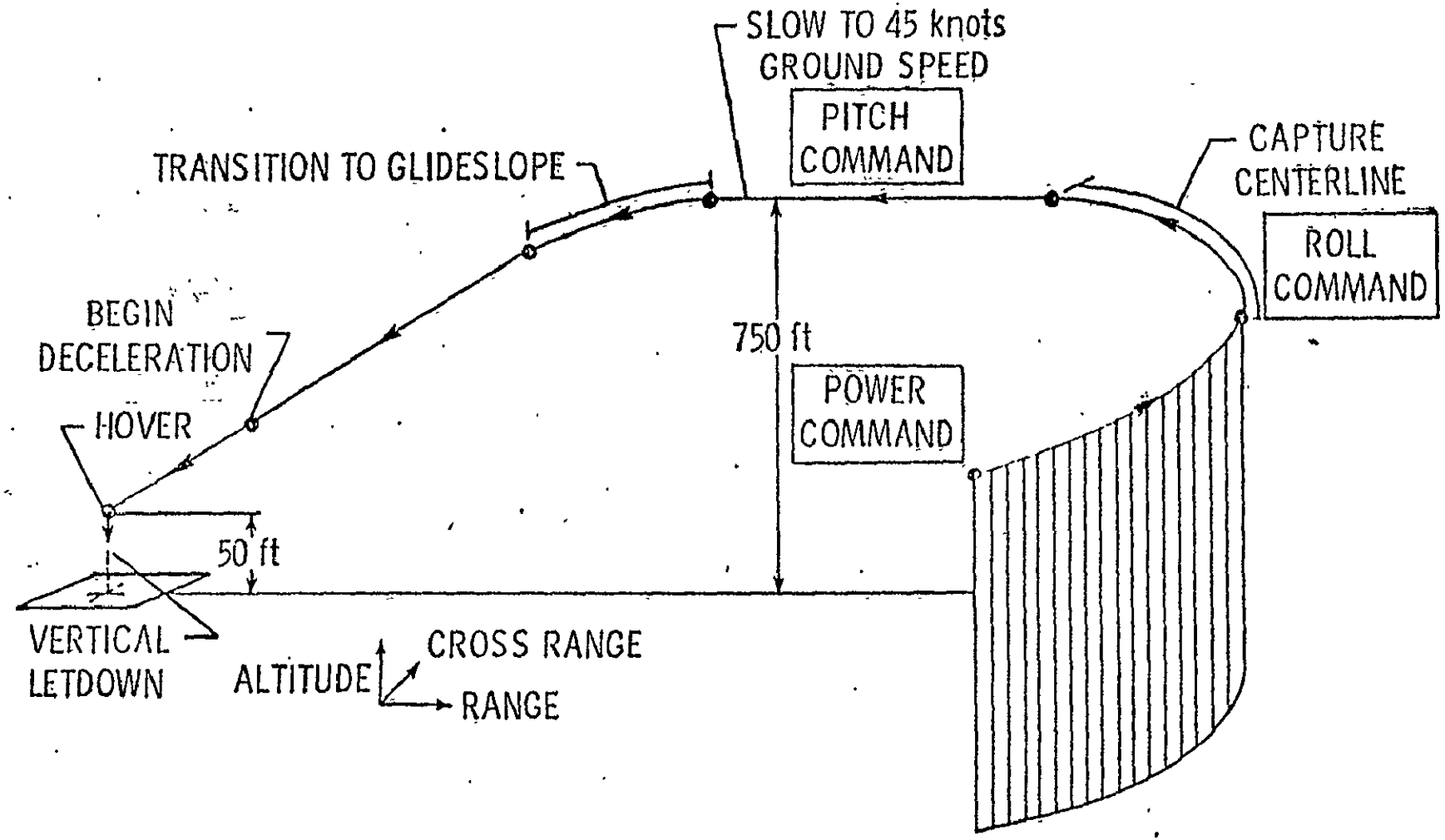
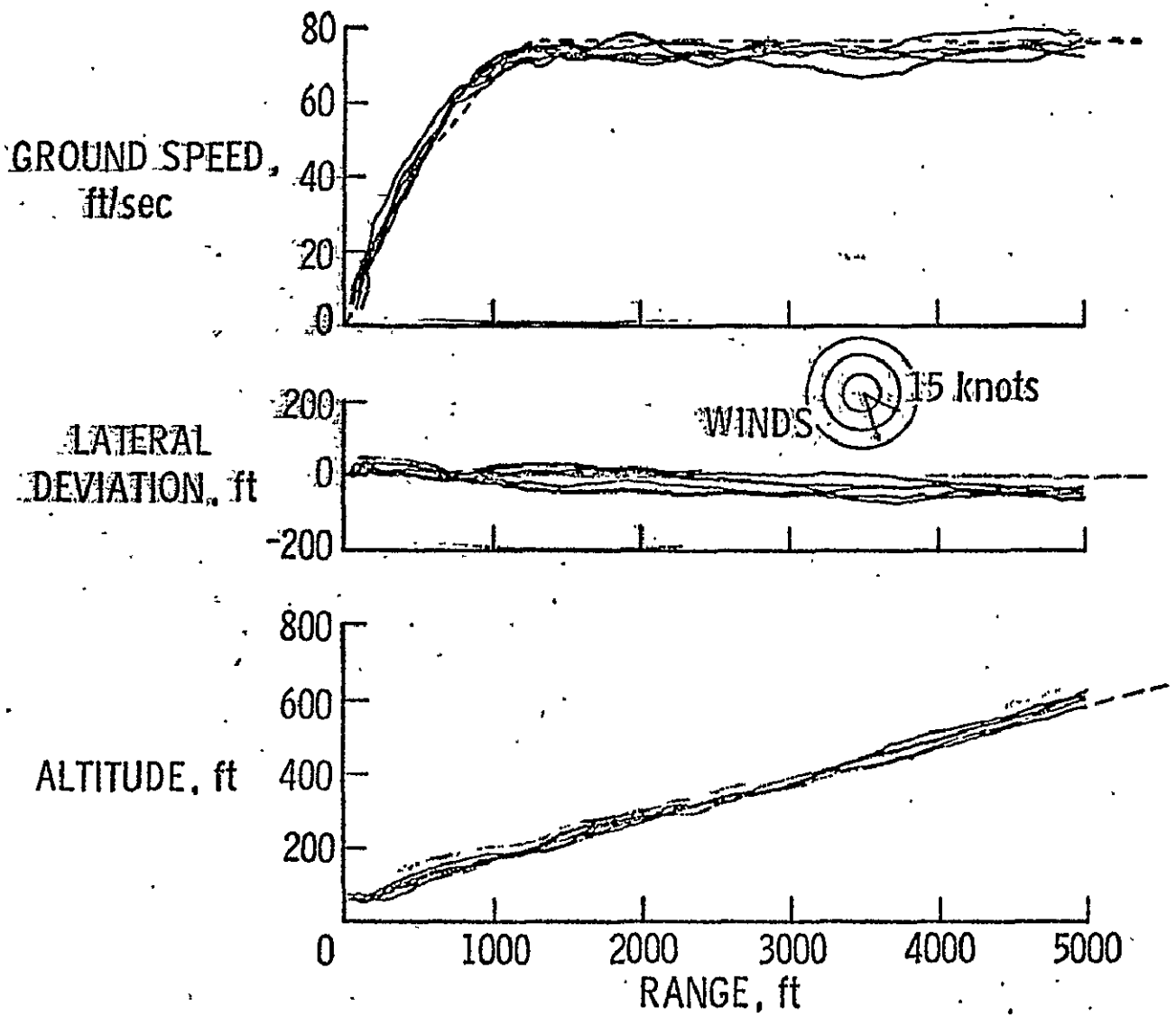
DECELERATING APPROACH TASK



SIX DEGREES MANUAL DECELERATING APPROACHES



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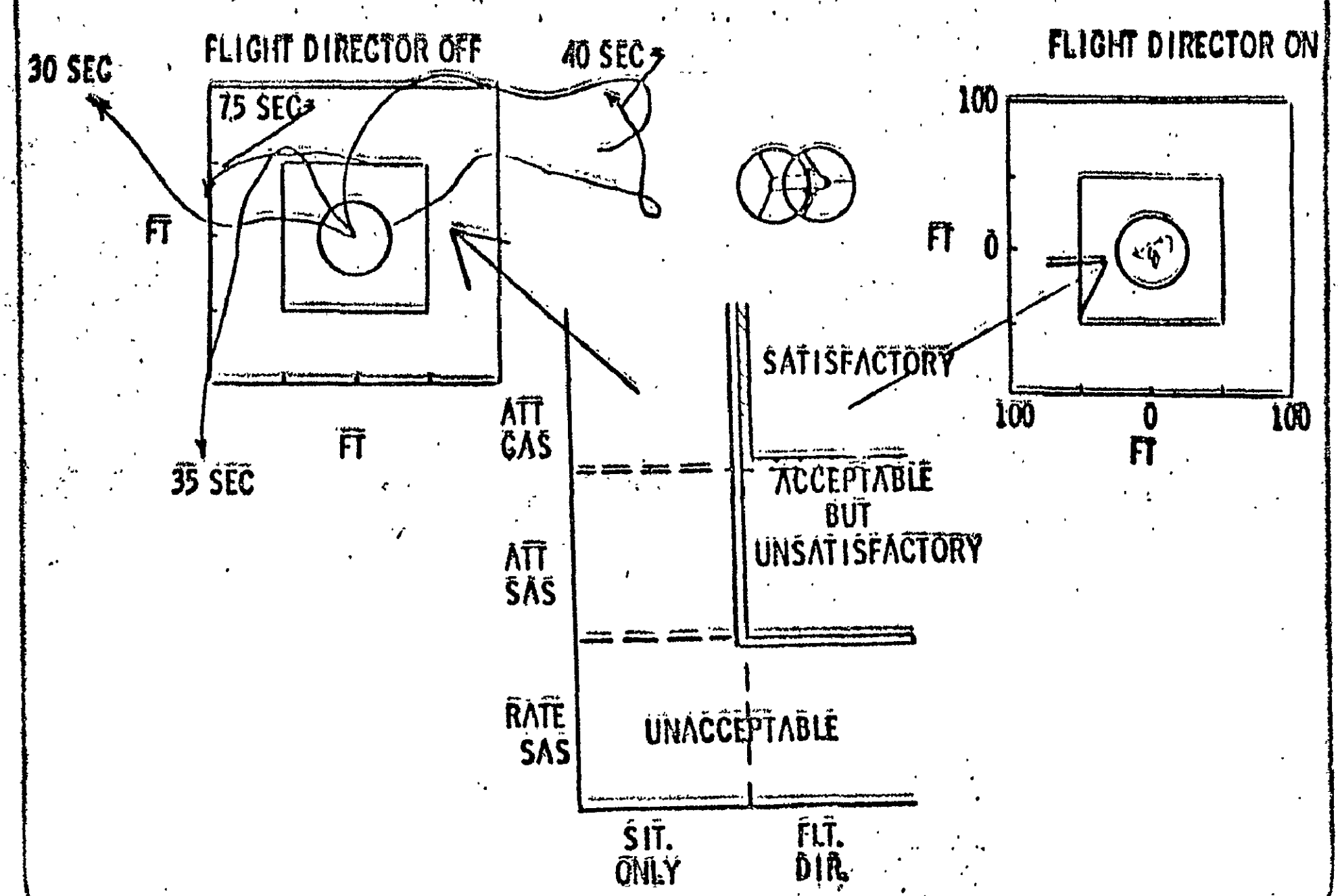
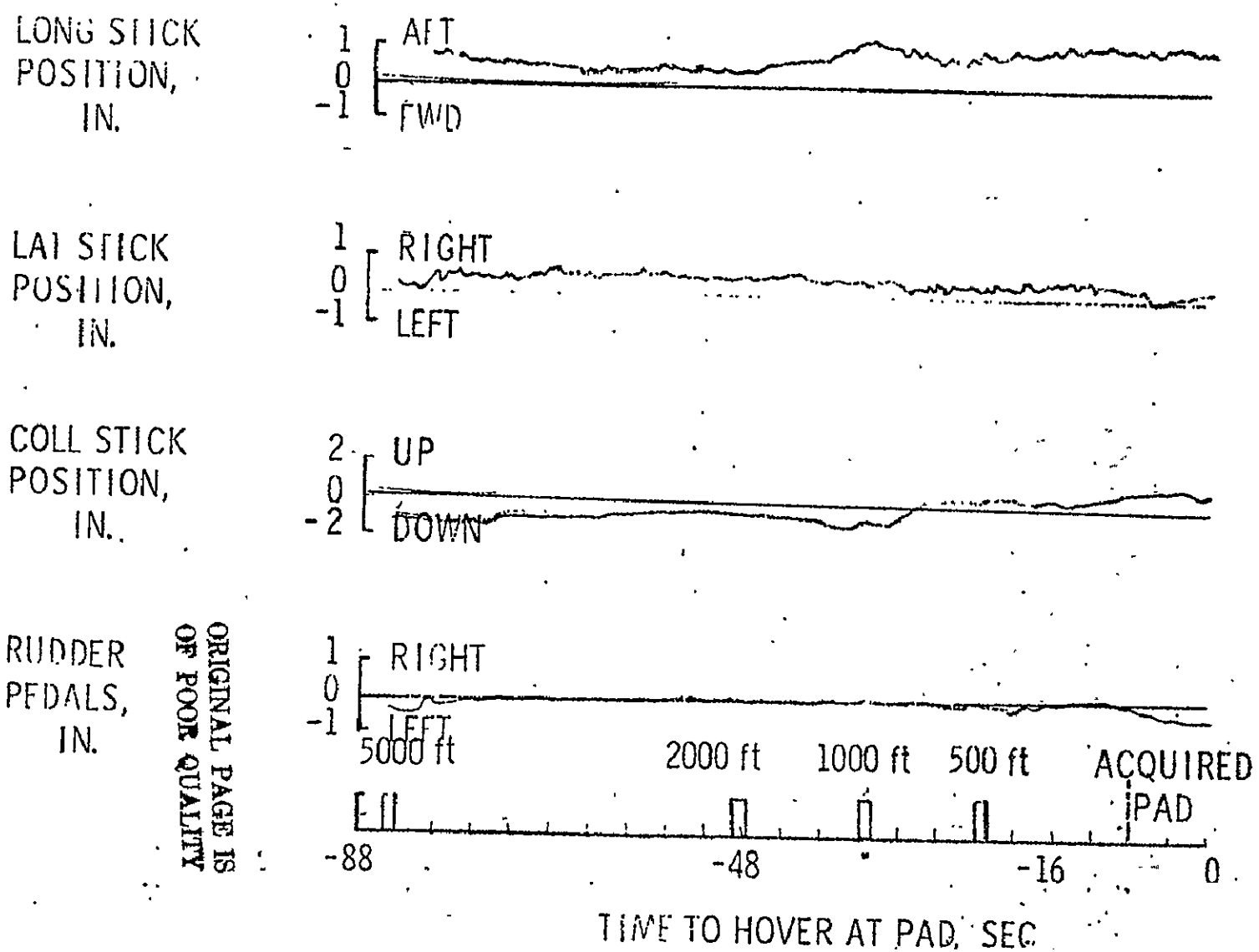
CH-46 CONTROL/DISPLAY VARIATIONS INVESTIGATION



PILOT CONTROL ACTIVITY



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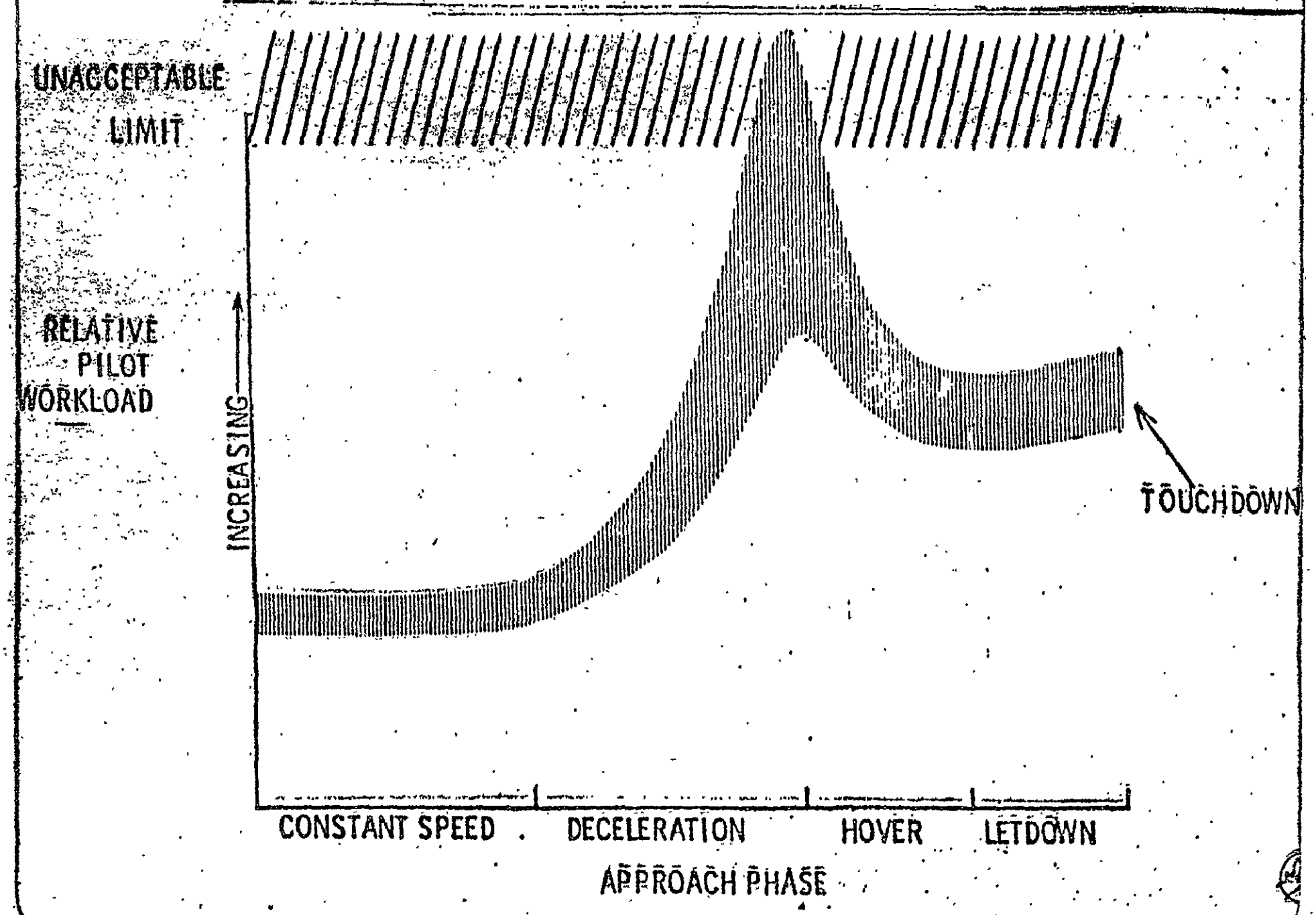
RELATIVE PILOT WORKLOAD AS A FUNCTION OF THE APPROACH PHASE



FEATURES

- ELECTRONIC CONTROL SYSTEM
- HARDOVER MONITORING SYSTEM
- DIGITAL COMPUTING SYSTEM
- ANALOG COMPUTING SYSTEM
- RADAR-LASER TRACKING AIDS
- TWO-WAY DIGITAL DATA LINK
- DUAL CRT DISPLAYS
- WIDE-BAND VIDEO LINK
- PILOTED AIRCRAFT DATA SYSTEM
- TELEMETRY DOWNLINK
- ELECTROMECHANICAL DISPLAY OPTION
- CONVENTIONAL NAV-AID OPTION

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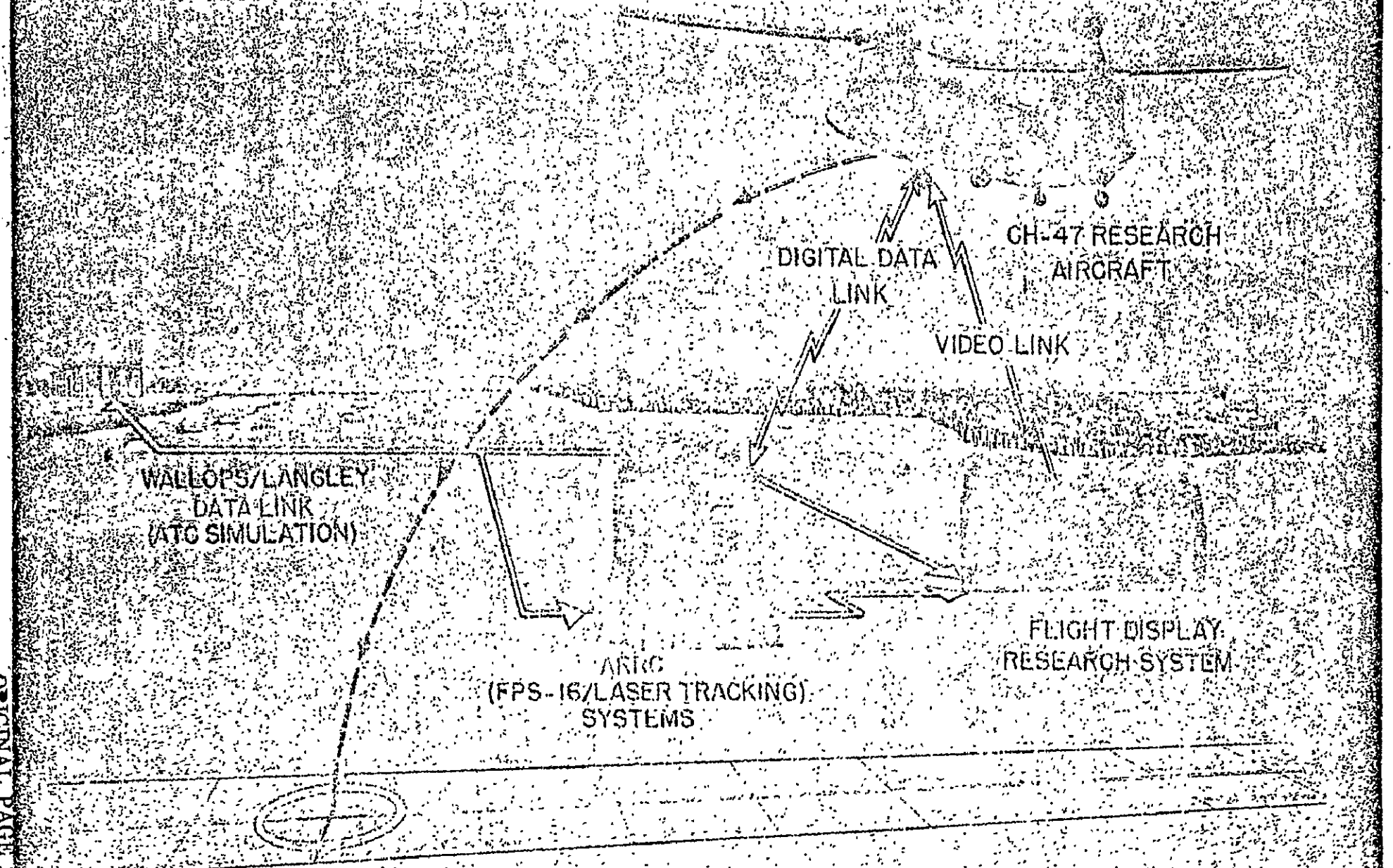
VALT INTEGRATED FLIGHT TEST FACILITIES



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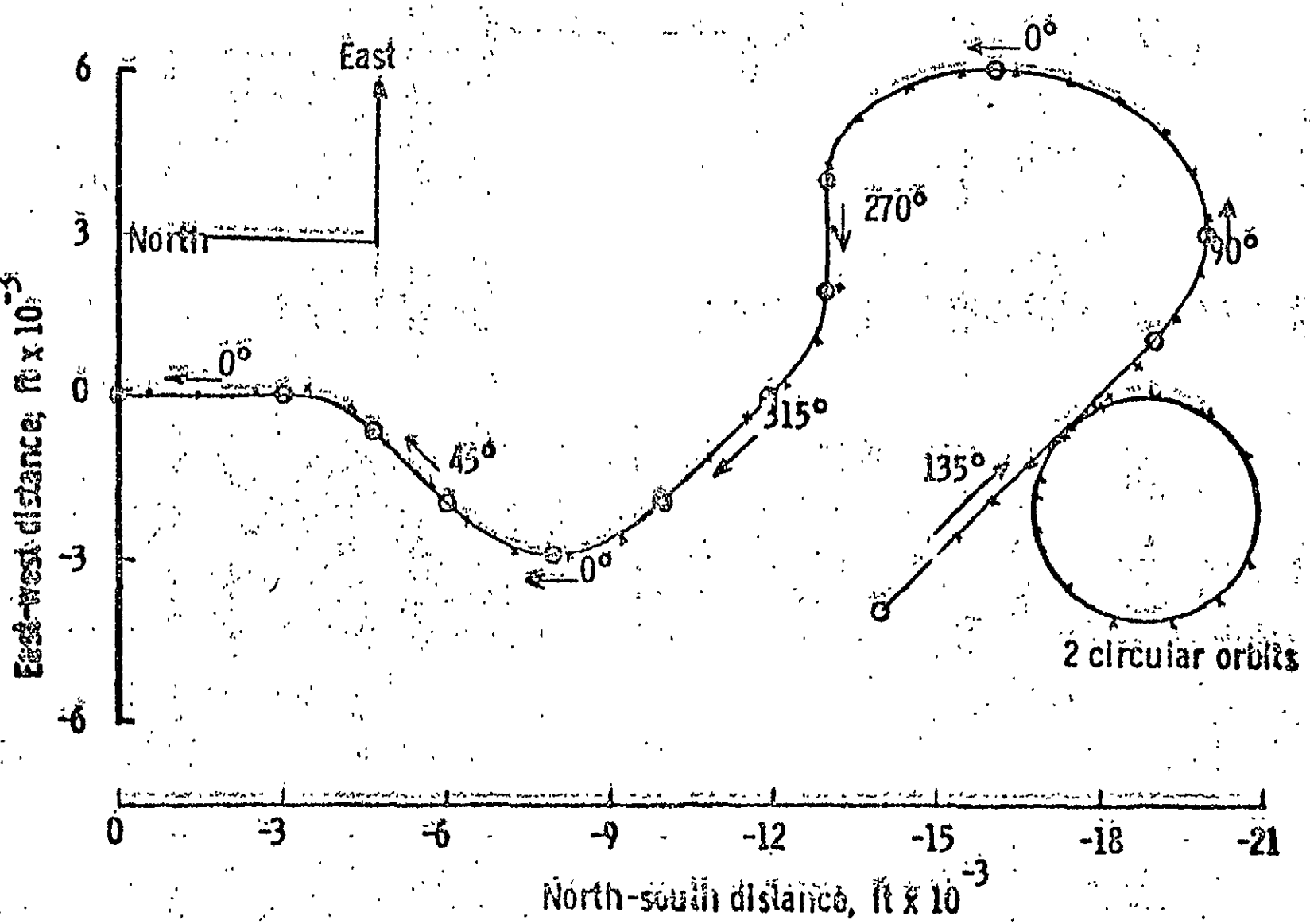
REPRESENTATIVE TRACK PROFILE



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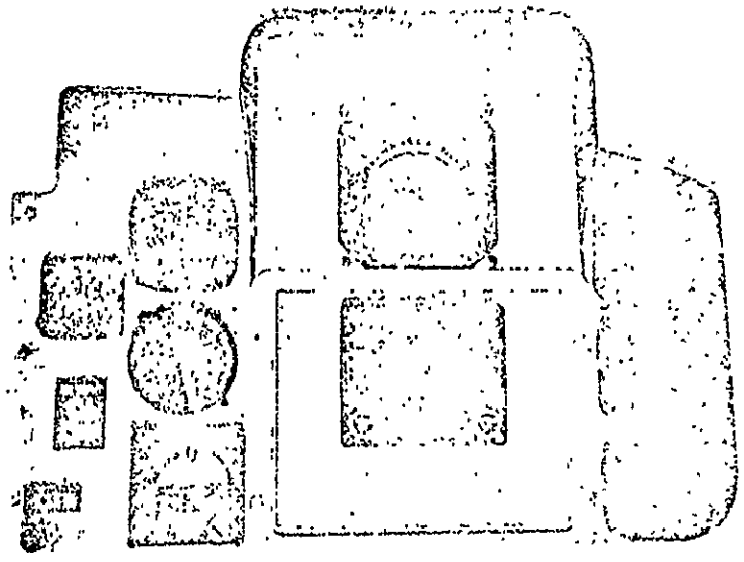
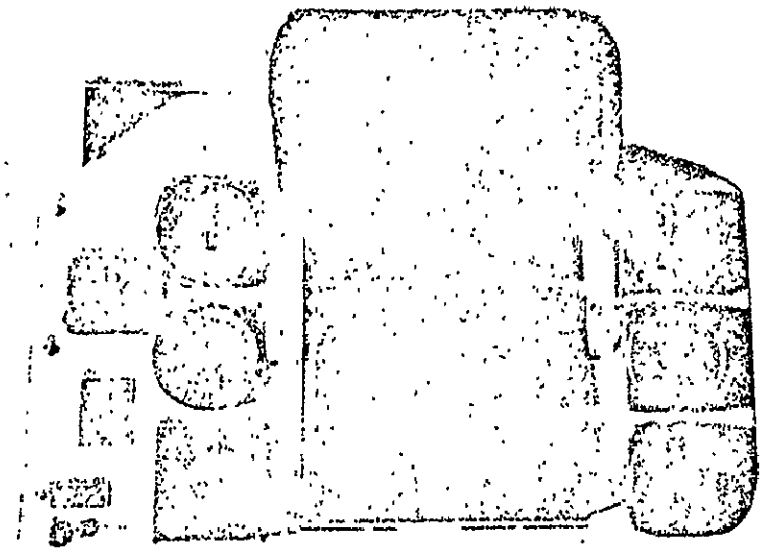
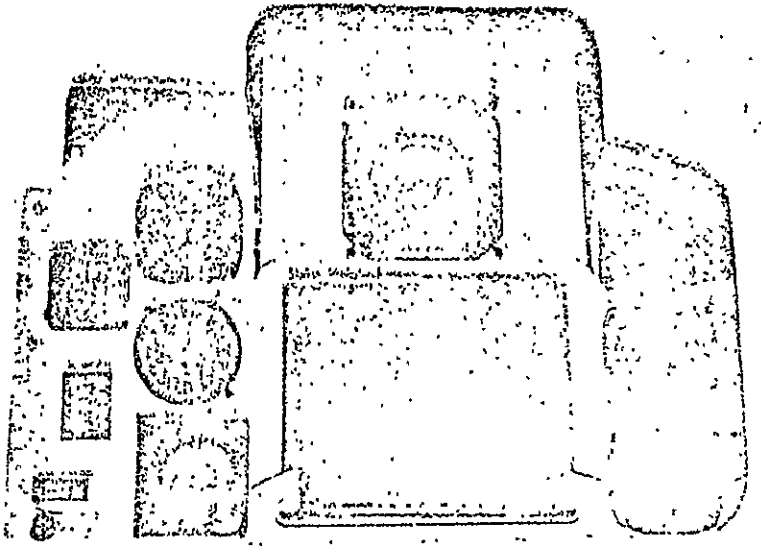
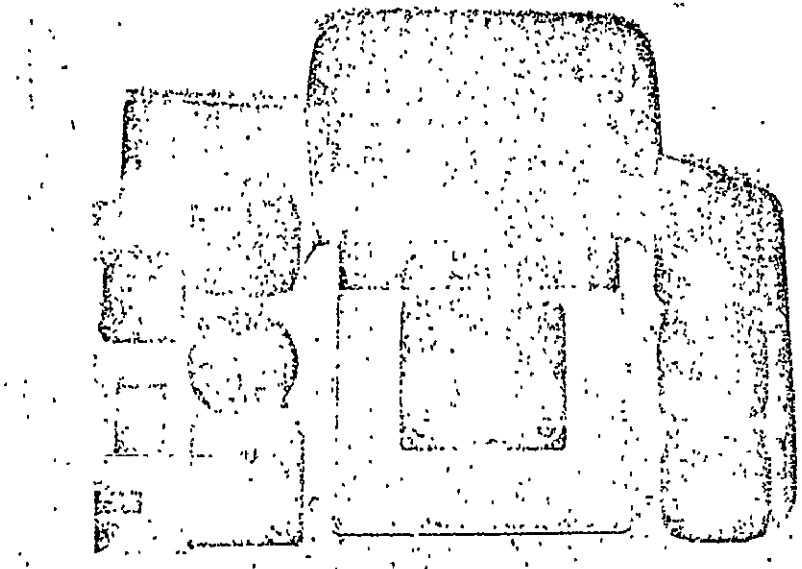
VALT CII-47 DISPLAY OPTIONS









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FY 78

RESEARCH AREA	1st QUARTER	2nd QUARTER	3rd QUARTER	4th QUARTER
TECH DEMO				
CRT DISPLAY FORMATS				
1) STRAIGHT-IN-APPROACH				
2) SPIRAL TRAJECTORY				
VECTOR VELOCITY CONTROL				
1) SHORT TERM				
2) LONG TERM				
SPIRAL APPROACH TECHNIQUES				
CROSS WIND TECHNIQUES				
HIGH-GAIN CONCEPT VALIDATION				

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VALT (RO and RA) SCHEDULE

VALT TECHNOLOGY DEMONSTRATION

CONTROL CONCEPT:

- ATTITUDE COMMAND SYSTEM
- TURN COORDINATION

} MANUAL

- SPLIT AXIS AUTOMATION
- FULLY AUTOMATIC APPROACH AND LANDING

DISPLAY CONCEPT:

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

TRAJECTORY:

- $\gamma \doteq 6^\circ$; 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

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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

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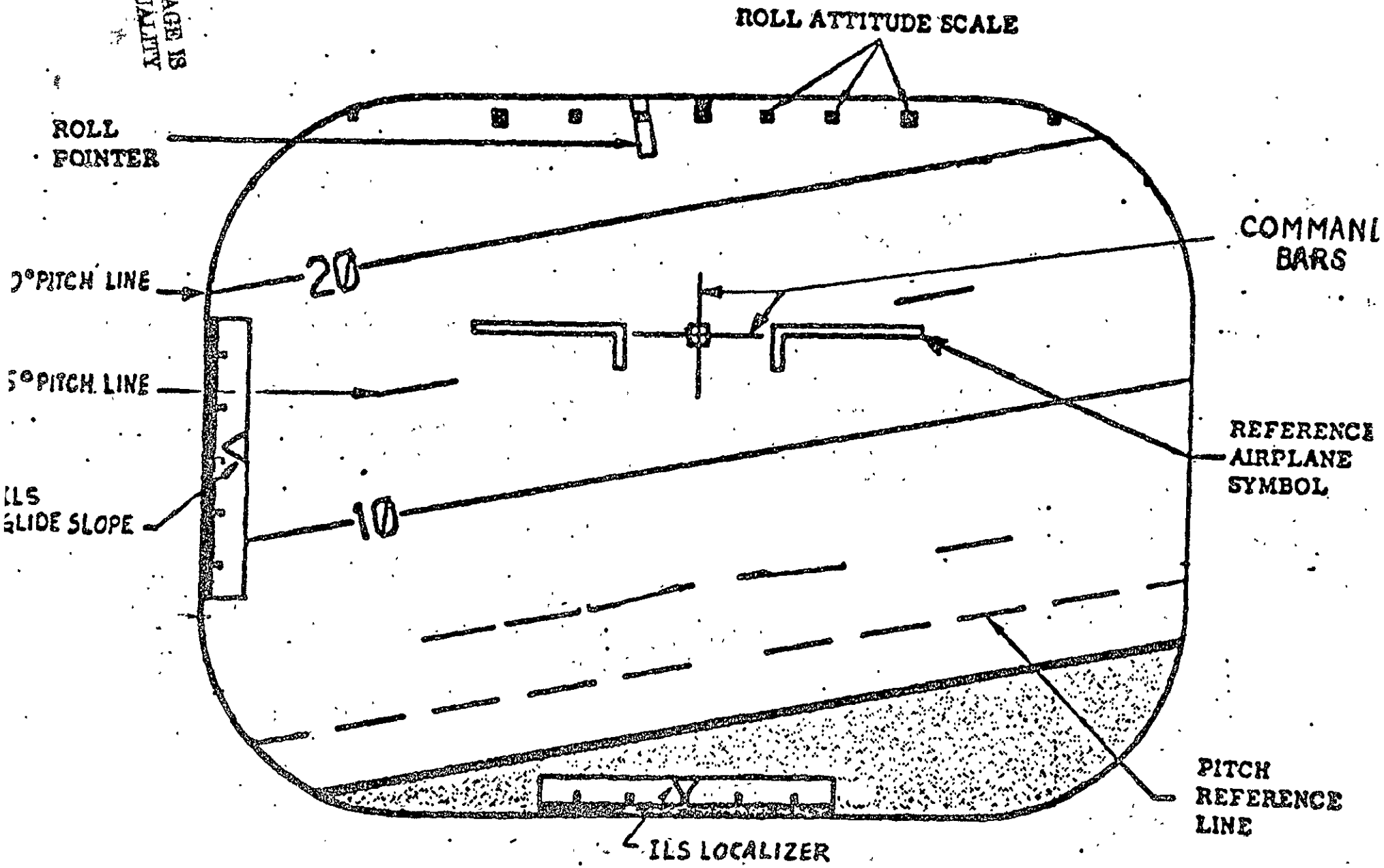

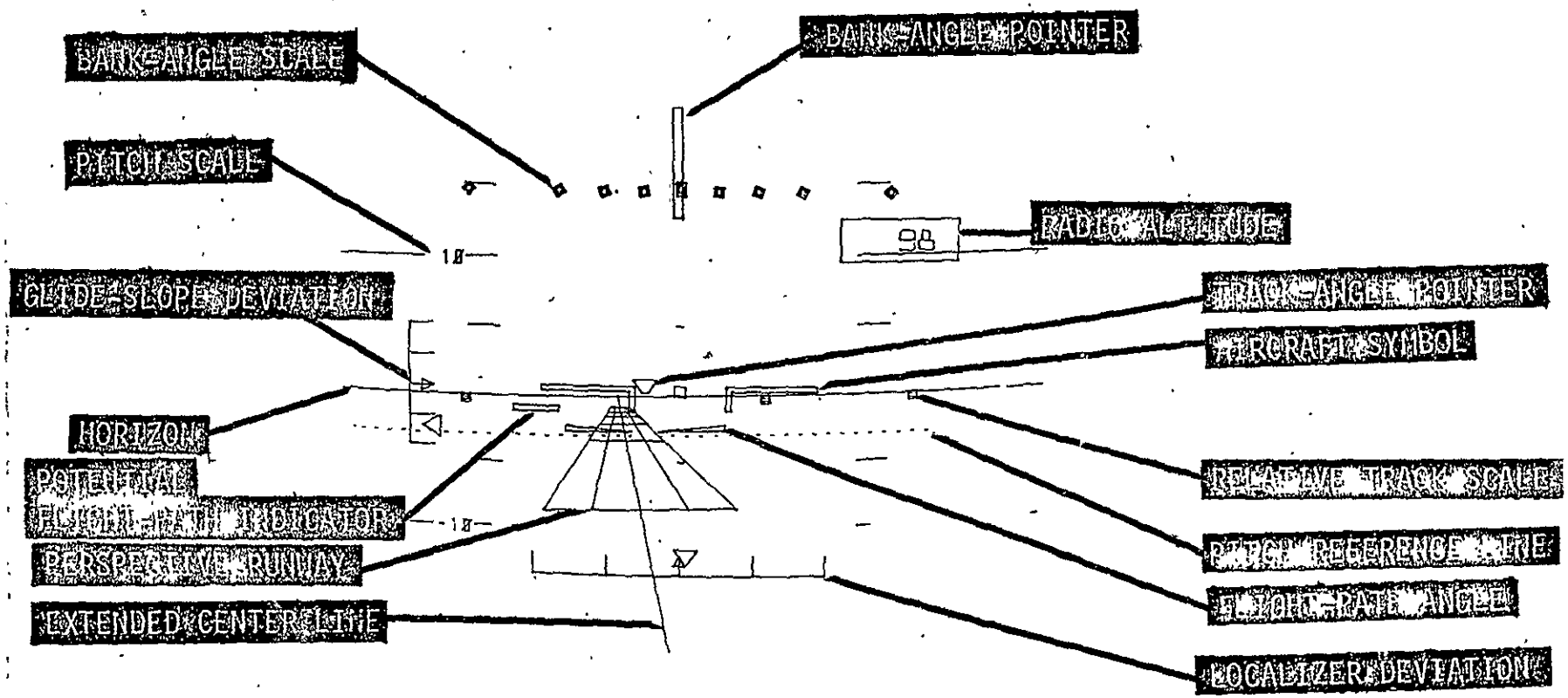
BANK-ANGLE SCALE
BANK-ANGLE POINTER
PITCH SCALE
RADIO ALTITUDE
98
10
GLIDE-SLOPE DEVIATION
TRACK-ANGLE POINTER
AIRCRAFT SYMBOL
HORIZON
POTENTIAL FLIGHT-PATH INDICATOR
RELATIVE TRACK SCALE
10
PERSPECTIVE RUNWAY
PITCH REFERENCE LINE
EXTENDED CENTERLINE
FLIGHT-PATH ANGLE
LOCALIZER DEVIATION

PERCENT TIME ON INSTRUMENTS

(ONE NASA TEST PILOT)

TEST CONDITIONS							
DISPLAY	CONTROL	TURB	AS	FD/EADI	BA	HSI	IVSI
FD (SIMULATED)	MANUAL	-	3.59	90.67	0.84	0.61	0.15
FD (SIMULATED)	MANUAL	MOD	2.45	92.21	0.49	0.00	1.27
FD (SIMULATED)	COUPLED	-	8.32	77.08	2.55	2.18	0.41
FD (SIMULATED)	COUPLED	MOD	11.01	77.50	0.24	0.35	1.13
EADI	MANUAL	-	1.08	95.47	0.63	0.01	0.15
EADI	MANUAL	MOD	1.67	95.61	0.58	0.02	0.07
EADI	COUPLED	-	6.37	82.49	3.57	0.60	0.83
EADI	COUPLED	MOD	2.87	91.45	0.18	0.01	0.53

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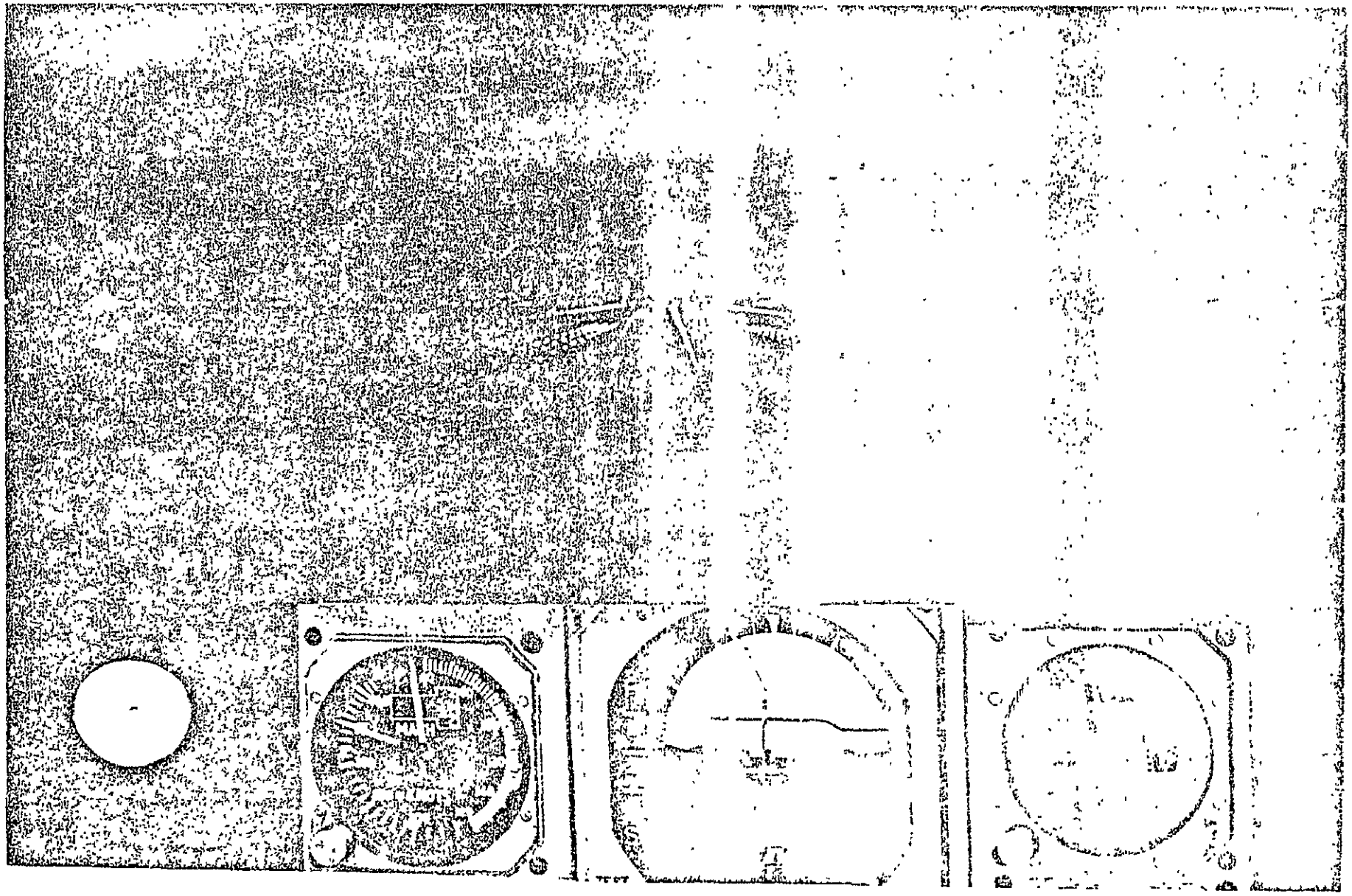

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Langley Form 92 (APR 69)

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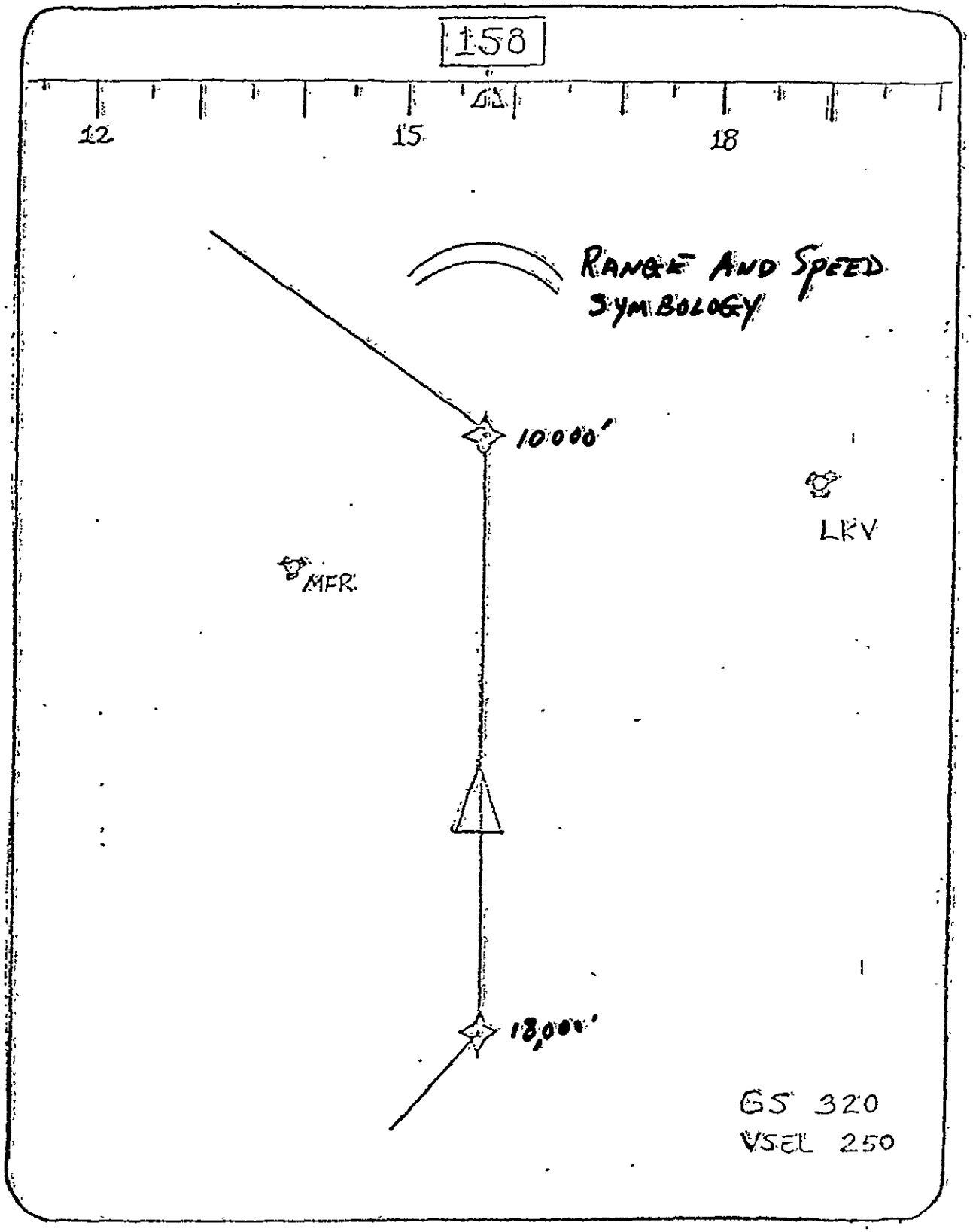
ADVANCED DISPLAY CONCEPTS

FLIGHT PHASE	CONCEPT
DESCENT	• CDTI
	• ENERGY DESCENT
FINAL APPROACH-TO-LANDING	• MLS INTEGRATED SITUATION
	• COMMANDED GAMMA
	• WINDSHEAR INFORMATION
CURVED DECELERATING APPROACH	• PATHWAY
	• TUNNEL
	• OTHERS



RANGE - SPEED SYMBOLOGY

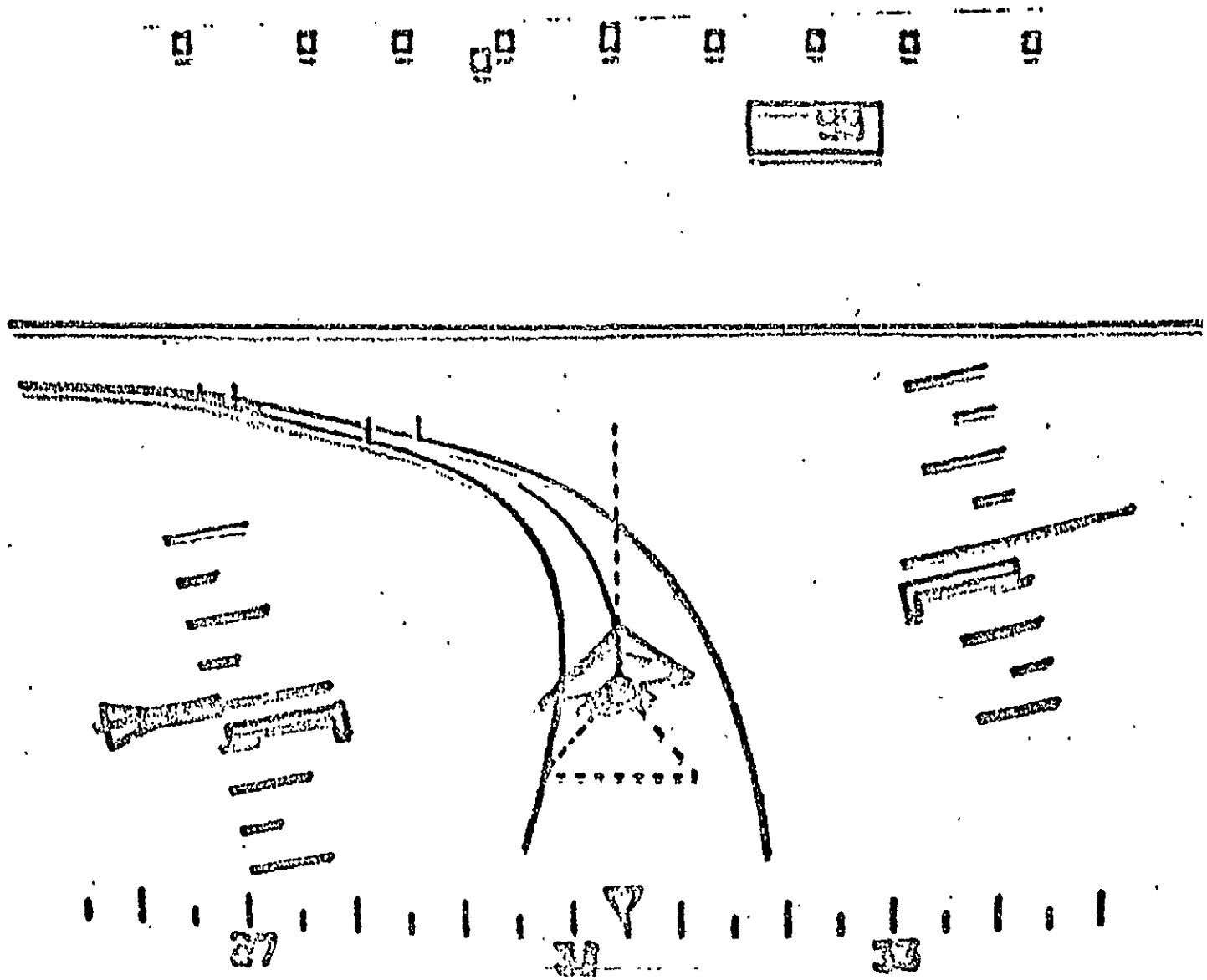


FIGURE 10 - THE PITS DISPLAY: AIRPLANE DISPLACED ABOVE THE PATH.

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APPENDIX K

INTEGRATED SITUATION DISPLAY OBJECTIVE

LUATE THE INTEGRATION OF HORIZONTAL INFORMATION
O A BASELINE VERTICAL SITUATION DISPLAY.

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RESEARCH COCKPIT LAYOUT

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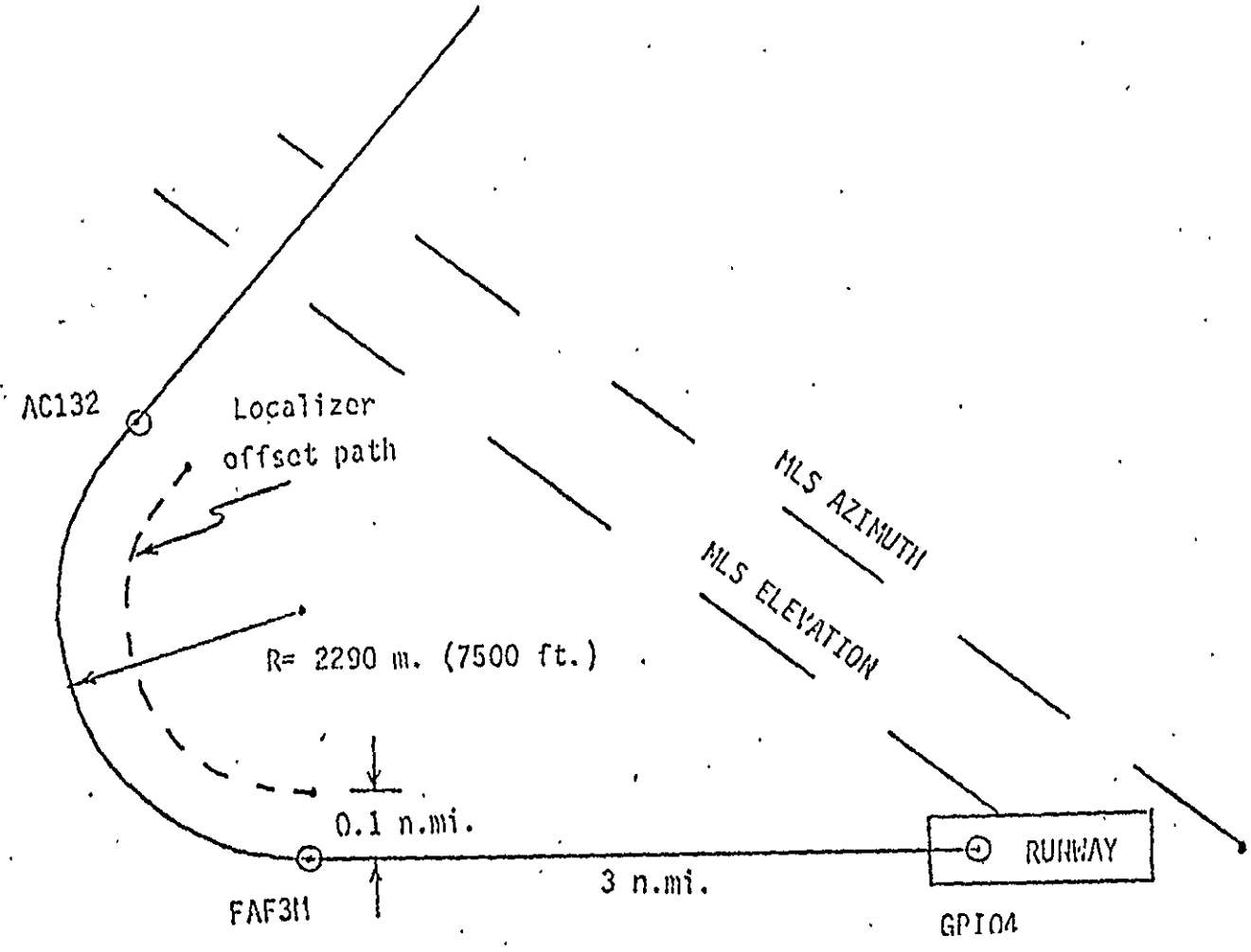
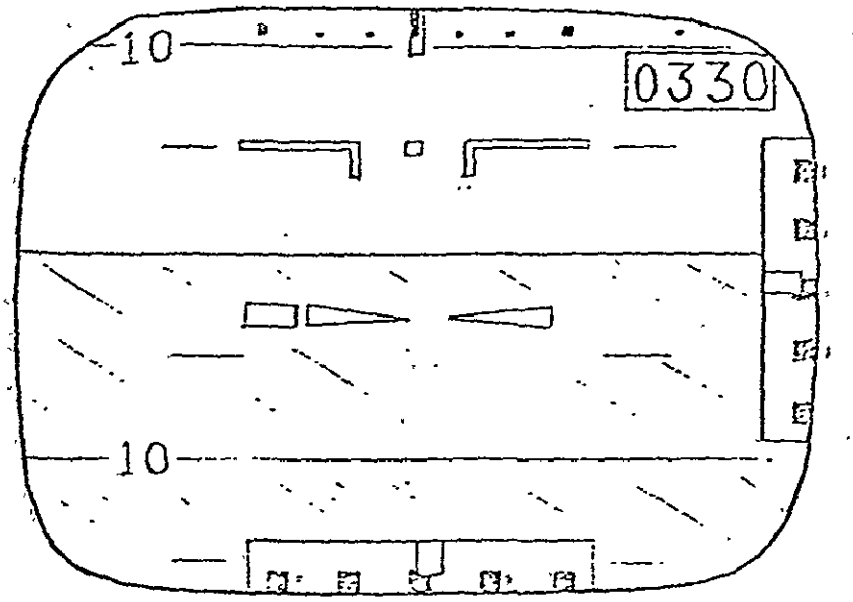
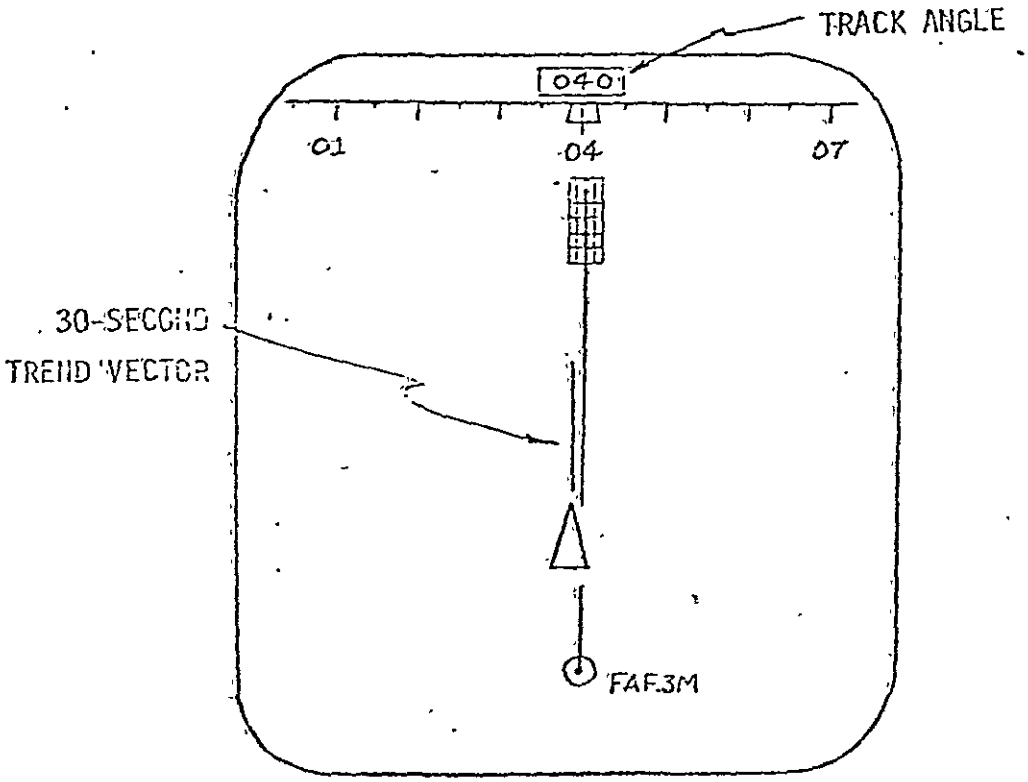

AC132
Localizer
offset path
MLS AZIMUTH
MLS ELEVATION
R= 2290 m. (7500 ft.)
0.1 n.mi.
RUNWAY
3 n.mi.
FAF311
GPI04





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BASELINE DISPLAY FORMAT

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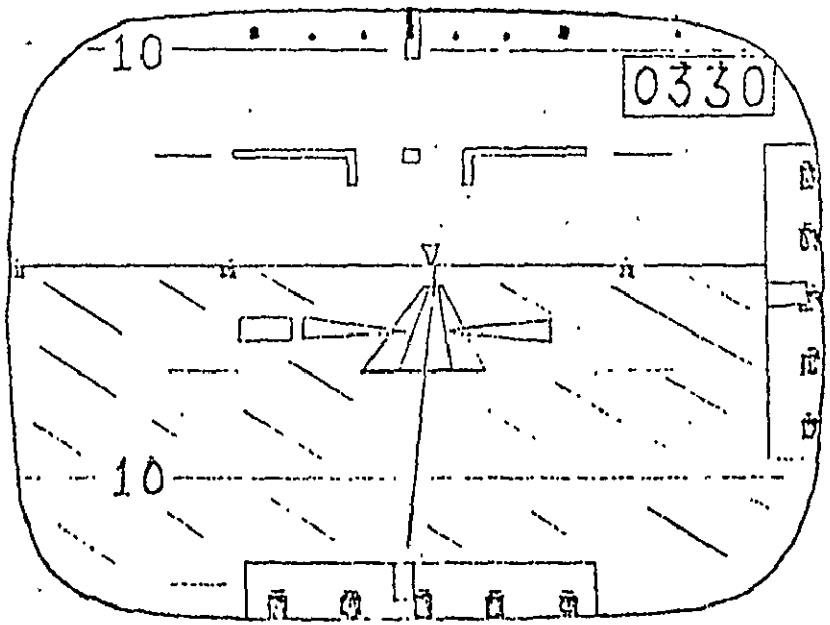

INTEGRATED DISPLAY FORMAT

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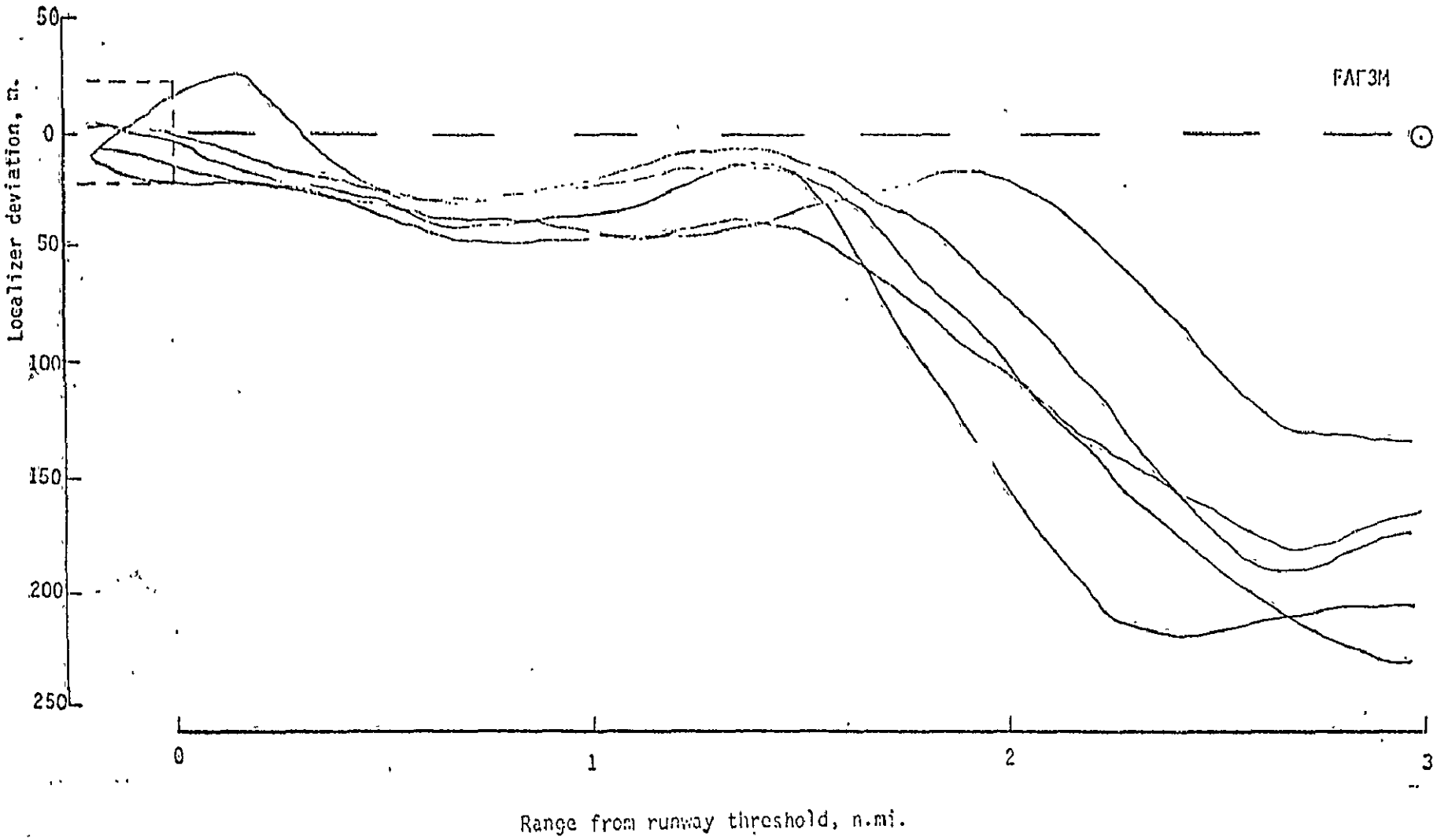
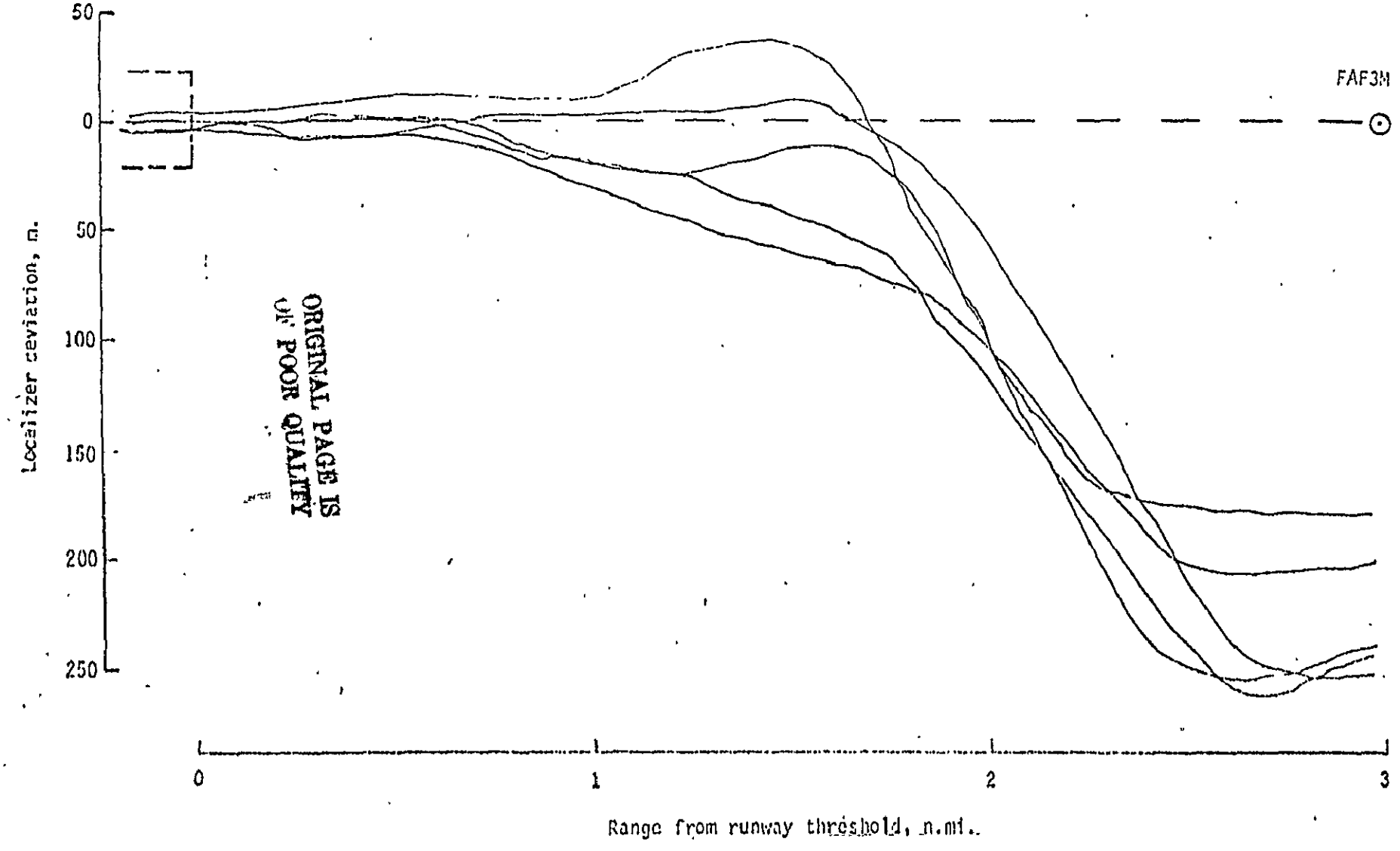


LOCALIZER TRACKING PERFORMANCE USING THE BASELINE DISPLAY FORMAT



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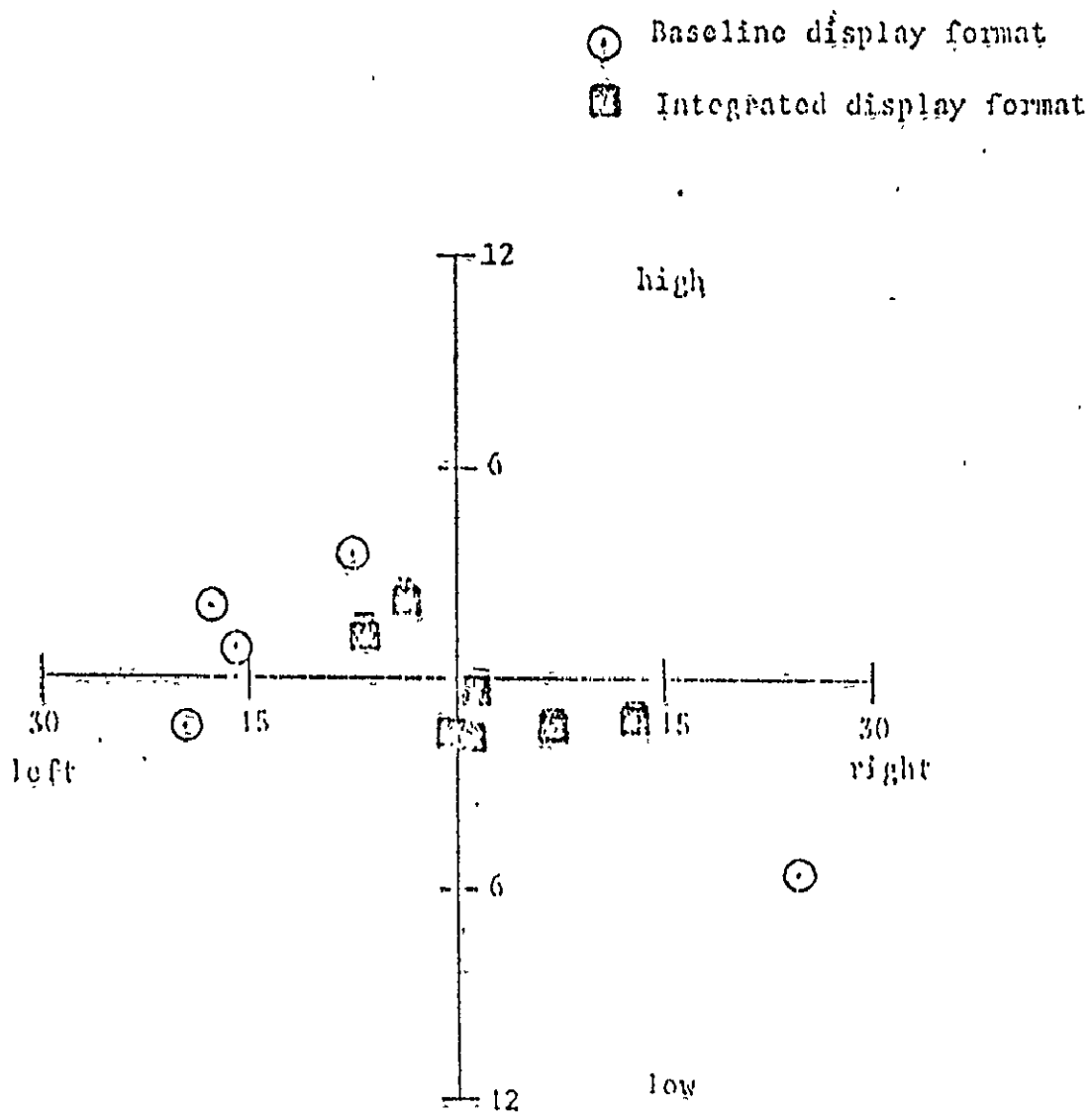
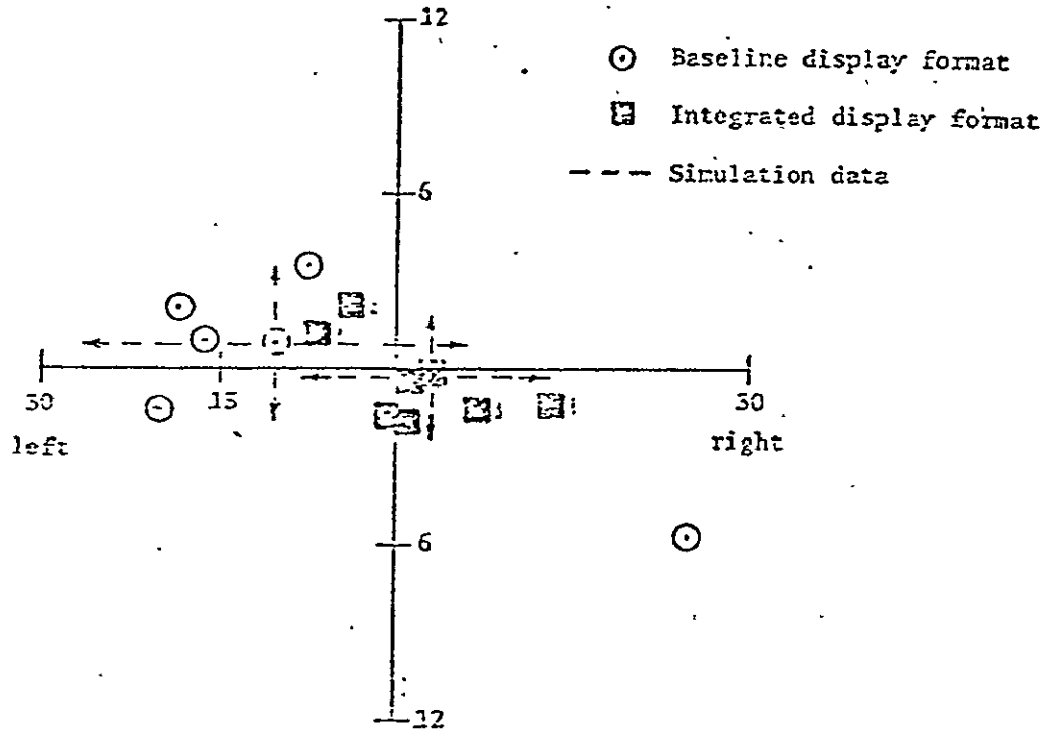
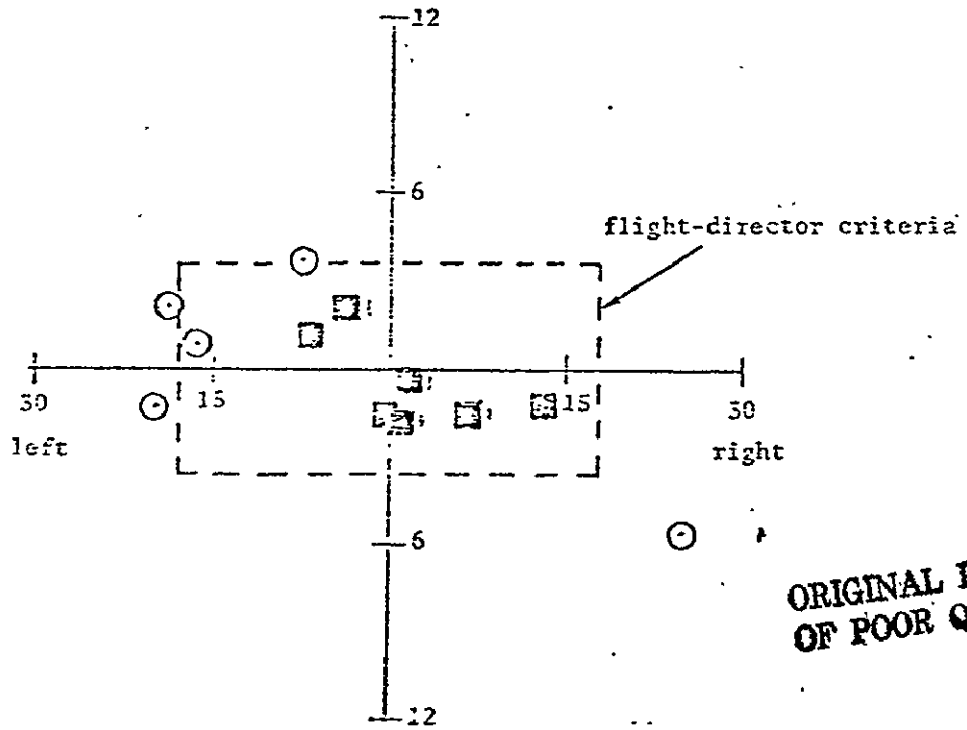
LOCALIZER TRACKING PERFORMANCE USING THE INTEGRATED DISPLAY FORMAT



30.5 - M (100-FT) WINDOW DATA OF VERTICAL AND LATERAL FLIGHT PATH DEVIATIONS



COMPARISON WITH SIMULATION RESULTS



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COMPARISON WITH CATEGORY II FLIGHT-DIRECTOR CRITERIA

CONCLUDING REMARKS

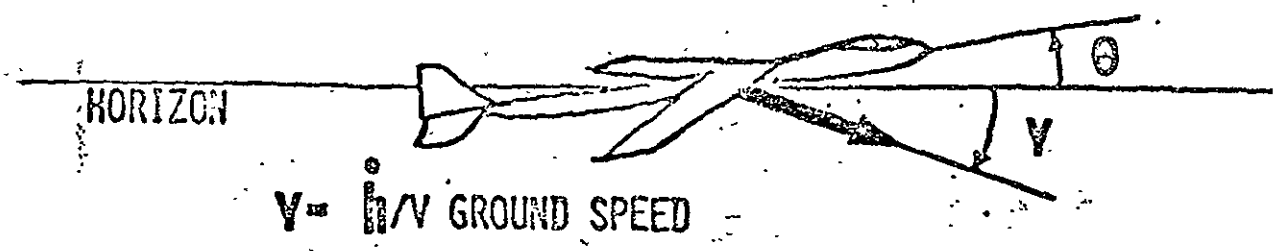
- INTEGRATED FORMAT INCREASED FLIGHT PATH ACCURACY OVER BASELINE FORMAT.

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

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

(FLIGHT PATH ANGLE)

CONTROL WHEEL STEERING



- RATE COMMAND SYSTEM
- FLIGHT PATH ANGLE HOLD
- BANK ANGLE HOLD
- TRACK ANGLE HOLD

DISPLAY

- ELECTRONIC CRT
- SITUATION INFORMATION

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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 (γ_I) THROUGH THE BROLLY HANDLES (COLUMN) AND
- PROVIDES AUTOMATIC HOLDING OF THE PILOT COMMANDED INERTIAL FLIGHT PATH ANGLE UPON RELEASE OF THE BROLLY HANDLES

V_A = AIRSPEED VELOCITY VECTOR

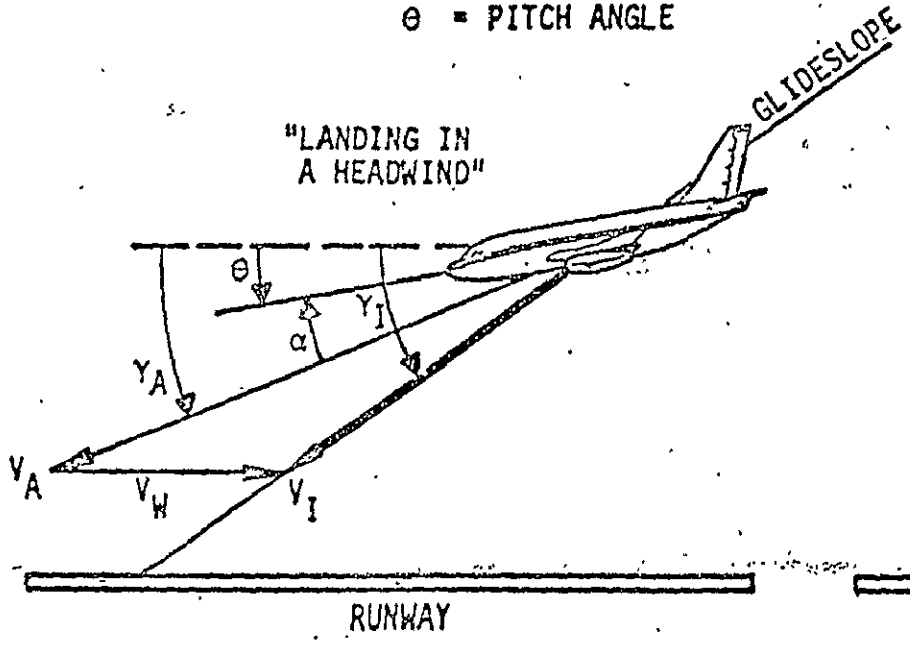
V_I = INERTIAL VELOCITY VECTOR

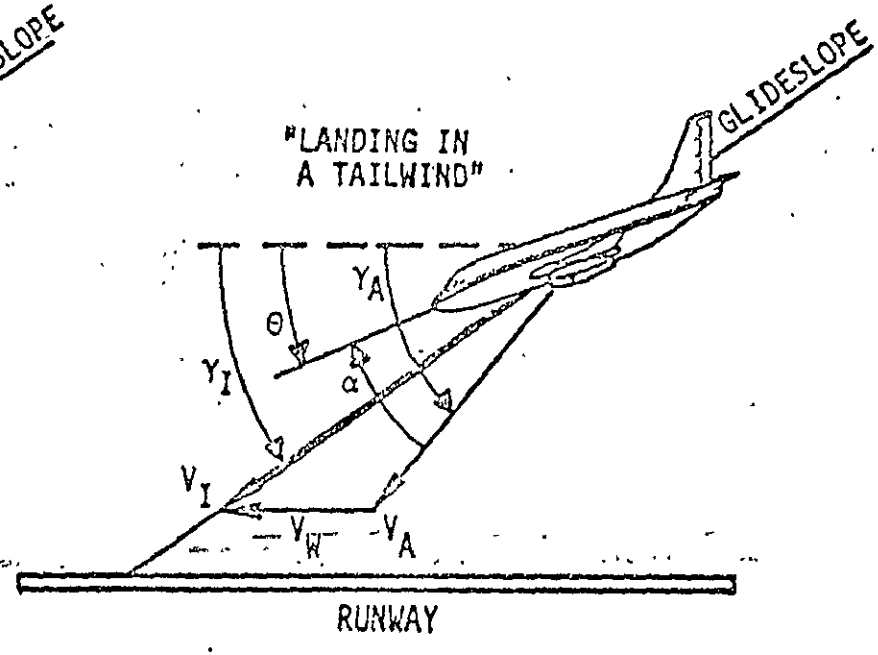
γ_I = INERTIAL FLIGHT PATH ANGLE

γ_A = AIR MASS REFERENCED FLIGHT PATH ANGLE

α = ANGLE OF ATTACK

θ = PITCH ANGLE





DEFICIENCIES IN PRESENT SYSTEM

- CONTROL SYSTEM
  - RELATIVELY LONG LAG IN V RESPONSE
  - MISMATCH OF RATES
  - OVERSHOOT OF HOLD REFERENCE
  - LOW DAMPING
- DISPLAY SYSTEM
  - LOOSENESS OF V SYMBOL
  - NO V REFERENCE INFORMATION

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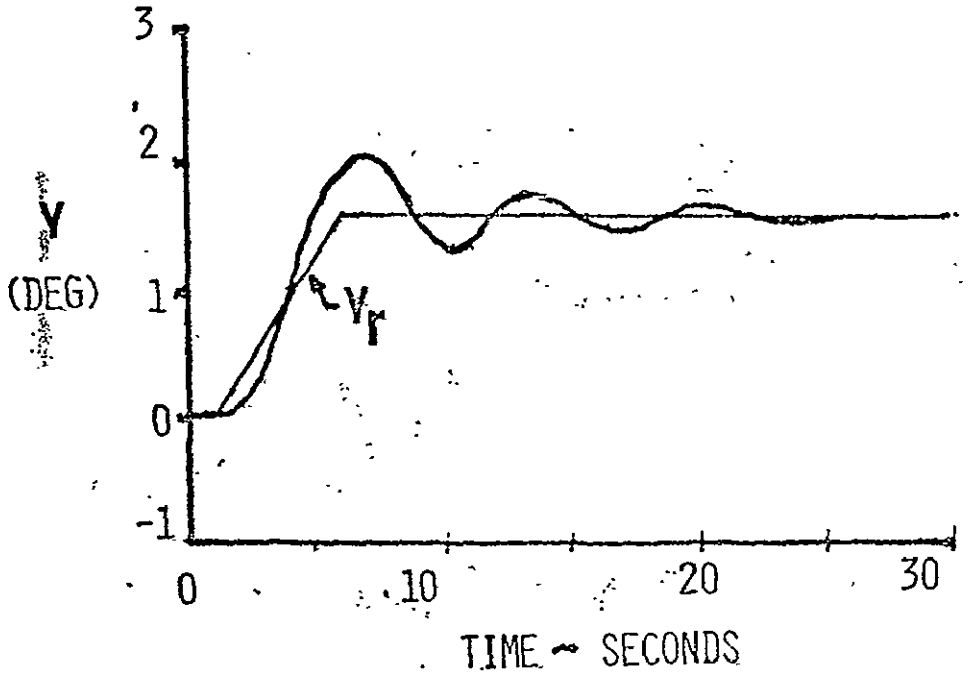
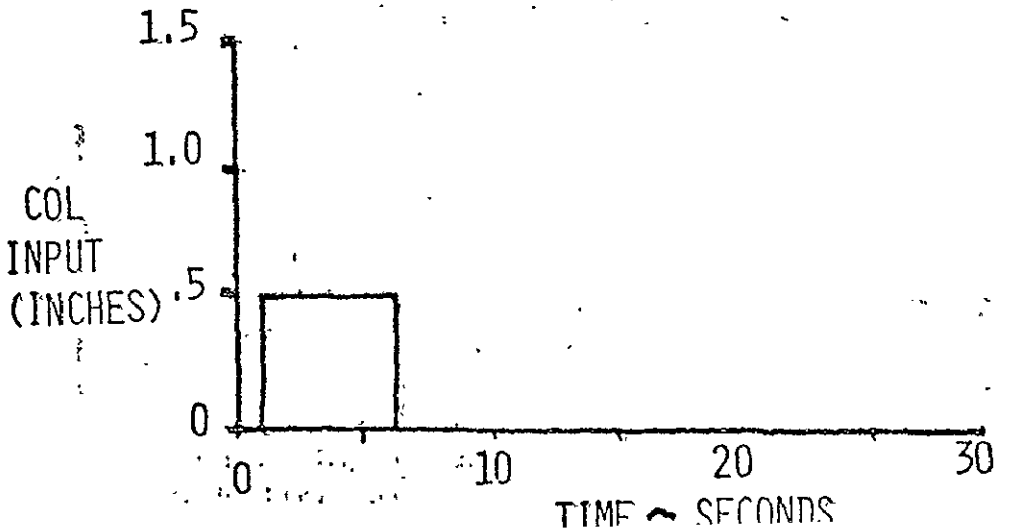

3
2
1
0
-1
γ
(DEG)
γ_r
0
10
20
30
TIME ~ SECONDS


1.5
1.0
.5
0
COL
INPUT
(INCHES)
0
10
20
30
TIME ~ SECONDS

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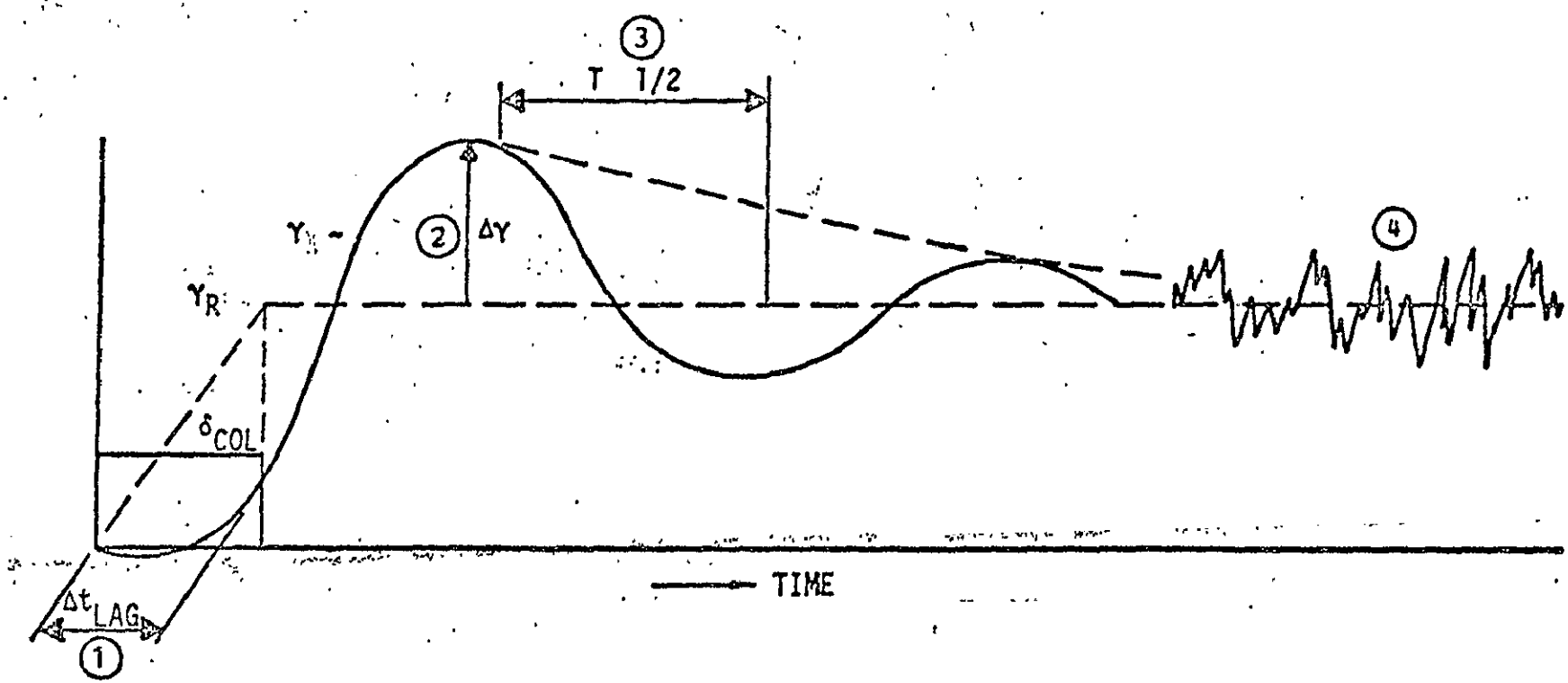
THE DISPLAY OF FPA (γ) IS INADEQUATE TO GUIDE THE PILOT IN SETTING UP AND INDICATING THE FPA REFERENCE (γ_R) BECAUSE OF

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 γ_{REF} FROM γ_I



PILOT DESIRES IN NEW SYSTEM

- QUICKER RESPONSE
- INCREASED SENSITIVITY
- MINIMUM OVERSHOOT IN V AND θ
- HIGH DAMPING
- V REFERENCE

APPROACH

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

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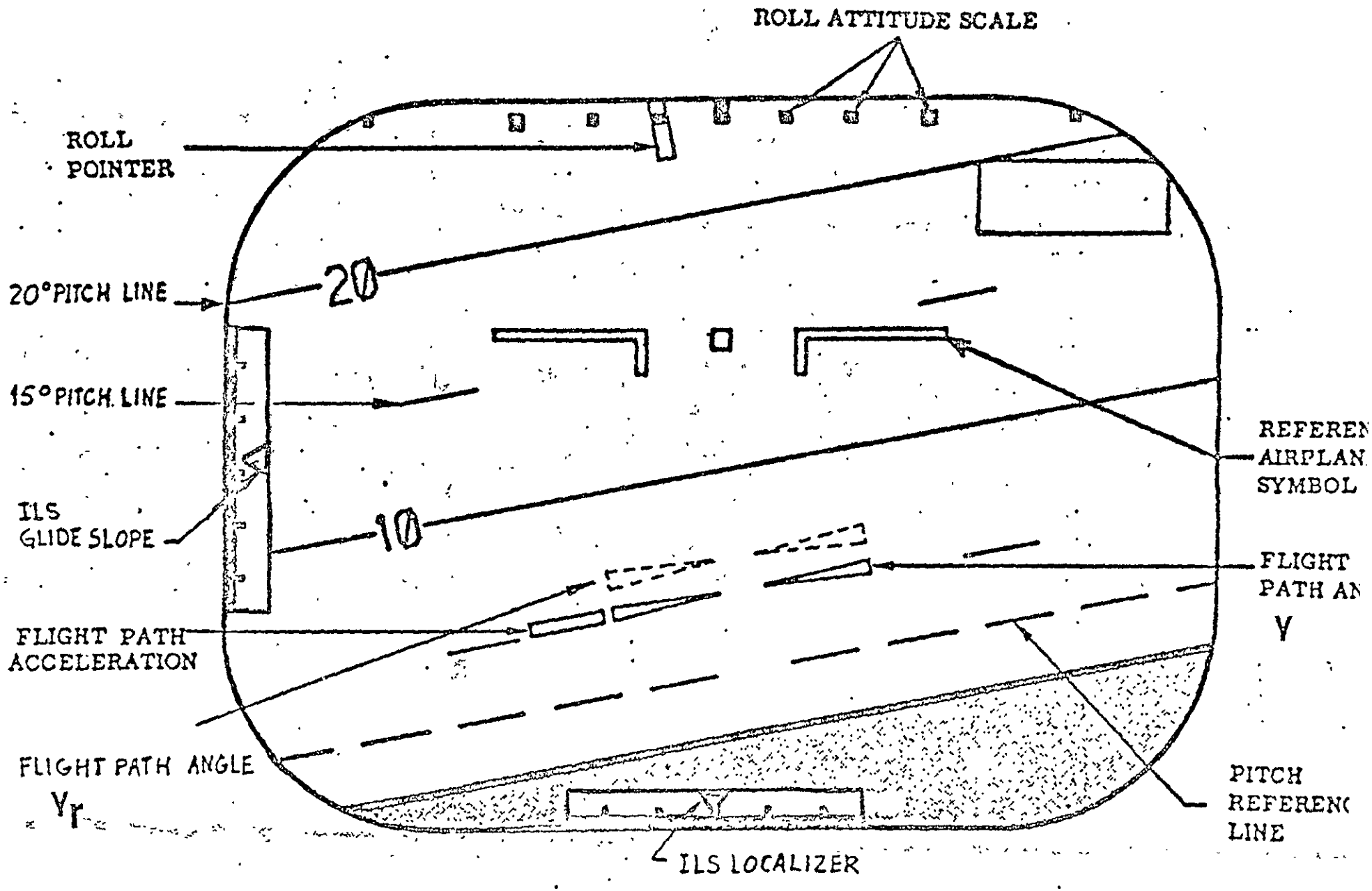
ROLL ATTITUDE SCALE
ROLL POINTER
20°PITCH LINE
20
15°PITCH LINE
ILS GLIDE SLOPE
10
REFEREN AIRPLAN SYMBOL
FLIGHT PATH AN
γ
FLIGHT PATH ACCELERATION
FLIGHT PATH ANGLE
γr
PITCH REFEREN LINE
ILS LOCALIZER

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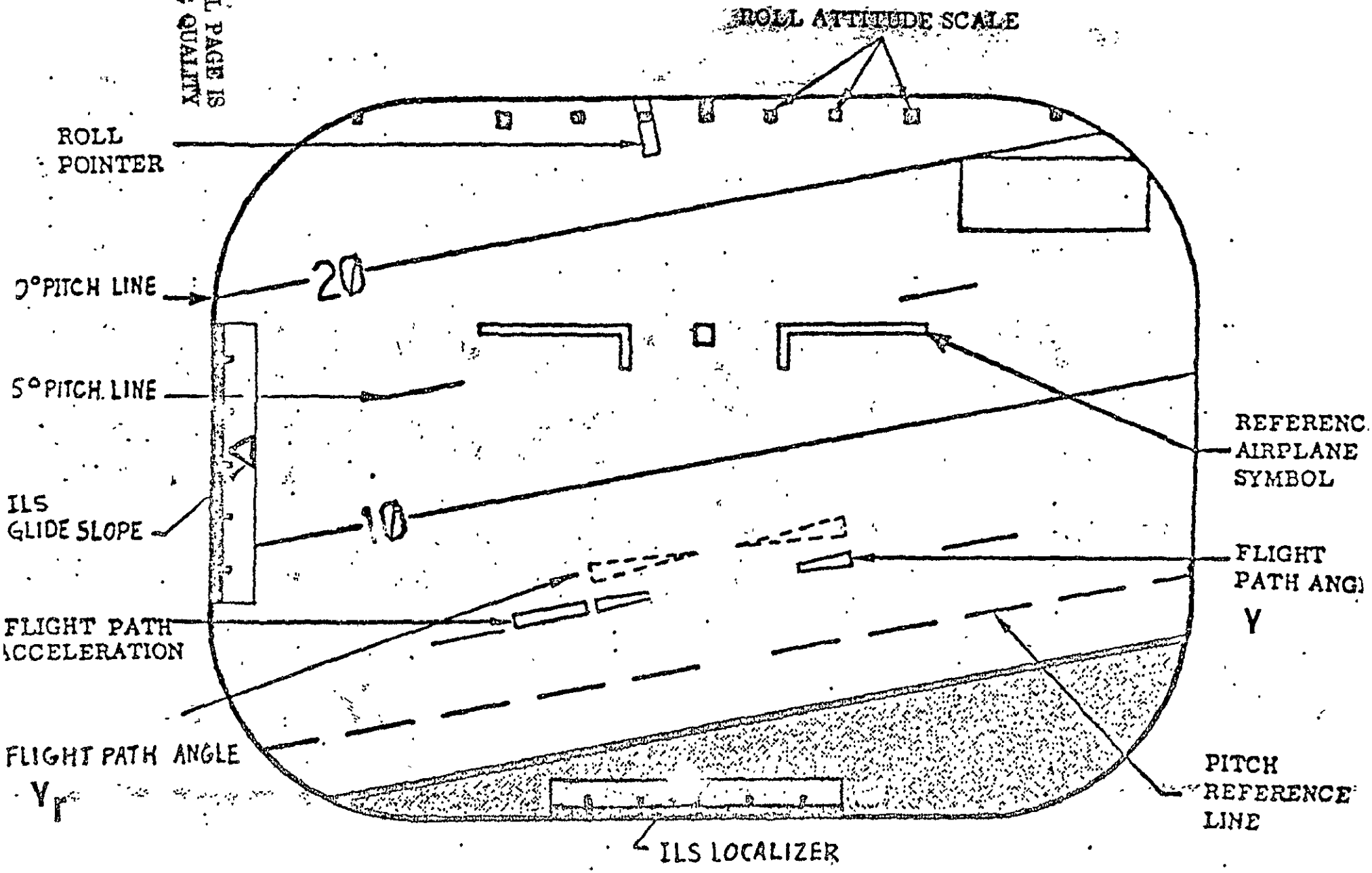

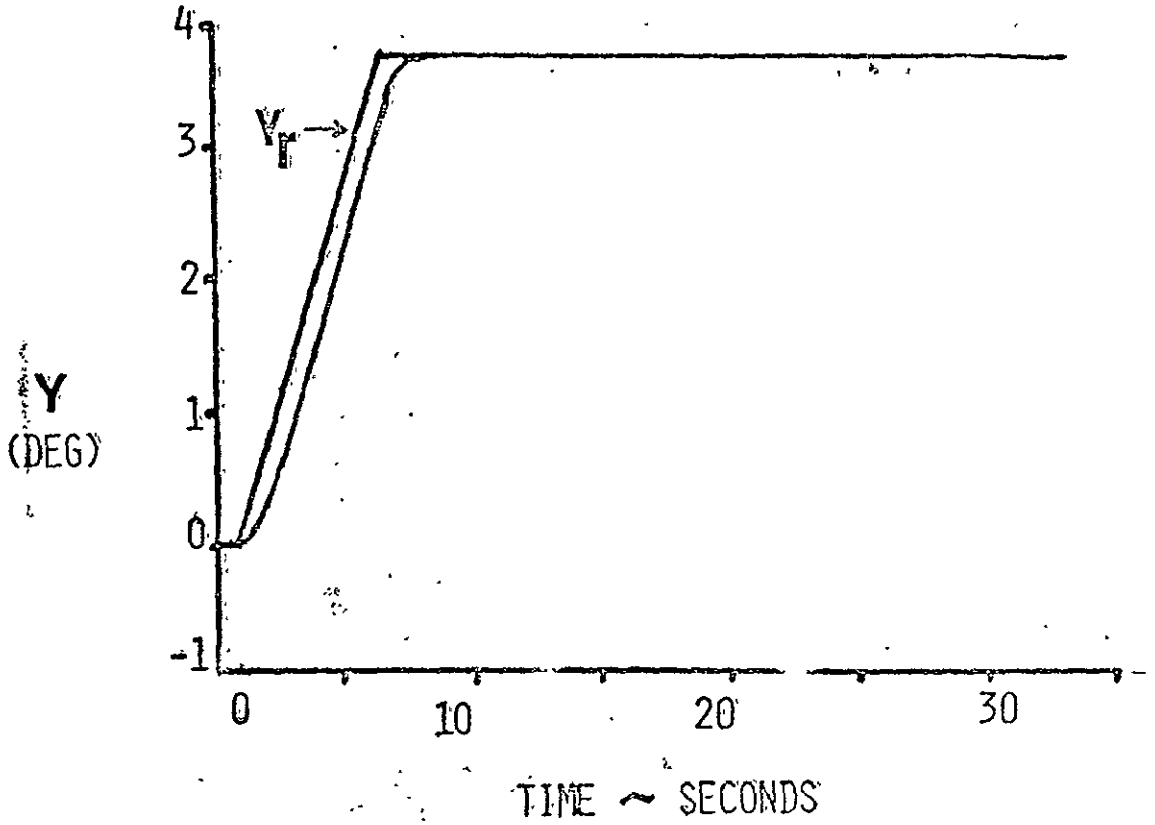

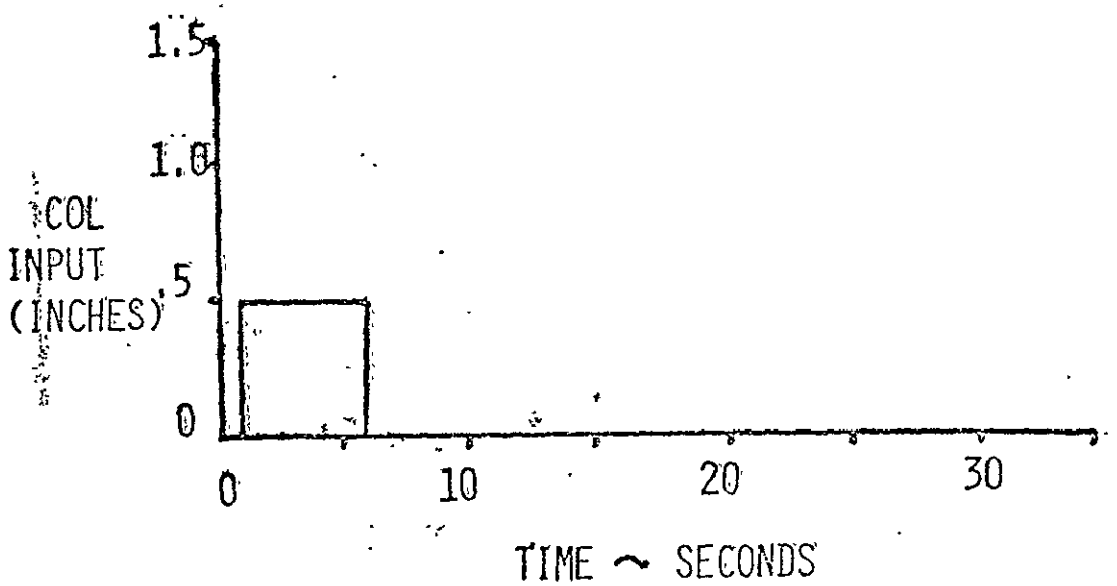

NASA LANGLEY RESEARCH CENTER

SUMMARY

- ADDED V REFERENCE TO DISPLAY
- MORE RESPONSIVE CONTROL SYSTEM
- MATCHED RATE WITH MINIMUM OVERSHOOT
- WELL DAMPED
- DECREASED WORKLOAD

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SIMULATION STUDY IN WIND SHEAR

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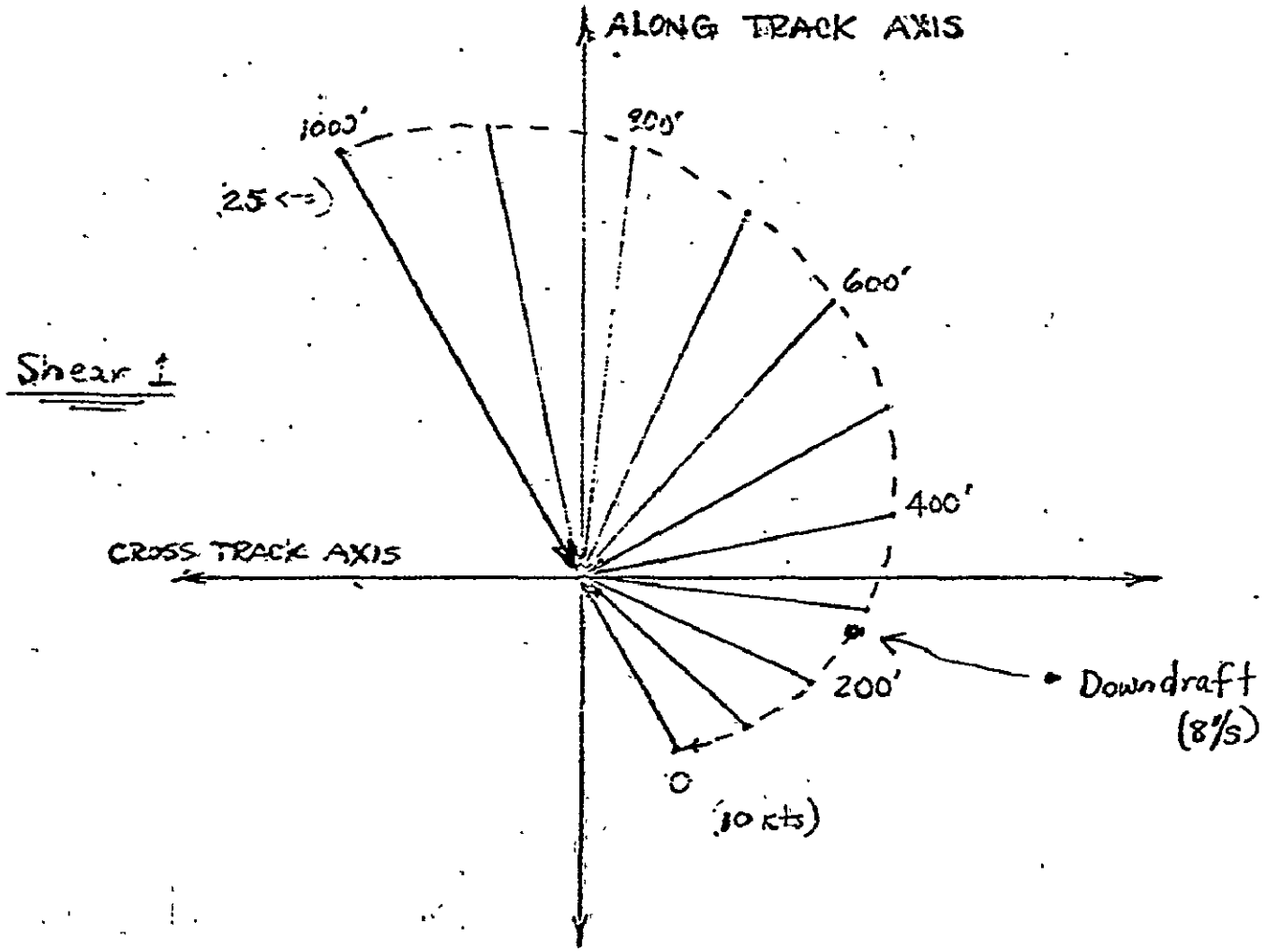
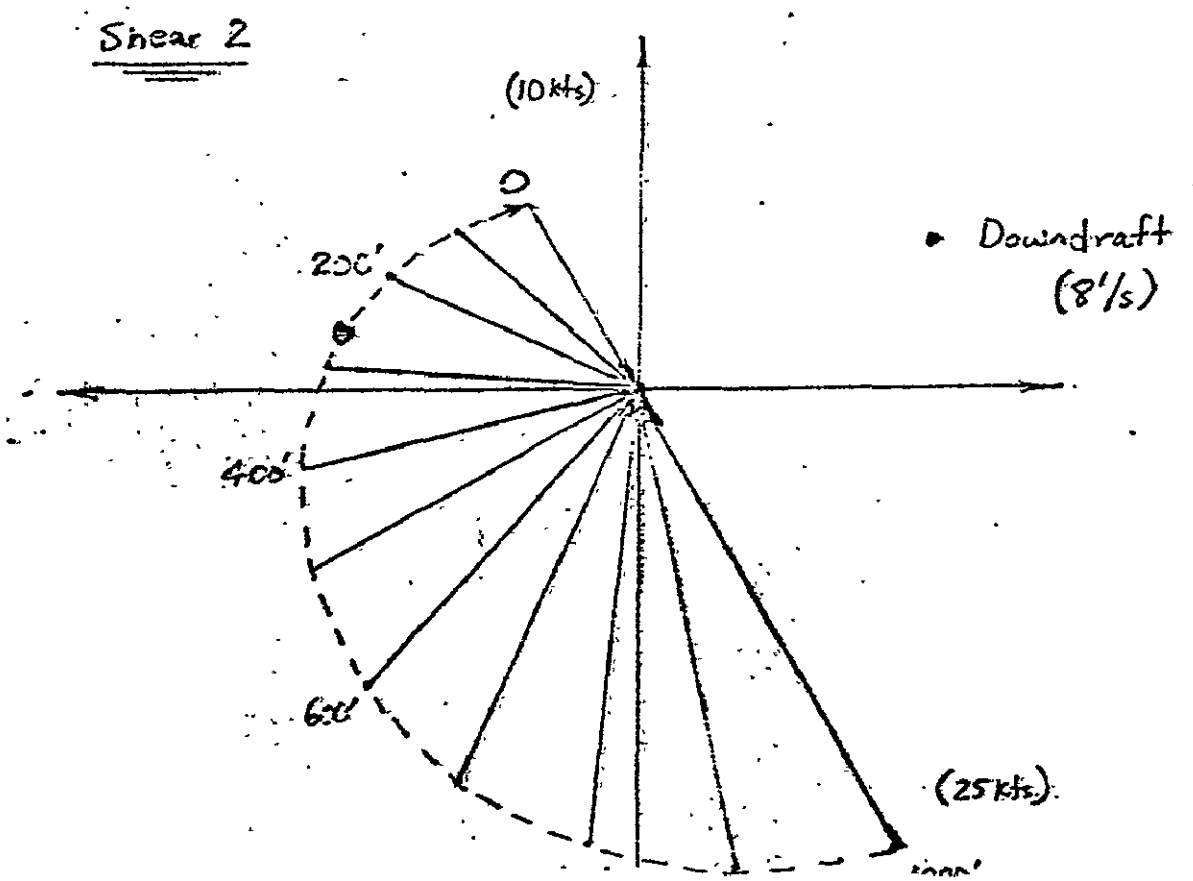
OBJECTIVE:

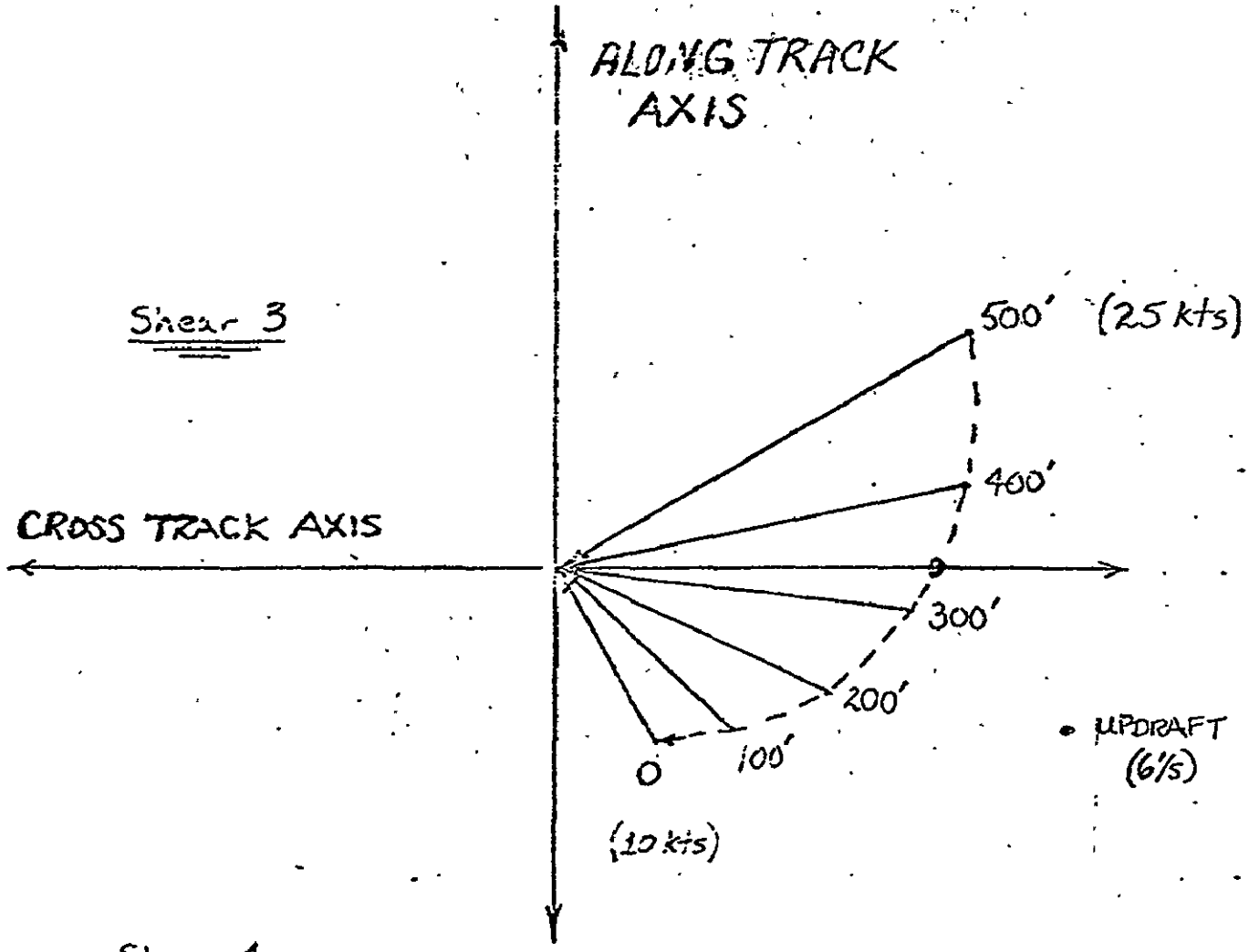
- INVESTIGATE BASELINE DISPLAY INFORMATION (FLIGHT DIRECTOR FORMAT) AND INTEGRATED DISPLAY INFORMATION IN THE WIND SHEAR ENVIRONMENT.

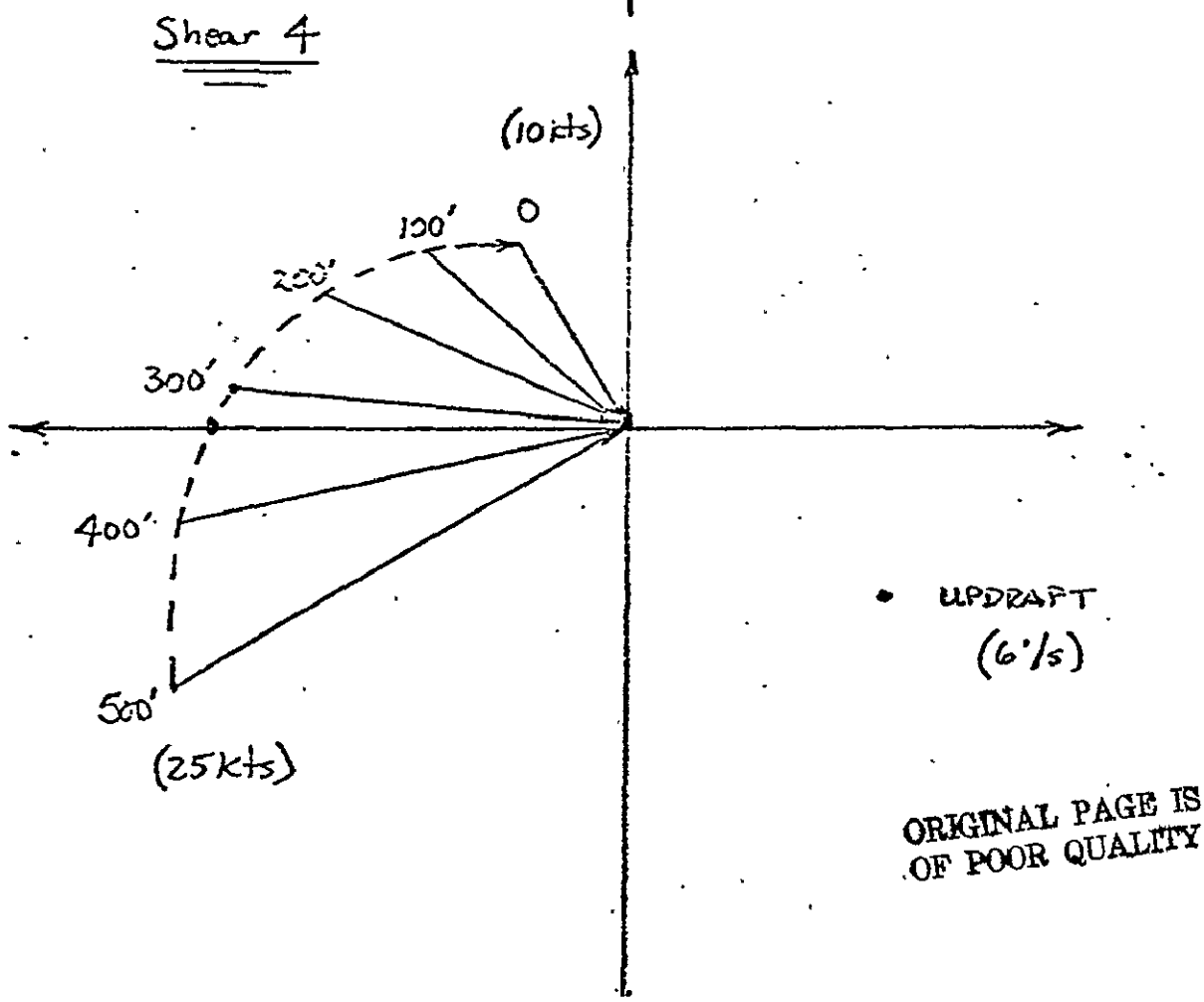
EXPERIMENT DESIGN:

- 3°, STRAIGHT-IN INSTRUMENT APPROACH
- 5 WIND PROFILES
- 2 DISPLAY/CONTROL CONFIGURATIONS


ALONG TRACK AXIS
1000'
800'
25 (kts)
600'
Shear 1
400'
CROSS TRACK AXIS
200'
Downdraft
(8'/s)
0
(10 kts)


Shear 2
(10 kts)
0
200'
Downdraft
(8'/s)
400'
600'
(25 kts)





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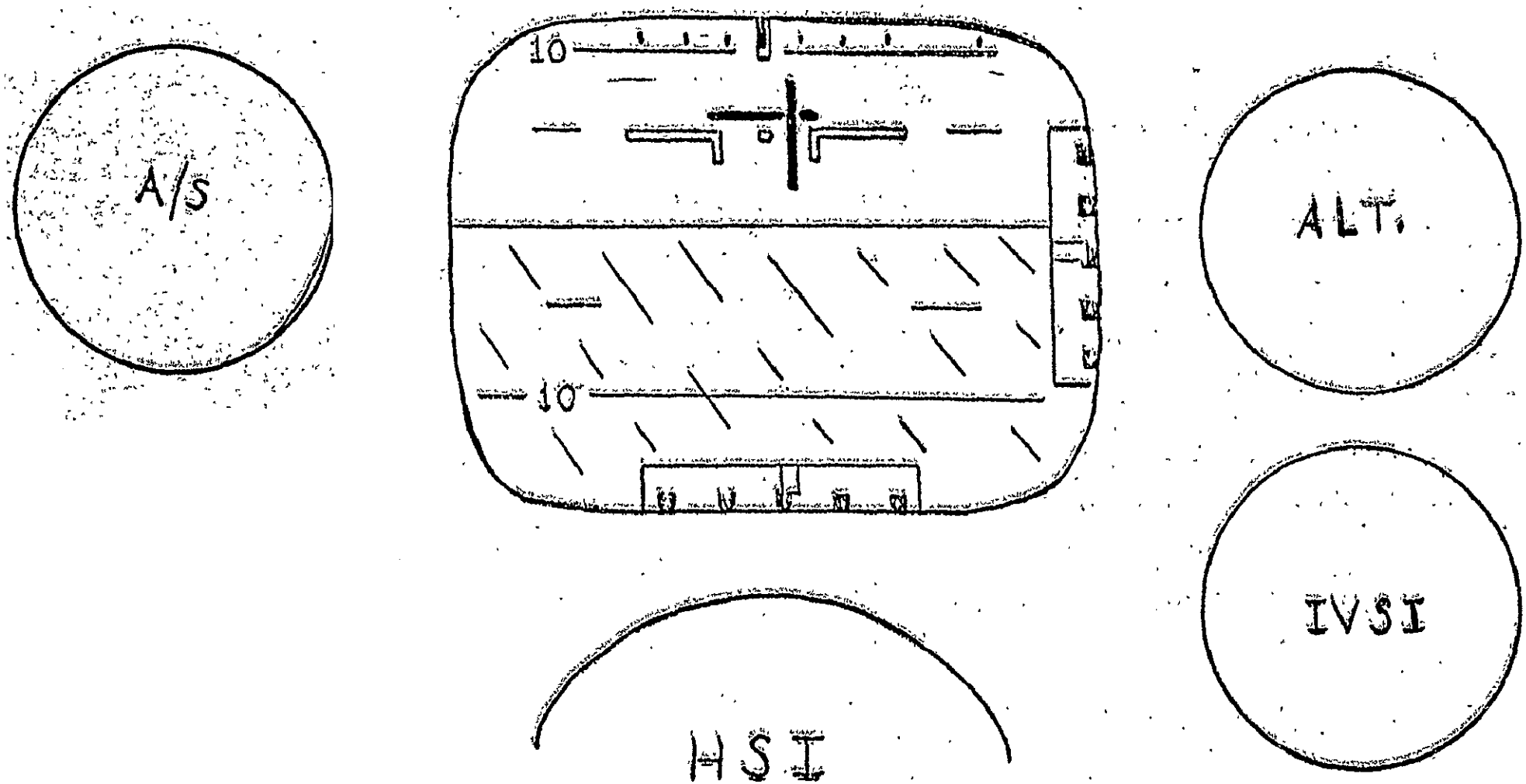
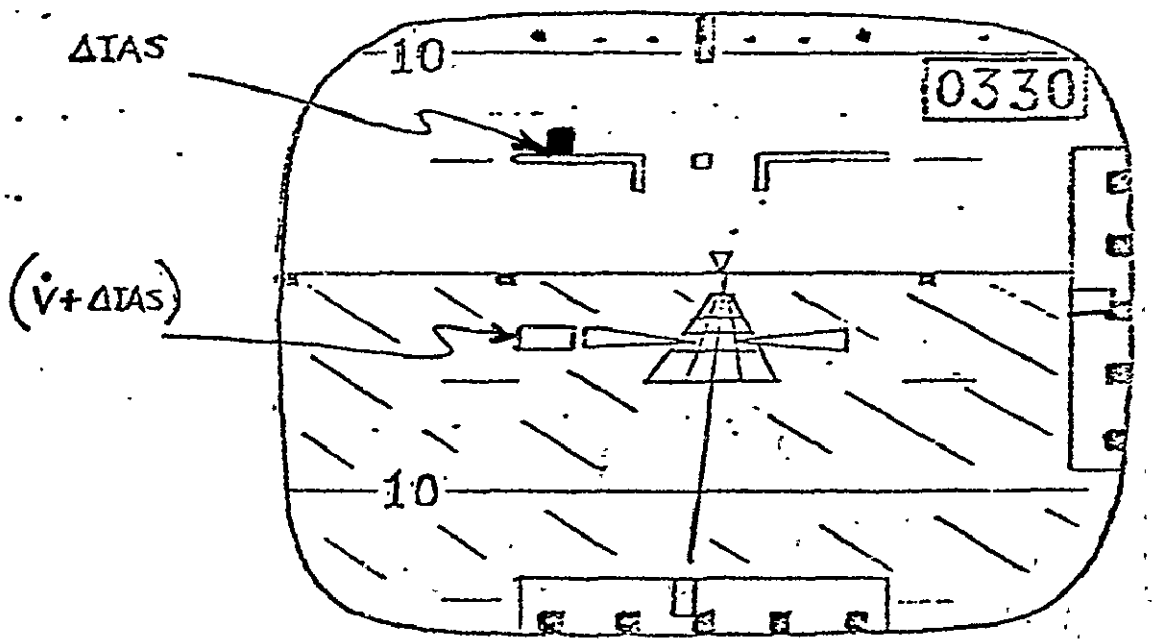


FLIGHT-DIRECTOR FORMAT



INTEGRATED DISPLAY FORMAT

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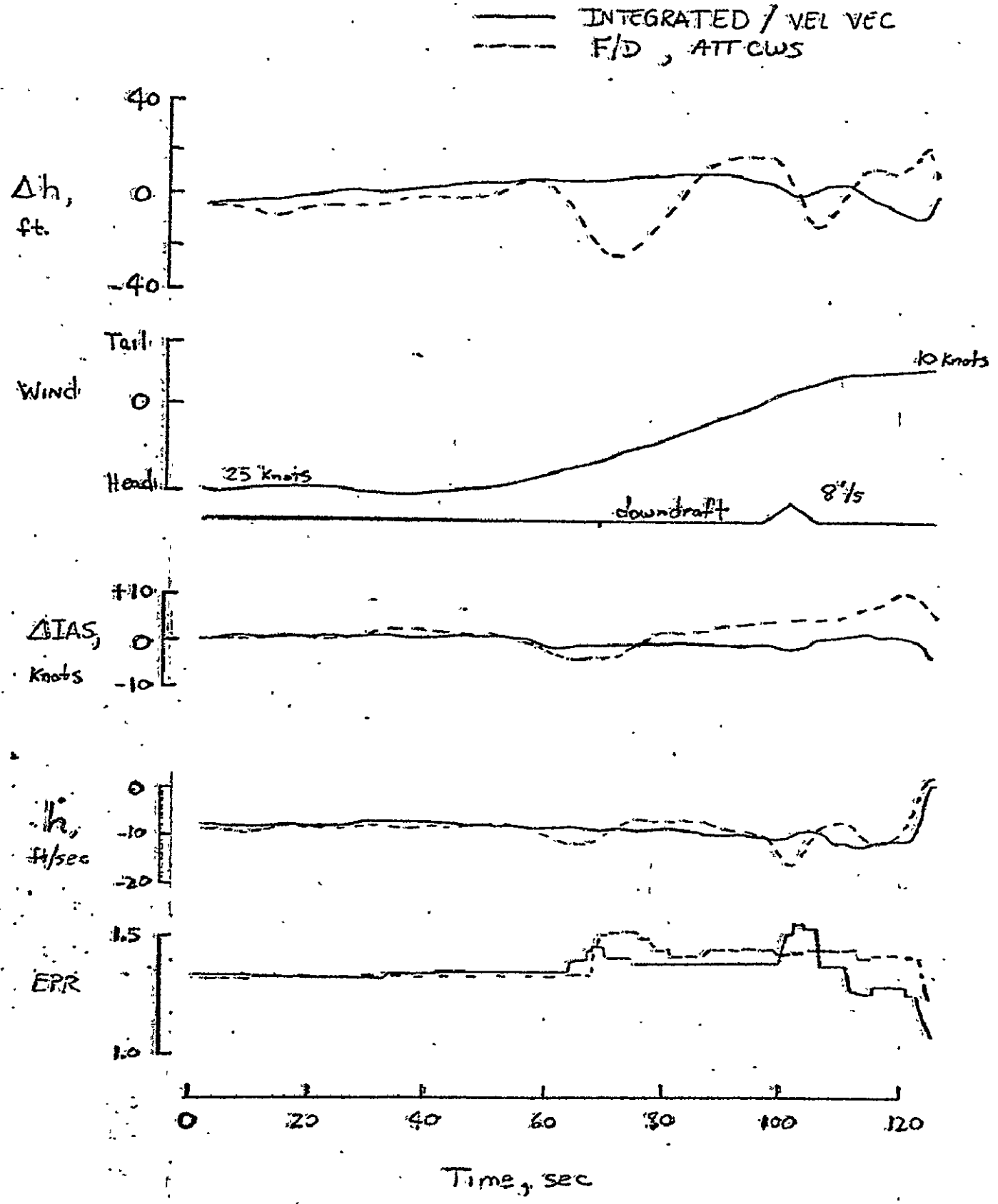
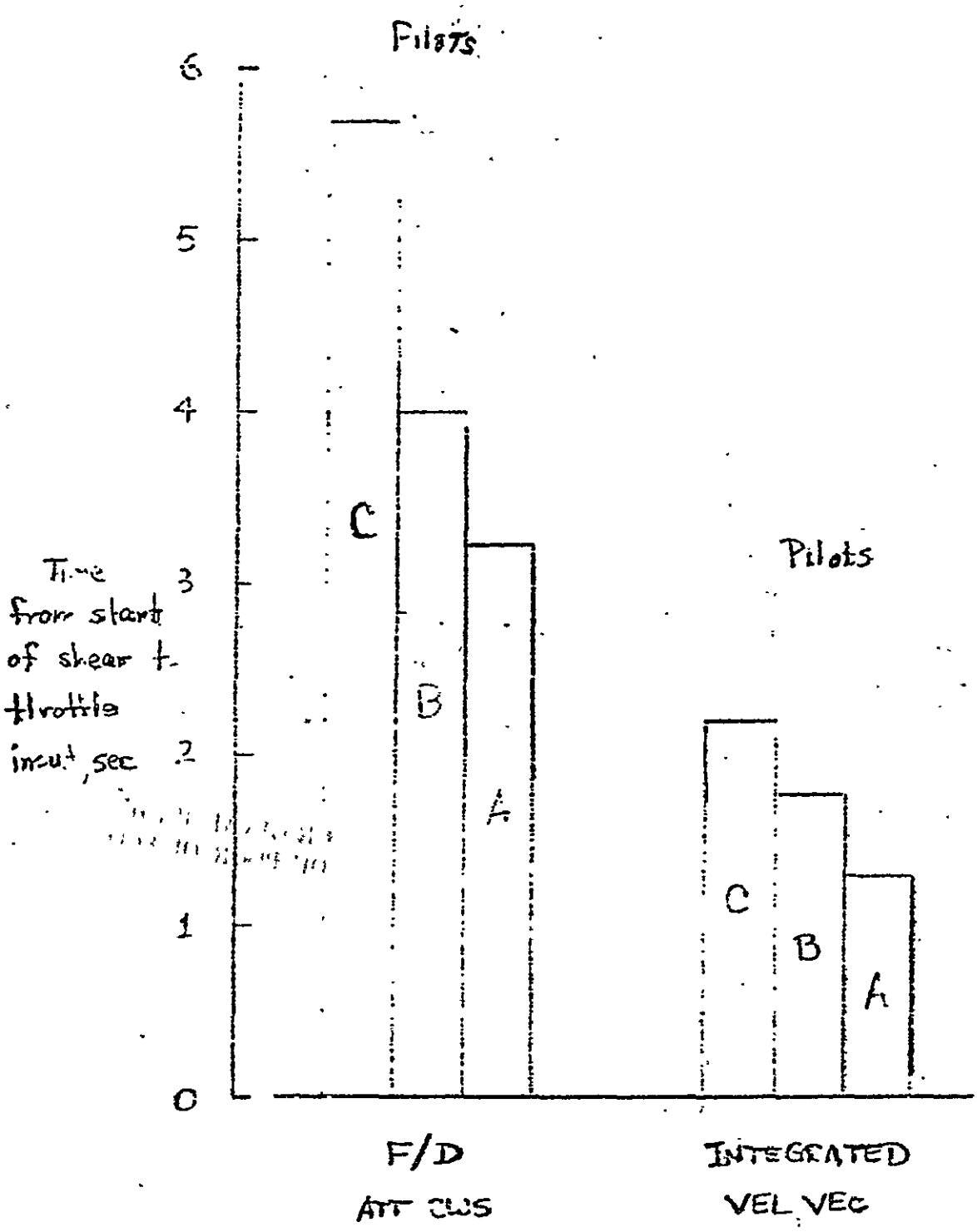
CKD. BY ..... DATE ..... JOB NO. .....

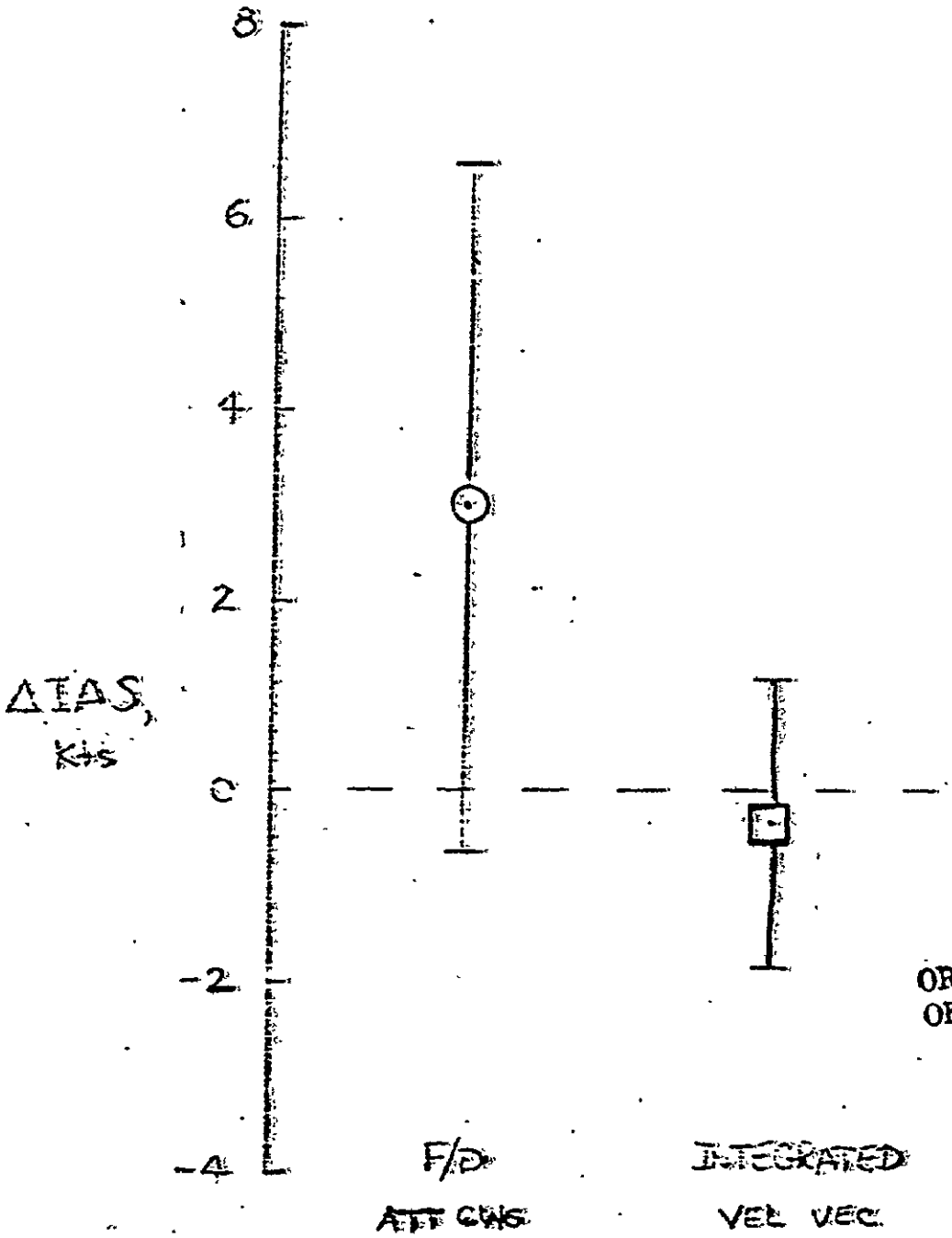


TIME HISTORY OF APPROACH WITH WIND SHEAR 1



DISPLAY/CONTROL CONFIGURATION

THRUST RESPONSE FOR WIND SHEAR 3



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SUMMARY DATA FOR SHEARS 1, 3, & 5

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

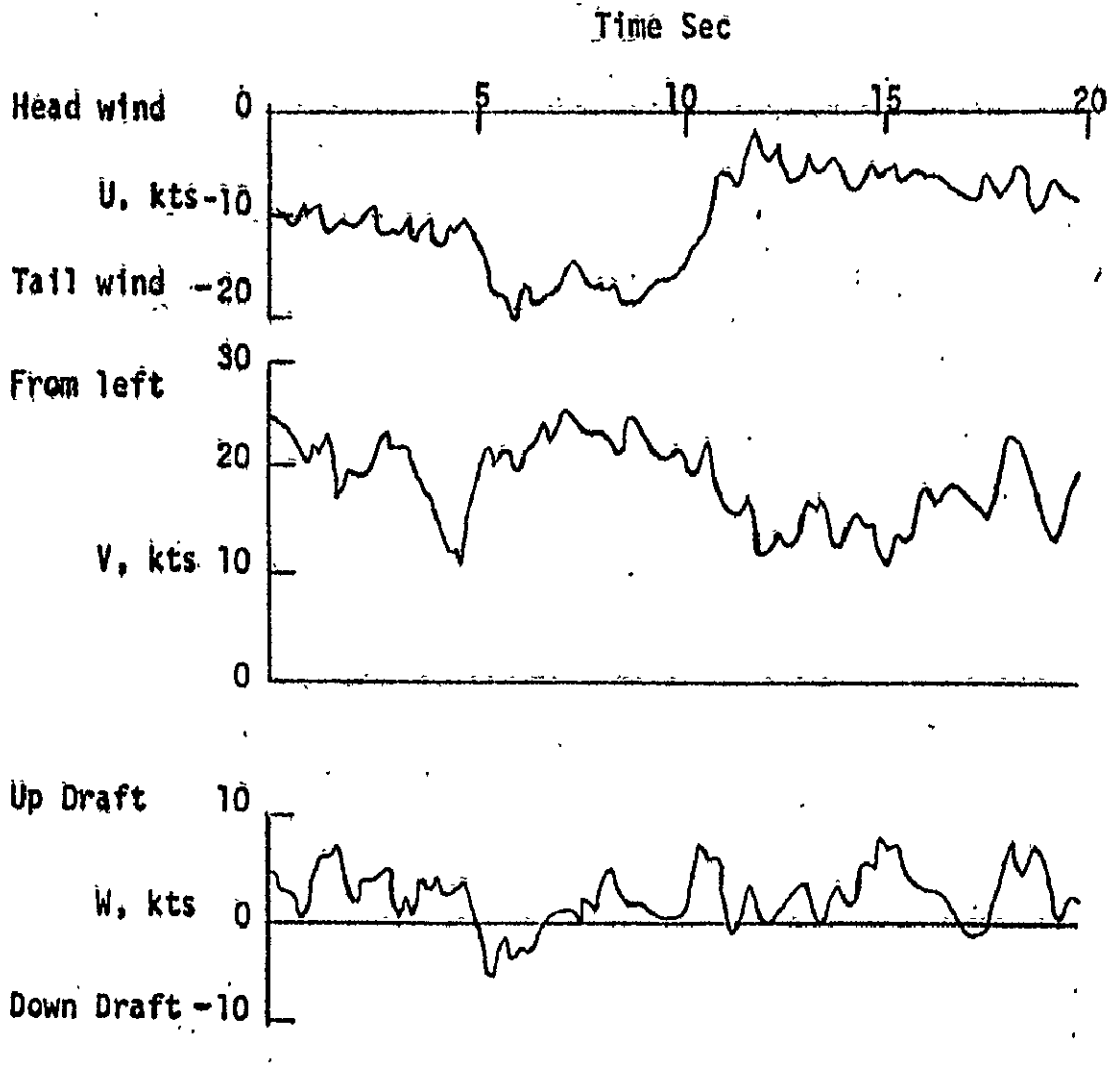
WIND SHEAR RESEARCH

OBJECTIVES

- MEASUREMENT OF SHEAR
- A WIND SHEAR DETECTOR

WIND VELOCITY COMPONENTS

MAY 19, 1976 13:44:21



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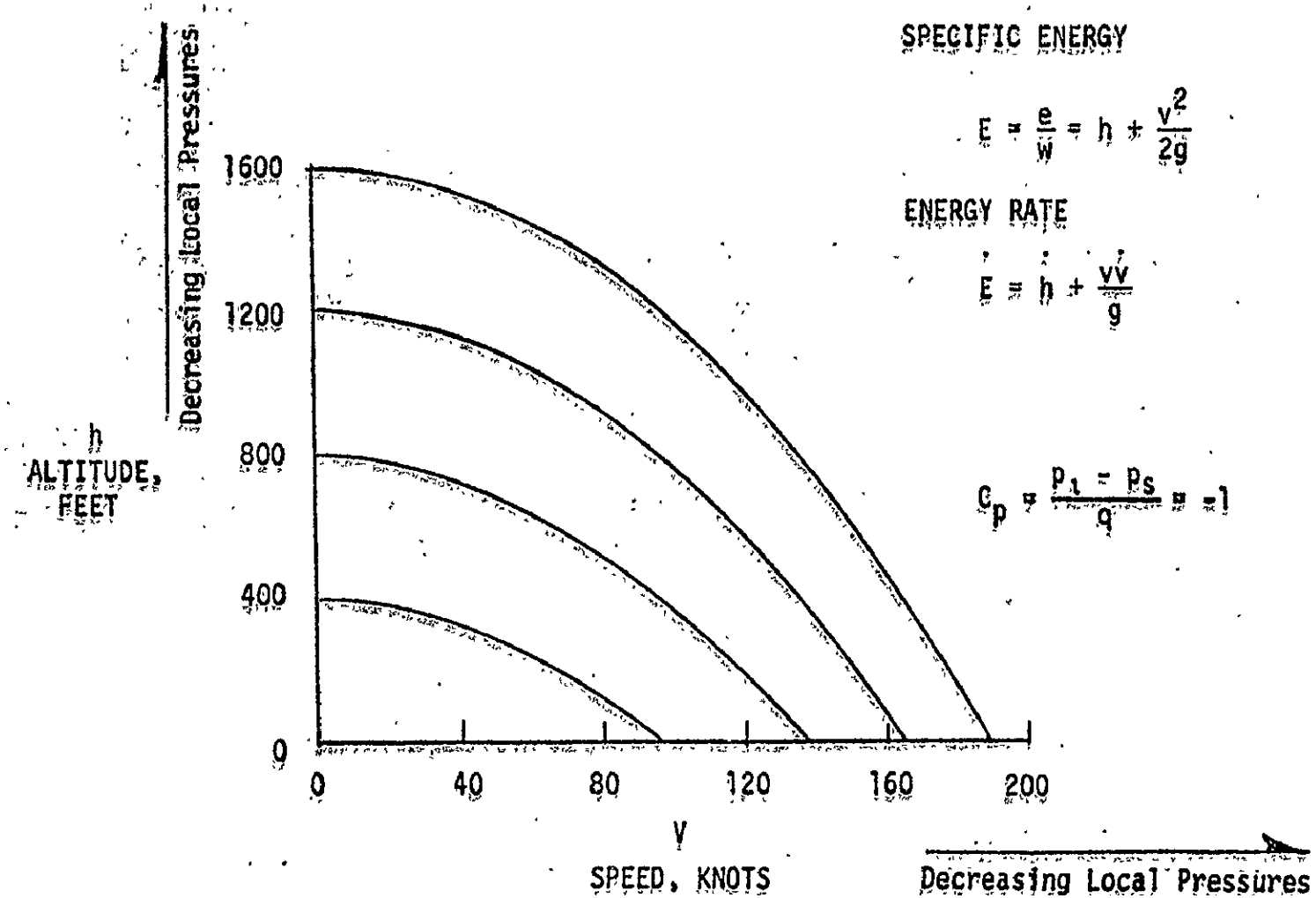
ENERGY CONCEPT



SPECIFIC ENERGY

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

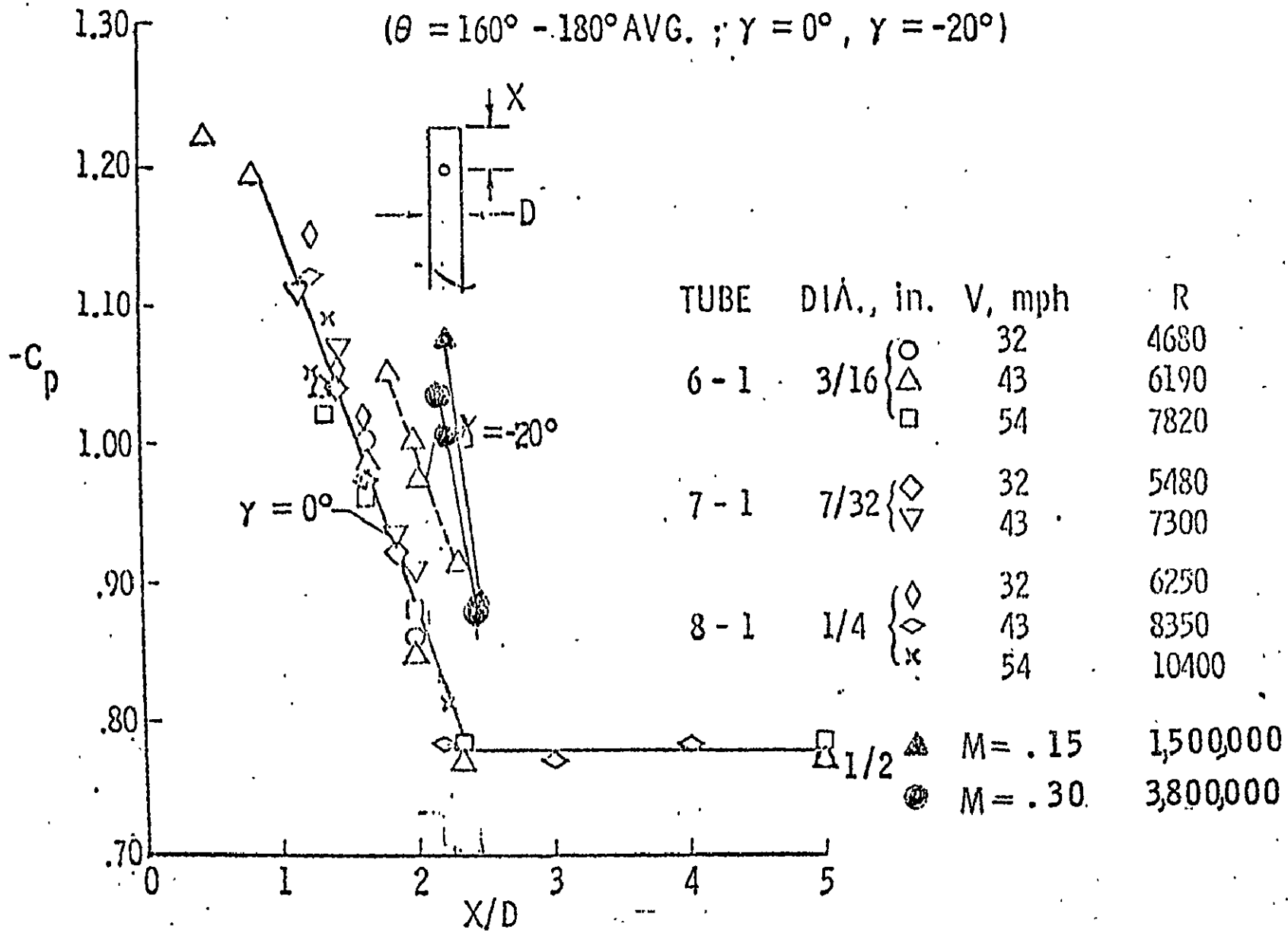
ENERGY RATE

$$\dot{E} = \dot{h} + \frac{v\dot{v}}{g}$$

$$C_p = \frac{p_t - p_s}{q} = -1$$

PRESSURE COEFFICIENTS AS FUNCTION OF HOLE POSITION

(θ = 160° - 180° AVG. ; γ = 0°, γ = -20°)



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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

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AIRPLANE LONGITUDINAL STABILITY AND CONTROL AS AFFECTED BY WIND SHEAR

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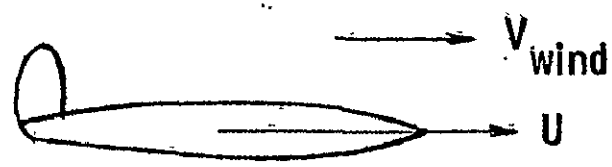
WINDSOR L. SHERMAN

DEFINITION OF WIND SHEAR



POSITIVE WIND SHEAR CHANGES A HEAD WIND INTO A TAIL WIND, THAT IS,

$$\frac{dV_w}{dt} \text{ IS POSITIVE}$$

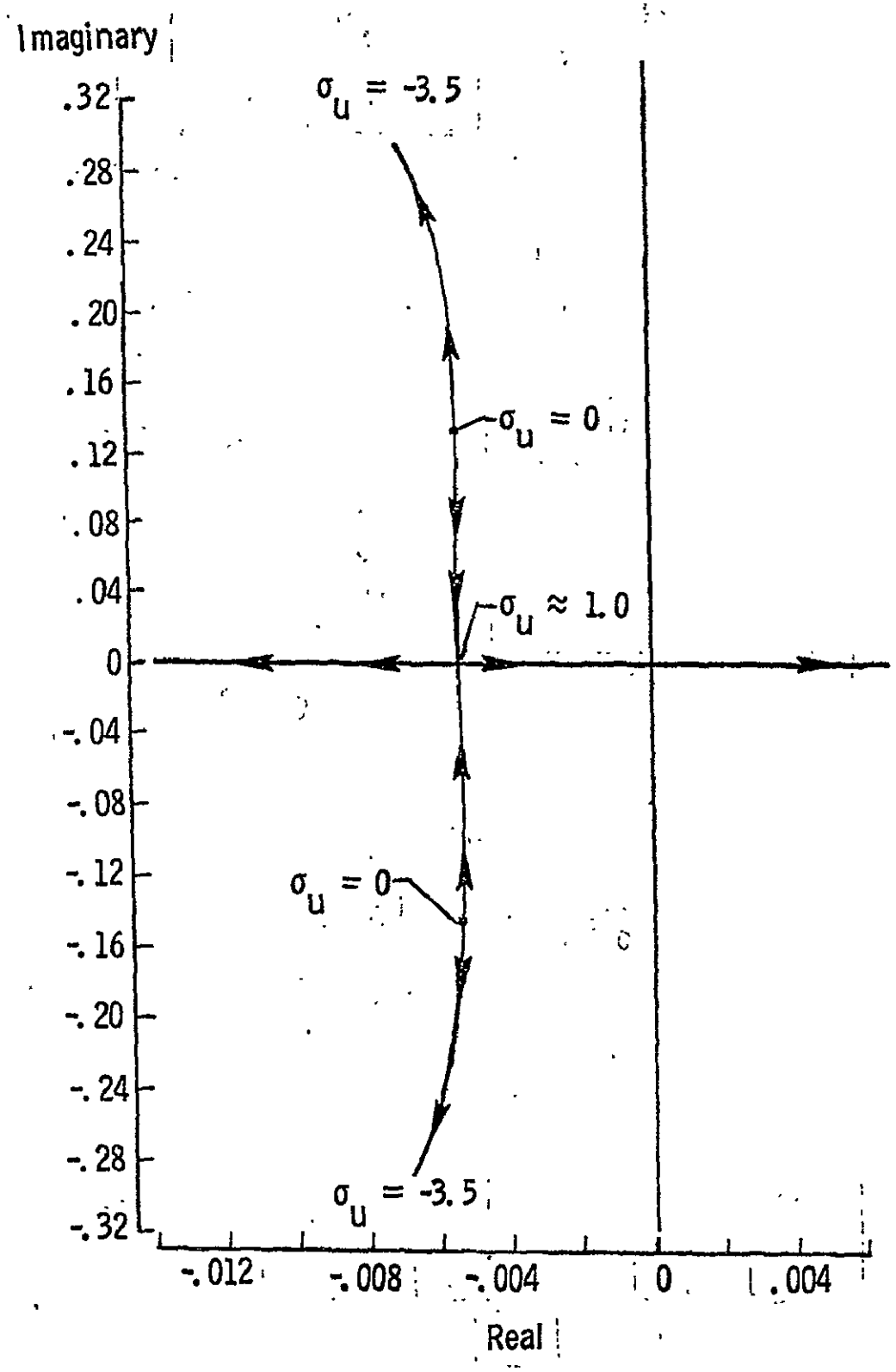
OR

$$V_w' = \frac{dV_w}{dh} (\text{sgn } \Gamma) \text{ IS POSITIVE}$$

WIND SHEAR PARAMETER:

$$\sigma_u = \frac{V_w' \, U_0}{g}$$

WIND SHEAR EFFECT ON THE LONG PERIOD LONGITUDINAL MODE, ROOT LOCUS



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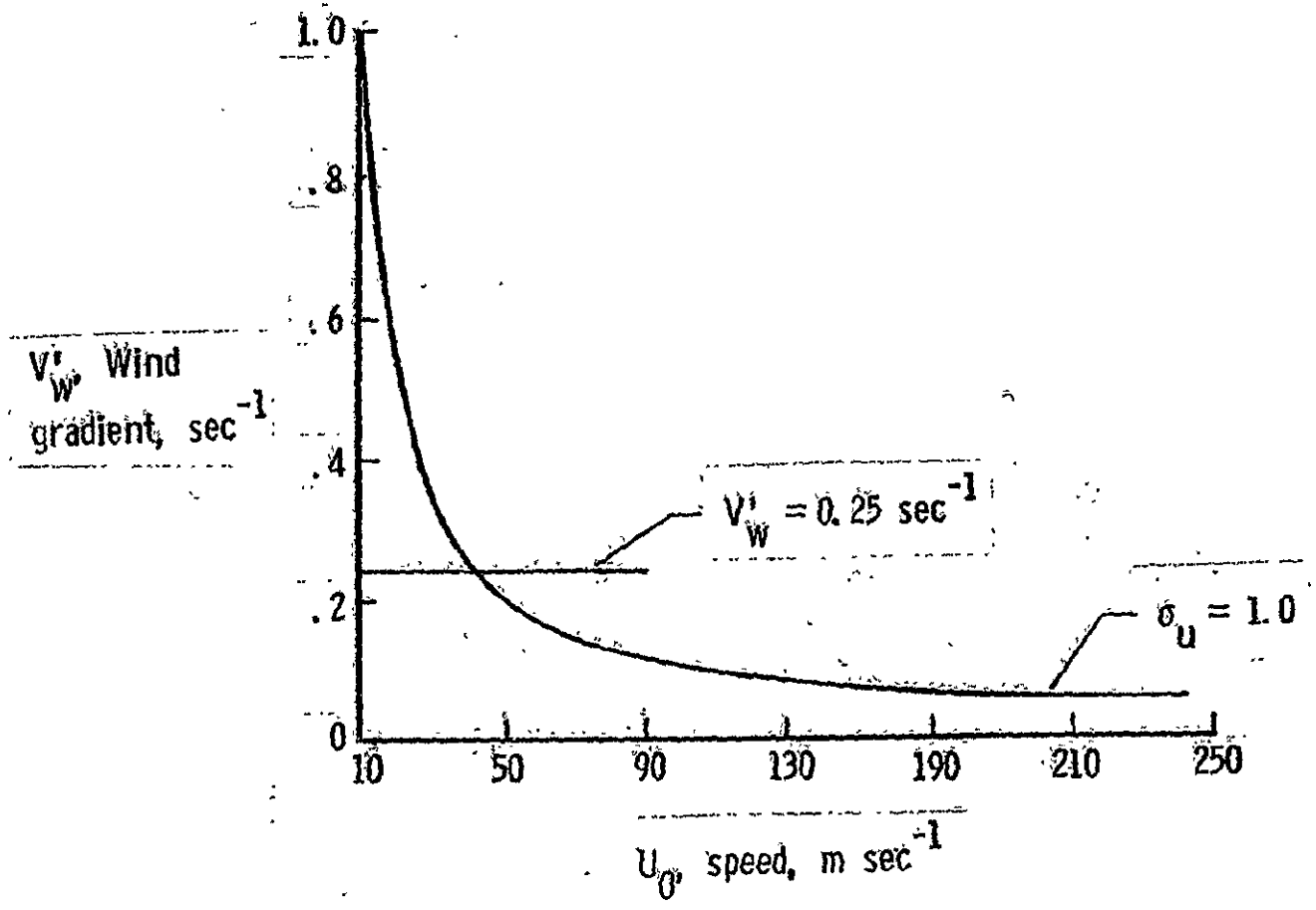
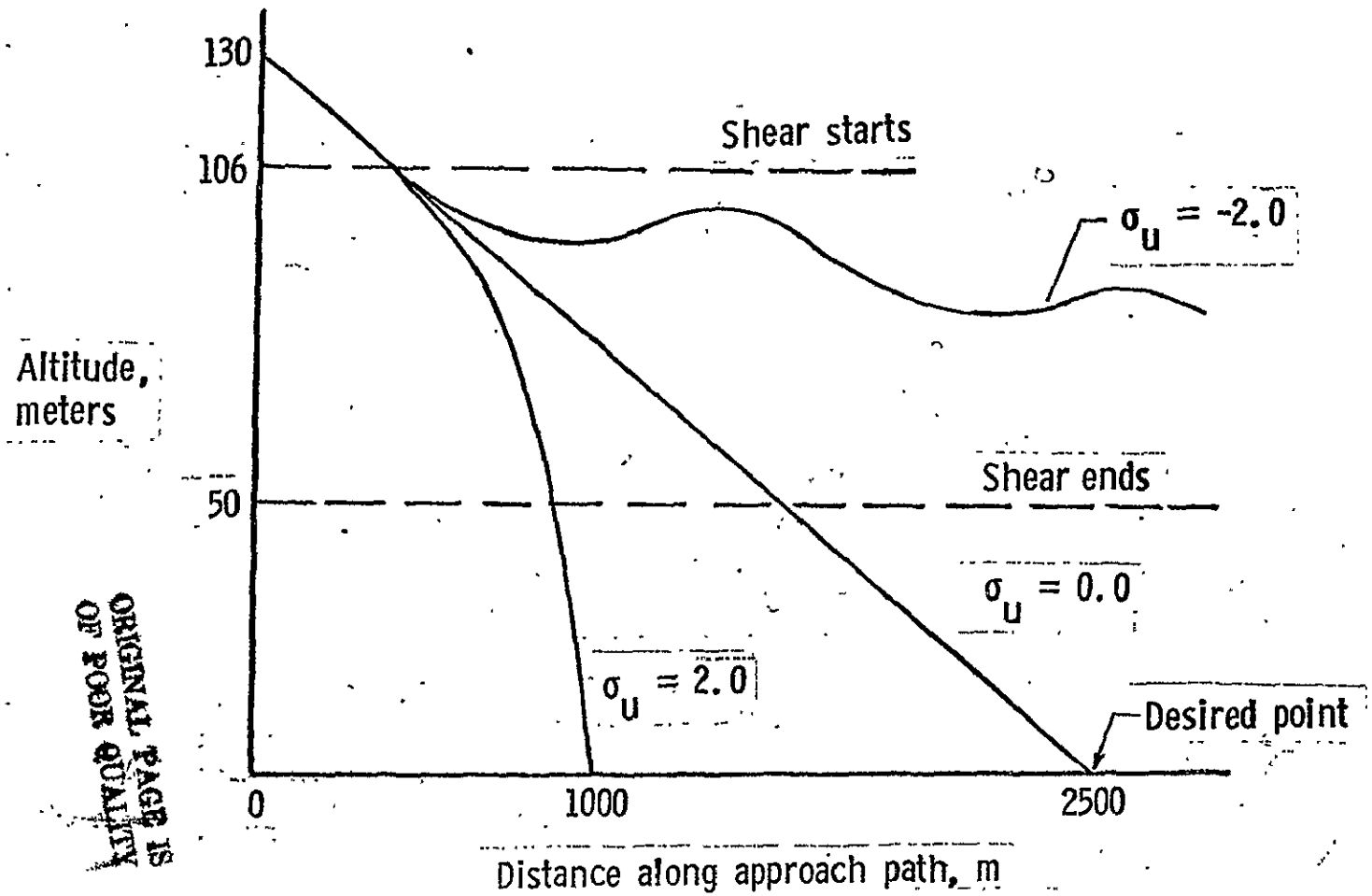
VALID FOR ALL AIRPLANES



EFFECT OF WIND SHEAR ON ALTITUDE TRACK

CONTROL FIXED CASE



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AUTOMATIC PILOTS

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

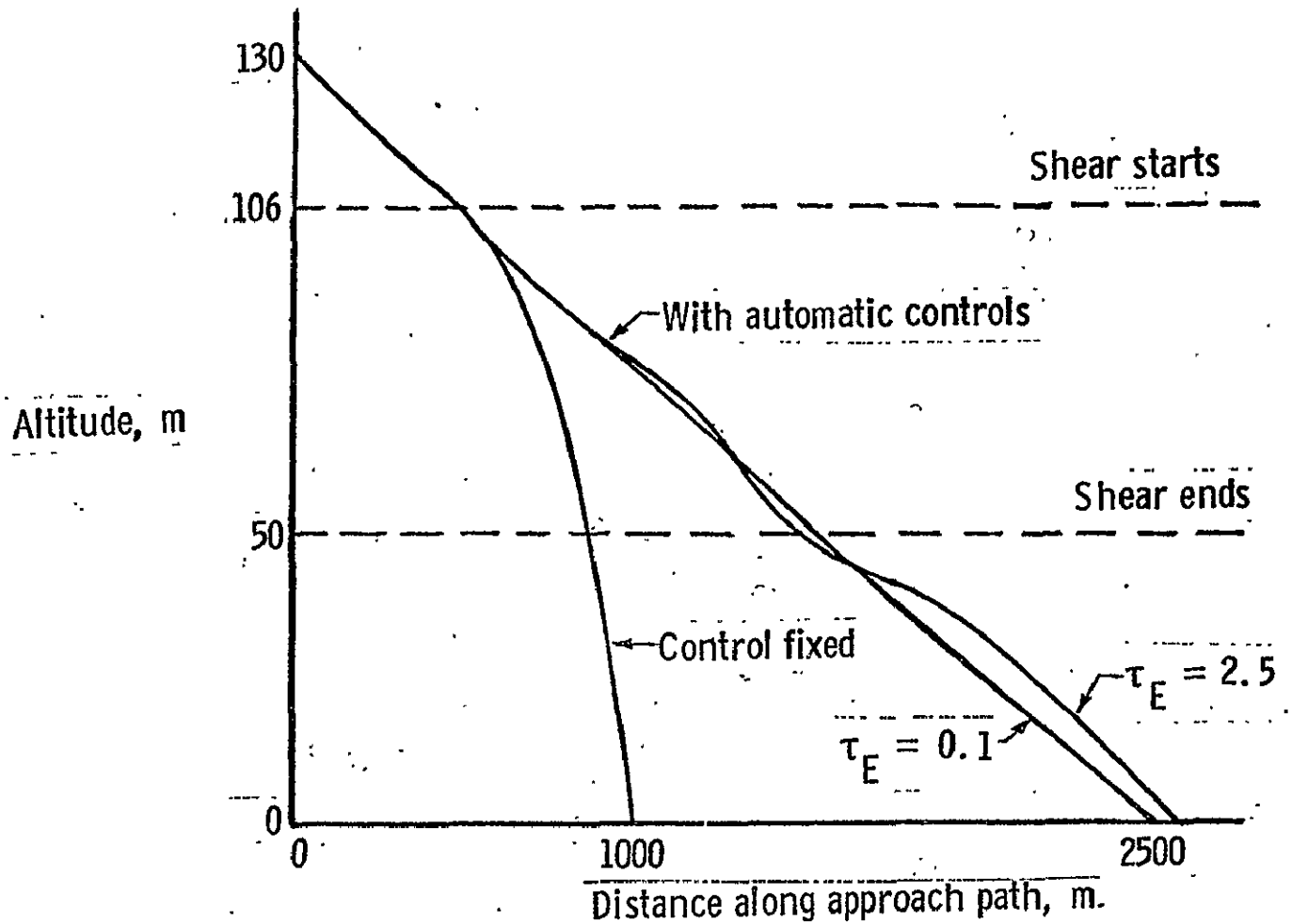
AIRSPEED AND FLIGHT PATH CONTROLS - PROVIDES GOOD CONTROL

AIRSPEED AND PITCH CONTROLS - PROVIDES GOOD CONTROL

ALTITUDE TRACK CONTROL BY AUTO PILOTS

AIRSPEED AND FLIGHT PATH CONTROLS

$\sigma_u = 2.0$



τ_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.

2
201

- OBJECTIVE

TO DETERMINE THE ADVANTAGES AND DISADVANTAGES OF THE HEAD UP DISPLAY CONCEPT IN APPROACH AND LANDING OPERATIONS.

Viewgraph 1a
R. F. Haines
February 16, 1977

500-3
201-

VIEWGRAPH 3

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

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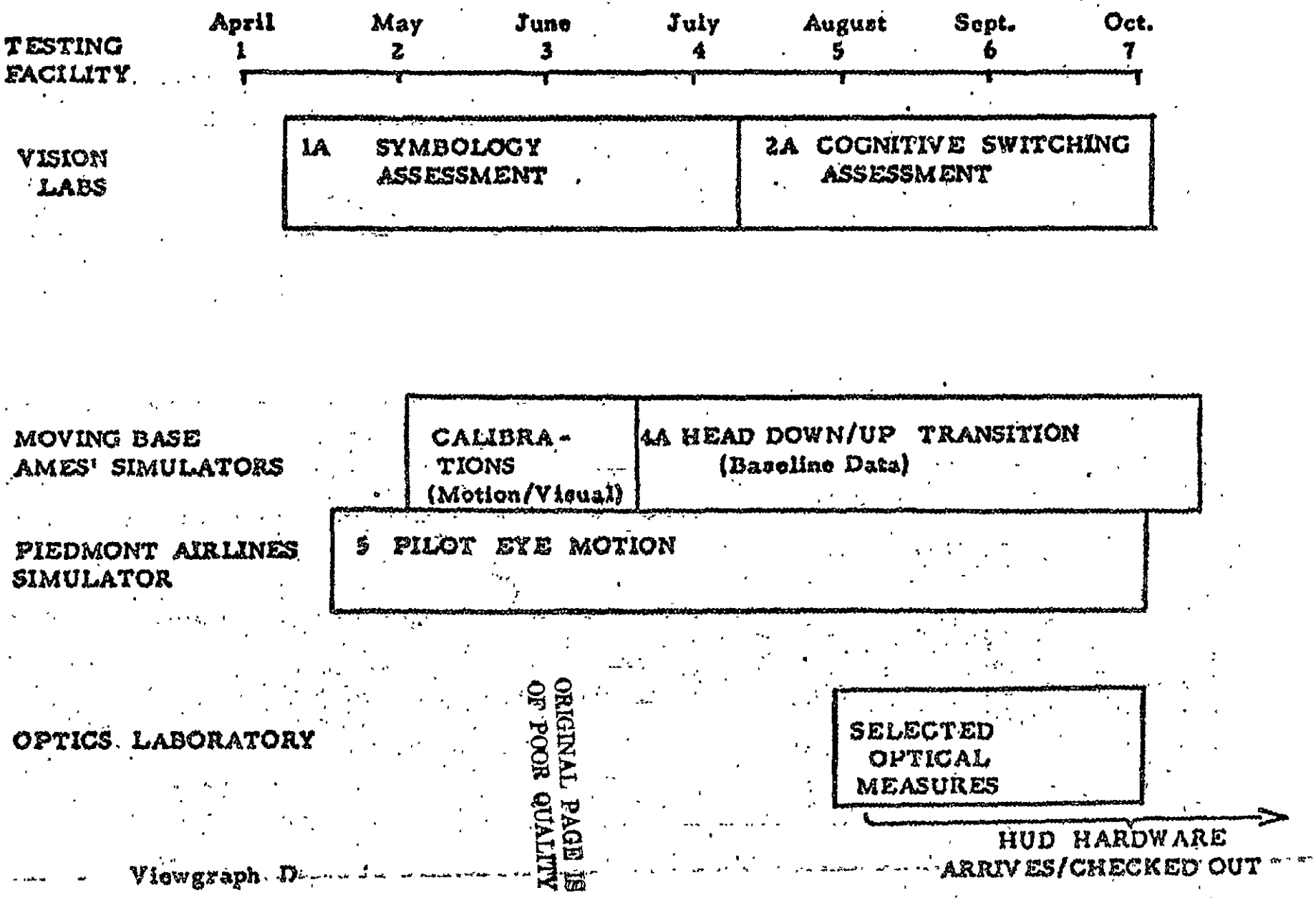
HUMAN FACTORS/PERCEPTION TESTS - SCHEDULE (1977)



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Viewgraph D

R. F. Haines 9-8-77

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HUMAN FACTORS/PERCEPTION TESTS - SCHEDULE (1977 - 1978)

TESTING FACILITY	Nov. 8	Dec. 9	Jan. 10	Feb. 11	March 12	April 13	May 14	June 15
VISION LABS	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							

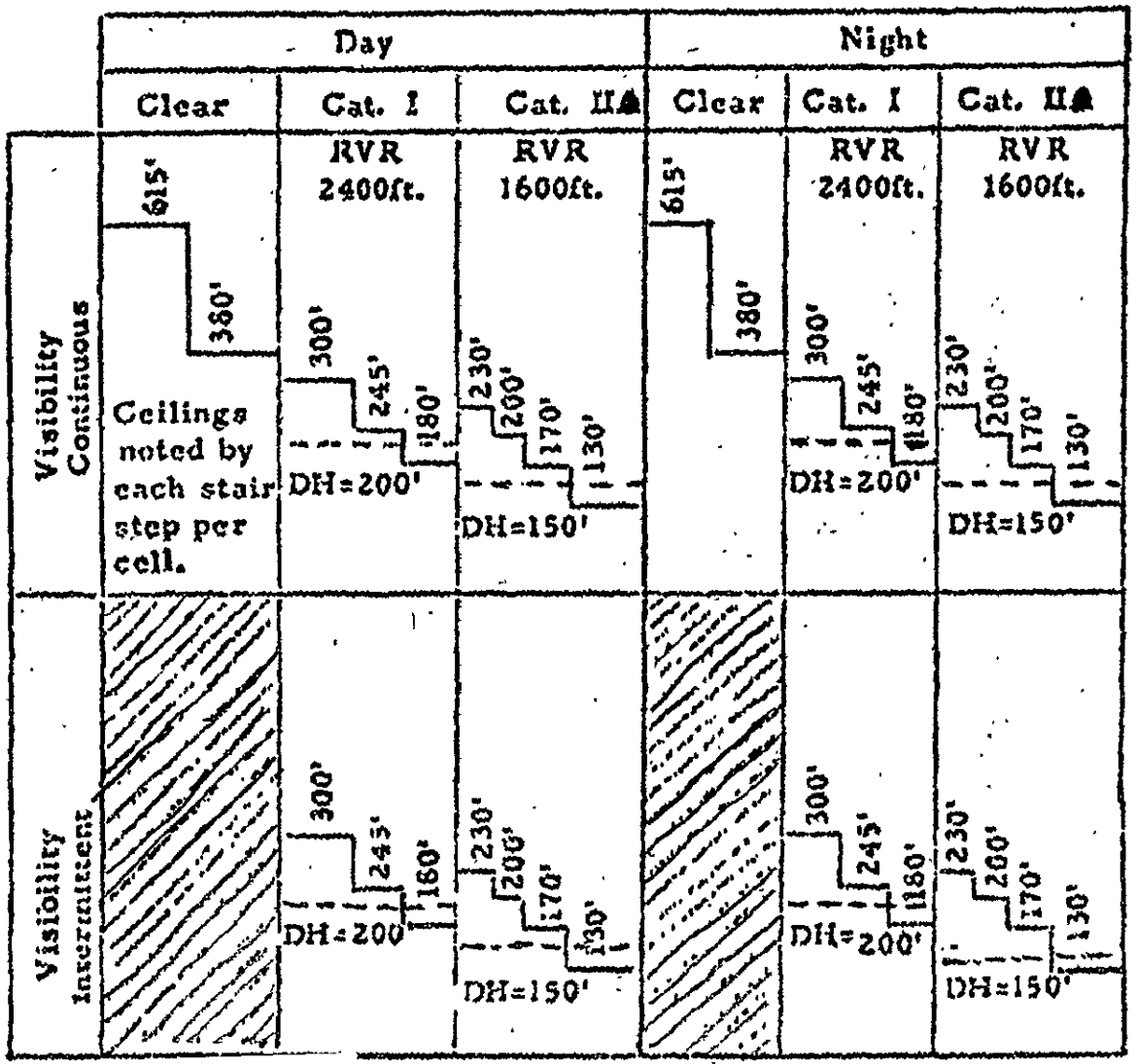
Viewgraph E

R. F. Haines 9-8-77

FAA/NASA
HUD Program
Viewgraph 1
July 29, 1977

Figure 9

Experimental Design for
737 Simulator Study at Ames



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Viewgraph 6 F

APPENDIX Q

AD HOC ADVISORY PANEL
TERMINAL-CONFIGURED VEHICLES PROGRAM

September 14-16, 1977

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)

- Flying Tigers/Sundstrand/B747 (Line Flying - Spring-Summer 1977)
- Eastern/ARMA - Lockheed/L-1011 (Service Eval. - Nov. 1977)
- Saudi Arabian (TWA)/ARM-LCC/L-1011 (Certified - Sept. 1977)

(Slides) - Eastern/Airbus Industries/A300 (Prototype Flt. Test - Summer 1978)

- Pan American/Delco Div. of GM/B747 (timing?)

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.

C-3

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 arn'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, "

APPENDIX K

TCV RELATED PUBLICATIONS

REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
AGARD Conference on Air Traffic Control Systems Edinburgh, Scotland	An Analytic Study of Near Terminal Area Optimal Sequencing and Flow Control Techniques	Stephen K. Park Terry A. Straeter John E. Hogge	6/26-29/72
CR-112195	Development of Simulation Techniques Suitable for the Analysis of Air Traffic Control Situations and Instrumentation	Research Triangle Institute	8/72
1972 Joint Automatic Contol Conf. Palo Alto, CA	Application of Optimization Techniques to Near Terminal Area Sequencing and Flow Control	Terry A. Straeter Stephen K. Park John E. Hogge	8/16-18/72
CR-132278	Study of the Impact of Air Traffic Management Systems on Advanced Aircraft and Avionic Systems	Research Triangle Institute	2/73
Mathematical Programing Society Symposium on Nonlinear Programing George Washington University Washington, DC	Near Terminal Optimal Sequencing and Flow Control As a Mathematical Programing Problem	Stephen K. Park Terry A. Straeter	3/14-16/73
AIAA 12th Aerospace Sciences Meeting Washington, DC	Electronic Displays and Digital Automatic Control in Advanced Terminal Area Operations	Seymour Salmirs Harold N. Tobie	2/74
TM X-71928	Preliminary Results of Flight Tests of Vortex Attenuating Splines	Earl C. Hastings Robert E. Shanks Robert A. Champine W. Latham Copeland Douglas C. Young	3/74
Working Paper No. 1159	A Review of Some Past Landing Display and ILM Work and Its Application to the Terminal Configured Vehicle Program	W. Thomas Bundick	4/3/74

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TCV RELATED PUBLICATIONS

REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
NASA TN D-7611	Preliminary Study of a Possible Automatic Landing System	Windsor L. Sherman Sylvia W. Winfrey	7/74
NASA TN D-7652	Parametric Analysis of an Imaging Radar for Use As an Independent Landing Monitor	W. Thomas Bundick	8/74
18th Symposium of the Society of Experimental Test Pilots Los Angeles, CA	Future Airborne Systems for Terminal Area Operations	John P. Reeder	9/26-29/74
TM X-72618	Flight-Test Handling Qualities Documentation of the Research Support Flight System	Samuel A. Morello Jerry J. Thibodeaux Lee H. Person, Jr. Kenneth R. Yenni	10/74
Final Report University of Virginia Charlottesville, VA	Research Studies in the Area of Optimal Landing Flight Path Trajectories	Gerald Cook Richard M. Witt Atalay Barkana	12/74
TM X-72006	New Design and Operating Techniques and Requirements for Improved Aircraft Terminal Area Operations	John P. Reeder Robert T. Taylor Thomas M. Walsh	12/74
CR-132562	Development and Modification of a Digital Program for Final Approach to Landing	William G. Duff Charles R. Guarino	1/75
Report No. 75-1 Analytical Mechanics Associates, Inc. Mountain View, CA	A Conceptual CTOL Navigation System for Curved-Descending-Decelerating Approaches	Stanley F. Schmidt	1/75
AIAA 13th Aerospace Sciences Meeting Pasadena, CA	Empirical Comparison of a Linear and a Nonlinear Washout for Motion Simulators	R. V. Parrish D. J. Martin, Jr.	1/20-22/75
1974 International Conference on System, Man and Cybernetics	On the Quadratic Sampled-Data Regulator With Unstable Random Disturbances	N. Halyo R. H. Foulkes	10/74

TCV RELATED PUBLICATIONS

REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
NASA TN D-7876	A General Algorithm for Relating Ground Trajectory Distance, Elapsed Flight Time, and Aircraft Airspeed and Its Application to 4-D Guidance	Edwin C. Foudriat	2/75
University of Virginia Charlottesville, VA	Microwave Landing System Airborne Receiver Analysis	G. A. McAlpine J. H. Highfill, III S. H. Irwin, Jr.	2/75
Journal of Aircraft Marquette University Milwaukee, WI	Position Accuracy of Aircraft Area Navigation Systems and the Effect of System Parameters	Edwin C. Foudriat	6/75
NASA TM X-72685	The Effect of Measurement Errors and Computational Approximations on a Perspective ILM Radar Image	W. Thomas Bundick	7/75
TM X-72760	Baseline Measurement of the Noise Generated by a Short-to-Medium Range Jet Transport Flying Standard ILS Approaches and Level Flyovers	Earl C. Hastings, Jr. Robert E. Shanks Arnold W. Mueller	8/4/75
CR-132713	Refinement and Validation of Two Digital Microwave Landing System (MLS) Theoretical Models	William G. Duff Charles R. Guarino	8/15/75
NASA TM X-72715	Wind Tunnel/Flight Data Correlation for the Boeing 737-100 Transport Airplane	Francis J. Capone	8/75
NASA TN D-7971	Effect of External Disturbances and Data Rate on the Response of an Automatic Landing System Capable of Curved Trajectories	Windsor L. Sherman	9/75

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REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
NASA TN D-7980	Automatic Guidance and Control of a Transport Aircraft During a Helical Landing Approach	Daniel J. Crawford Roland L. Bowles	9/75
University of Virginia Charlottesville, VA	Optimization and Sensitivity Studies of Flight-Path Trajectories	Gerald Cook Richard M. Witt	9/75
NASA CR-132687	Analytical Evaluation of ILM Sensors	Raymond J. Kirk	9/75
NASA CR-144902	Analytical Evaluation of ILM Sensors (Supplement)	Raymond J. Kirk C. Edward Johnson Douglas Doty	10/75
Paper Application of Computer Graphics in Engineering Conference NASA Langley Research Center Hampton, VA	The Design and Implementation of CRT Displays in the TCV Real-Time Simulation	John B. Leavitt Syed I. Tariq George Steinmetz	10/75
NASA CR-144959	Simulation, Guidance, and Navigation of the B-737 for Rollout and Turnoff Using MLS Measurements	S. Pines S. F. Schmidt F. Mann	12/75
NASA TN D-8083	Development and Flight Tests of Vortex-Attenuating Splines	Earl C. Hastings, Jr. J. C. Patterson, Jr. Robert E. Shanks Robert A. Champine W. Latham Copeland Douglas C. Young	12/75
Interim Report University of Virginia Charlottesville, VA	Optimization of MLS Receivers for Multipath Environments	G. A. McAlpine J. H. Highfill, III S. H. Irwin, Jr. J. E. Padgett	12/75

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REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
Guidance and Control Laboratory Stanford University, Stanford, CA	Aircraft Digital Control Design Methods	J. David Powell Eric Parsons Michael G. Tashker	2/76
Semi-Annual Report Ohio State University, Columbus, OH	Research on MLS Airborne Antenna	C. L. Yu W. D. Burnside	4/76
Technical Report Ohio State University, Columbus, OH	Volumetric Pattern Analysis of Fuselage-Mounted Airborne Antennas	C. L. Yu W. D. Burnside	4/76
NASA TN D-8190	A Simulation Study of Curved, Descending, Decelerating, Landing Approaches for Transport Aircraft	James E. Dieudonne Randall D. Grove George Steinmetz	4/76
NASA CR-144942	Timeline Analysis Program (TLA-1)-Final Report	K. H. Miller	4/76
NASA TN D-8183	A Piloted-Simulation Evaluation of Two Electronic Display Formats for Approach and Landing	George C. Steinmetz Samuel A. Morello Charles E. Knox Lee H. Person	4/76
NASA TM X-72683	A Comparison of Two Commercial and the Terminal Configured Vehicle Area Navigation Systems	Charles E. Knox Desmond Hartnell	6/76
NASA CR-144987	Vehicle Dependent Aspects of Terminal Area Guidance and Control	Research Triangle Institute	6/76
Masters Thesis VPI and State University Blacksburg, VA	Simulation of Runway Exit Systems	James H. Kranich, Jr.	6/76
Masters Thesis VPI and State University Blacksburg, VA	A Decision Problem Involving the Introduction of RTOL Aircraft into Commercial Air Transportation Systems	Gary A. Schmitt	6/76
NASA CR-144943	Timeline Analysis Program (TLA-1) Final Report - Appendices	K. H. Miller	4/76

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REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
NASA TM X-3387	Noise Measurements for a Twin-Engine Commercial Jet Aircraft During 3° Approaches and Level Fly-overs	Earl C. Hastings Robert E. Shanks Arnold W. Mueller	7/76
Bolt Beranek and Newman Cambridge, MA	Analytic and Experimental Evaluation of Display and Control Concepts for a Terminal Configured Vehicle	William H. Levison Sheldon Baron	7/76
NASA TM X-73952	Airborne Antenna Polarization Study for the Microwave Landing System	Melvin C. Gilreath	7/21/76
NASA CR-2687	Information and Display Requirements for Independent Landing Monitors	J. A. Sorensen J. S. Karmarkar	8/76
NASA TM X-73943	The Design, Development, and Flight Test Results of the Boeing 737 Aircraft Antennas for the ICAO Demonstration of the TRSB Microwave Landing System	T. G. Campbell W. F. White M. C. Gilreath	8/17/76
NASA CR-2720	Development of an Optimal Automatic Control Law and Filter Algorithm for Steep Glideslope Capture and Glideslope Tracking	Nesim Halyo	8/76
Annual Report University of Virginia Charlottesville, VA	Use of Steepest Descent and Various Approximations for Efficient Computation of Minimum Noise Aircraft Landing Trajectories	G. Cook R. M. Witt	8/76
NASA CR-145107	An Avionics Sensitivity Study, Vol. I	Ronald W. Scott Edwin D. McConkey	9/76
NASA CR-145108	An Avionics Sensitivity Study, Vol. II	Walter Heine	9/76
NASA CR-145024	Airborne Advanced Reconfigurable Computer System (ARCS)	B. E. Bjurman G. M. Jenkins C. J. Masreliez K. L. McClellan J. E. Templeman	8/76

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REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
Paper AIAA Aircraft Systems and Technology Meeting Dallas, TX	TCV Software Test and Validation Tools and Techniques	T. Straeter James R. Williams	9/27-29/76
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 Aircraft Safety and Operating Problems Conf. NASA Langley Research Ctr. Hampton, VA	Review of Operational Aspects of Initial Experiments Utilizing the U.S. MLS	Thomas M. Walsh Samuel A. Morello John P. Reeder	10/18-20/76
Paper Research Triangle Institute	Research in Ground-Based Near Terminal Area 4D Guidance and Control	C. L. Britt L. Credeur C. M. Davis W. Capron	10/76
Paper Radio Technical Commission for Aeronautics Washington, DC	Flight Experience with Electronic Displays Having Predictive Information	John P. Reeder	11/18-19/76
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

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REPORT NO.	TITLE	AUTHOR(S)	DATE TRANSMITTED
Report Analytical Mechanics Jericho, NY	Automated Landing, Rollout, and Turnoff Using MLS and Magnetic Cable Sensors	S. Pines S. F. Schmidt F. Mann	2/77
CR-145109	An Avionics Sensitivity Study: Automated RNAV/ MLS Transition, Vol. III	K. S. Karmarkar	3/77
NASA TM X-74019	Analysis of Transmission Error Effects on the Transfer of Real-Time Simulation Data	Leonard Credeur	4/77
NASA TN D-8441	Noise Data for a Twin-Engine Commercial Jet Aircraft Flying Conventional, Steep, and Two-Segment Approaches	Earl C. Hastings Arnold W. Mueller John R. Hamilton	5/77
NASA CR-2834	Development of a Digital Automatic Control Law for Steep Glideslope Capture and Flare	Nesim Halyo	6/77

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REPORT NO.	TITLE	AUTHOR	DATE
Paper ACM Sigmini/ Sigplan Interface Meeting New Orleans, La. (NSG-1170)	Proving the correctness of a Flight Director Program for an Airborne Minicomputer	Dr. W.D. Maurer	4/76
NASA TM X-73986	A Remotely Operated Multiple Array Acoustic Range(ROMAAR) and its Application for the Measurement of Airplane Fly-over Noise Footprints	David A. Hilton Herbert Henderson	11/76
Paper 7th Technical Symp. on C.S. Edcation Atlanta, Ga. (NSG-1170)	The Teaching of Program Correctness	Dr. W.D. Maurer	2/77
Paper 1977 Conference on Information Science&Systems (NSG-1170)	A New Method of Generating Verification Conditions	Dr. W.D. Maurer	3/77
Paper 15th Annual ACM S.E. Regional Conference (NSG-1170)	The Modification Index Method of Generating Verification Conditions	Dr. W.D. Maurer	4/77
Paper 16th Annual Technical Symp. on Systems & Software Gathersburg, Md. (NSG-1170)	An IBM 370 Assembly Language Program Verifier	Dr. W.D. Maurer	6/77
Report Nsg-1170 Geo. Wash. U.	Proving the Correctness of the Flight Director Program EADIFD Vols. I,II,III	Frank J. Lee	7/77