AD-783 987

# ADVANCED FLIGHT CONTROL AND ELECTRONIC DISPLAY SYSTEMS FOR ALL-WEATHER FLIGHT OPERATIONS

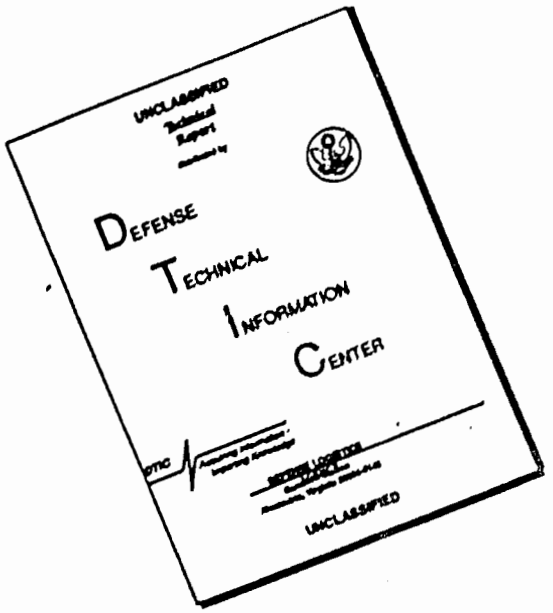
## A LITERATURE REVIEW AND BIBLIOGRAPHY

NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER

PREPARED FOR
FEDERAL AVIATION ADMINISTRATION

JUNE 1974

# DISCLAIMER NOTICE




THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

AD-783 987

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| FAA-EM-74-12 | | |

4. Title and Subtitle
ADVANCED FLIGHT CONTROL AND ELECTRONIC DISPLAY SYSTEMS FOR ALL-WEATHER FLIGHT OPERATIONS: A LITERATURE REVIEW AND BIBLIOGRAPHY

5. Report Date: June 1974

6. Performing Organization Code:

7. Author(s): Jack J. Shrager

8. Performing Organization Report No.: FAA-NA-73-78

9. Performing Organization Name and Address
Federal Aviation Administration
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

10. Work Unit No. (TRAIS):

11. Contract or Grant No.: 011-001-010

12. Sponsoring Agency, Name and Address
Department of Transportation
Federal Aviation Administration
Systems Research and Development Service
Washington, D. C. 20590

13. Type of Report and Period Covered: Final
January 1968 - October 1973

14. Sponsoring Agency Code:

15. Supplementary Notes

16. Abstract

A review of all literature published since 1967 relating to aircraft flight controls and displays was made. Special emphasis was placed on the contents of those documents as they related to the all-weather landing and takeoff operational envelope. The results of this review are evaluated, summarized, and conclusions drawn. This is supplemented by an annotated bibliography and author's index.

COLOR ILLUSTRATIONS REPRODUCED IN BLACK AND WHITE

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Flight Control<br>Aircraft Displays<br>Digital Systems<br>Auto Pilots<br>All-Weather Landing Human Factors | Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151 |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 142 | $4.75 / 1.45 |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

# INTRODUCTION

## BACKGROUND.

The Federal Aviation Administration (FAA) has initiated many development activities designed to enhance the terminal area capacity and, at the same time, operational flight safety.

One of the major areas, which has a direct bearing on both aspects of these activities, is the improvement in all-weather operations. The areas of principal concern with such operations are the approach, landing, rollout, and takeoff. Many of the FAA experimental programs in this area have been undertaken by the National Aviation Facilities Experimental Center (NAFEC) under the general heading of the all-weather landing systems (AWLS).

The Boeing Airplane Company, under sponsorship by the Department of Transportation (DOT), undertook a technological study program as a follow-up to the efforts initiated by the supersonic transport program. Two of the tasks within this program, flight control development (Task IV) and advanced electronic display system (ADEDS) (Task VI) (reference 1), reflect a logical application to the AWLS efforts.

As is true when considering the impact of any broad new technology on established techniques, careful consideration must be given to weighing all technological and economic factors, as well as the impact of such new technology on the safety of flight operations.

## OBJECTIVE.

The objectives of this undertaking are:

1. Identify all available publications within the past 7 years concerning flight controls and displays which may relate to the AWLS tasks.

2. Survey the various segments of the aviation community to determine their current thinking and active research as it relates to the all-weather landing problems.

3. Summarize the results of items 1 and 2 above in a manner which could be used as the basis of follow-on efforts which could enhance terminal area capacity and operational flight safety, especially under low visibility and adverse weather conditions.

Due to its significance, it is important to note that this undertaking is concerned only with the information: (1) after it has been received aboard the aircraft from some ground-based navigation aid, (2) that is detected by some type of onboard sensor, or (3) a combination of both, and not with the ground-based navigation aid itself.

LITERATURE SURVEY.

The annotated bibliography contained in appendix A of this report was based on the following sources:

1. Defense Document Center Search Control 003153.

2. NASA Literature Search 23138.

3. Related documents referenced in those reports identified in items 1 and 2 above.

As was previously noted, the literature search was to be limited to those documents published since 1967. In establishing the control parameters for the literature search, documents published prior to that date which related to pilot displays and all-weather landing programs were reviewed. Some of these documents have also been included due to the value of the material contained therein.

This literature search uncovered 305 publications which relate to the specific objectives. The documents in appendix A are listed by title, in alphabetical order. An abstract, or summary, for each report has been included where possible and practical.

The operation of an aircraft in the close proximity to an airport under all types of weather conditions can be segmented as follows:

1. Information displayed to the pilot for controlling the aircraft in pitch, roll, yaw, airspeed, altitude, angle-of-attack, etc.

2. Information displayed to the pilot to guide (navigate) the aircraft along a predetermined path to a desired point (navigation aid) or place (runway).

3. The workload imposed on the pilot in interpreting displayed information as it relates to him accomplishing his task during the operation of an aircraft.

4. The control system of the aircraft, its relationship to pilot input, aircraft response, system reliability, etc.

5. The specific factors which relate to the approach and landing task which are influenced by pilot displayed information and aircraft flight control systems.

6. The parameter of the problems of terminal environment as they are or may be influenced by information displayed to the pilot and an aircraft's flight control system.

7. The pilot's flight procedures and operational techniques in accomplishing all-weather operations in the terminal area.

Using the above criteria of segmentation, the documents were subgrouped as follows:

I. Electronic Flight Control Displays

II. Electronic Navigation Guidance Displays

III. Human Factors

IV. Advanced Flight Controls

V. Approach and Landing

VI. Terminal Environment

VII. Pilot and Flight Operational Procedures

Accordingly, appendix B is an alphabetical listing, by title and index number of the reports relating to a given subgrouping. In those cases where a document pertains to more than one of the noted classifications, it has been listed in each applicable subgroup. Neither the method of listing, nor the omission from all categories for any given document, should be interpreted as a reflection of the relative importance of its contents.

Appendix C provides the reader a cross reference by author according to alphabetical order. The particular articles, either authored or coauthored, are identified by their index number, as noted in appendix A.

## SUMMARY OF RESULTS

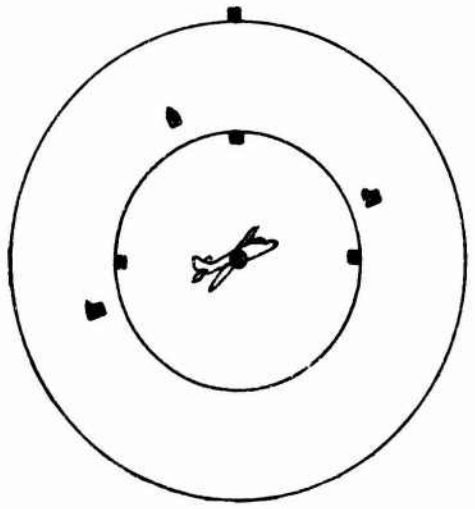
### I. ELECTRONIC FLIGHT CONTROL DISPLAYS.

The documents contained within this group are related to those displays which are concerned with the management of the aircraft's flight path in the horizontal (XY), or vertical (XZ) planes. Horizontal guidance is displayed as chart information on an electronic horizontal situation indicator (HSI), or an electronic multifunction display (MFD). Attitude, horizontal and vertical deviation, and command information is displayed on an electronic attitude director indicators (EADI), although this is not a precise nomenclature.

Most of the publications and current work in the field are concerned with the flight control display problems as they relate to the approach and landing task. Thus, there is very little or no information and documentation concerning flight control display technology for: (1) collision avoidance, (2) optimized flight path for fuel management, (3) energy management of the flight profile, (4) noise abatement control of the flight path, and (5) low-altitude pollution control of the flight path.

There are two broad approaches to the EADI as covered in the literature: (1) a windshield presentation of selected flight path control information, head-up display (HUD); and (2) the presentation of the same information on one or more flight panel located devices, head-down display (HDD).

The HUD, figure 1, is the outgrowth of the air-to-air combat technology developed during World War II for gunsights, and later for airborne radar ranging. This type of display allows the combination of selected instrument cues and "real world" cues in a complementary manner which is more useful than when the cues are used independently. A more advanced system would use onboard computers to process the derived information in a manner to produce a synthetic real world, thereby, giving the pilot similar images on his windshield under instrument conditions and visual flight conditions.



73-78-1

FIGURE 1. HEAD-UP DISPLAY (HUD) FOR MILITARY APPLICATION

The principal advantage, which is anticipated from HUD, is in minimizing the transfer problems associated with transitioning from instrument flight to visual flight management of the flight path. Thus, the implementation of a HUD could effect runway visual range (RVR) and decision height (DH) minimums for categories (CAT) I and II landing criteria and CAT III rollout.

Some of the problems associated with HUD include large variations in ambient light, varying background contrast, and the possibilities for misinterpreting fluctuating synthetic and real world visual cues. Index No. 142 noted, "while HUD information may have application to a broad range of the military aircraft's flight mission, its short-range future application in civil aviation appears to be restricted to takeoff, approach, landing," (and, with some form of onboard high-resolution, short-range, forward-looking detection systems, the taxi regimes).

The principal sponsors of research efforts in HUD have been the various military organizations. The results of a very recent (July 1973) in-depth study of HUD, which was undertaken for the U.S. Air Force, are contained in index No. 146. The objectives of this program were: (1) define the functional requirements of a HUD for the 1980 time period aircraft; (2) determine the capabilities and limitations of current technology in meeting these requirements; and (3) define a baseline design approach for an advanced program to meet such requirements. A HUD display conforming to the specifications reflected in index No. 146 is shown in figure 2. An advanced military flight path guidance HUD configuration is shown in figure 3.

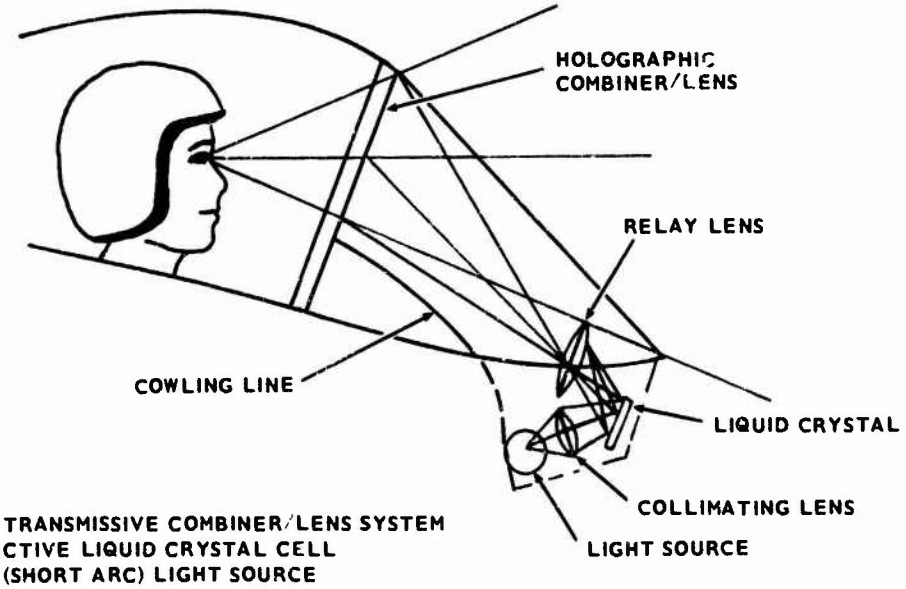
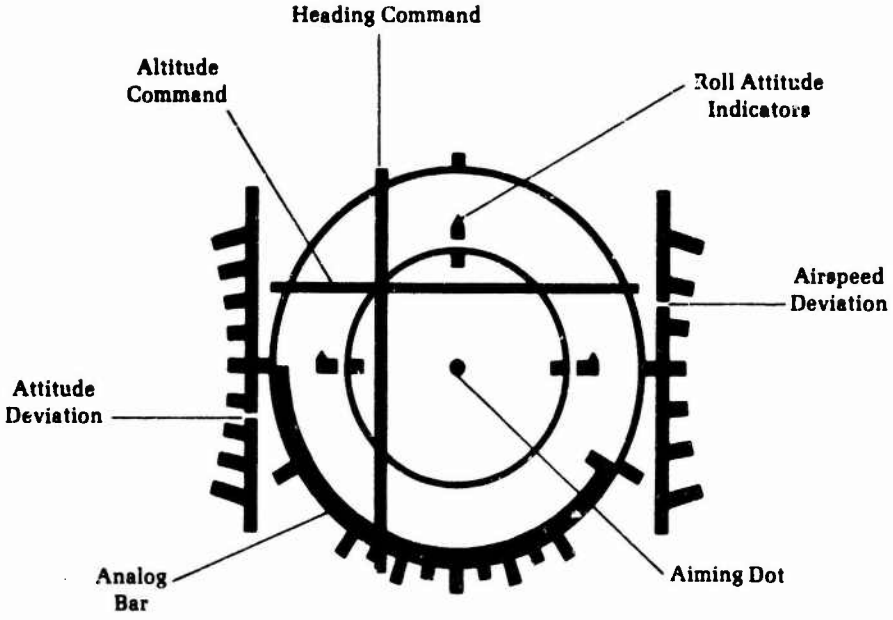



FIGURE 2. HEAD-UP DISPLAY BASELINE SYSTEM DESIGN (INDEX NO. 146)




**PILOT'S DISPLAY**

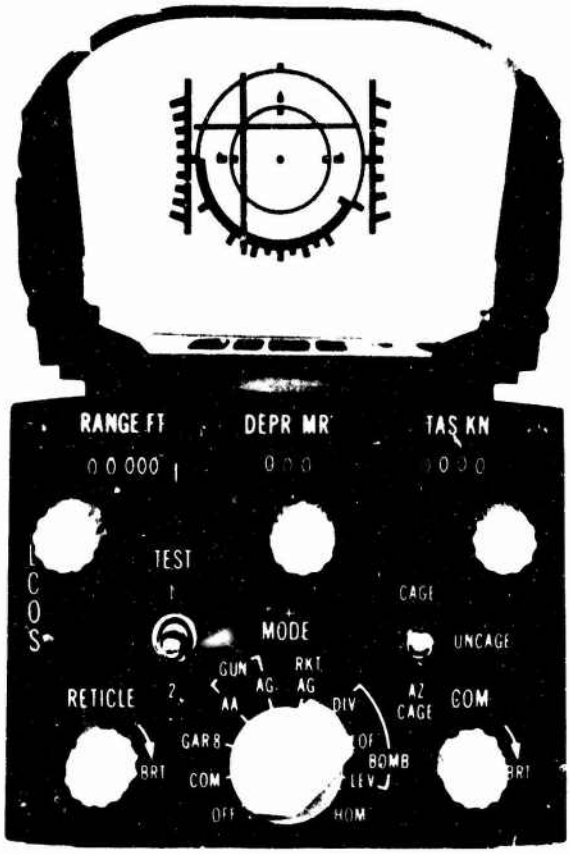



FIGURE 3. HEAD-UP DISPLAY AIRCRAFT FLIGHT PATH GUIDANCE

During restricted visibility conditions, the pilots of today utilize various flight panel-mounted instruments, figure 4, to determine the control inputs necessary to establish or maintain a given flight path. This is basically a HDD technique. Refinements in cathode ray tubes (CRT) and computer technologies have led to new concepts, figure 5, in presenting HDD information to the pilot. The literature reflecting these new CRT displays infer that only the HDD will be utilized throughout the approach, landing, and rollout. Due to the capability of image or video enhancements of the EADI display, the presentation to the pilot may be significantly better than the real world. Thus, while the problems relating to transfer from HDD to visual are ignored, such techniques would have a direct influence on determining minimum RVR requirements for CAT II (see to land) operations with both passive and active failures of such displays.

Some of the potential advantages of EADI's are discussed in index No. 142. The resulting experimental hardware and software systems, which were developed under the previously cited ADEDS program, are noted in reference 1.

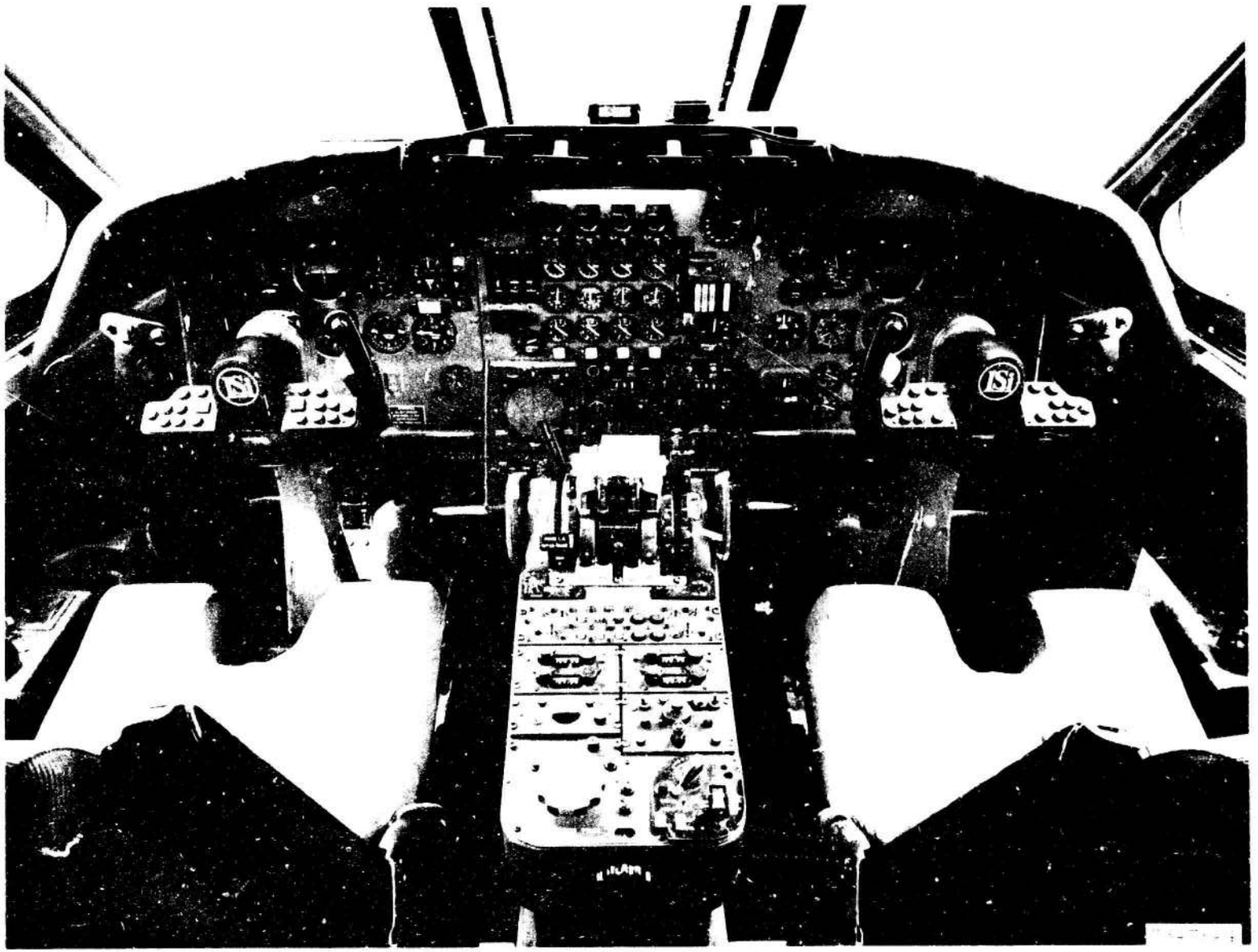
In figures 6 and 7 are two of the different types of EADI presentations shown in reference 1 which may enhance localizer and glide path monitoring and/or control during approach and landing. Although Task VI of the previously referenced DOT contract includes both laboratory and flight testing, the tests are functional, not experimental, in scope.

The potential use of HDD cathode ray displays to provide both flight path management and terrain collision avoidance is documented in index No. 150. Figure 8 shows the potentials of such a display combination which would have a significant influence on flight safety enhancement in letdown, approach, and landing phases of flight operations in mountainous or irregular terrain.

Figure 9 reflects very recent industry efforts in the use of color for an EADI. The only recent document uncovered in this survey dealing with the use of color was a contractual effort done for the U.S. Air Force and published in 1971, index No. 28. The advantages, disadvantages, or limitations in the use of simulated real-world color in a dynamic flight display, such as an EADI, are not documented. Informal conferences and conversations with several of the expert, human factors researchers working in this field who have published work in the area, confirm the lack of any useful experimentation in this area.

They further concede not only the difficulties in conducting such experiments, but they also note the controversial aspects of real-world color coding to dynamic flight control displays and question its physiological advantages.

Other areas which are not covered to any significant degree are flight control displays as they relate to: (1) takeoff roll, (2) multi-segment stage climbout profiles, (3) noise abatement, and (4) pollution control through critical energy management. Several areas of aircraft operation, in the terminal area not covered, are the potential usage of electronic flight directors for aborted landing due to the effective runway surface friction characteristics and related usable runway length, and aircraft ground operations.



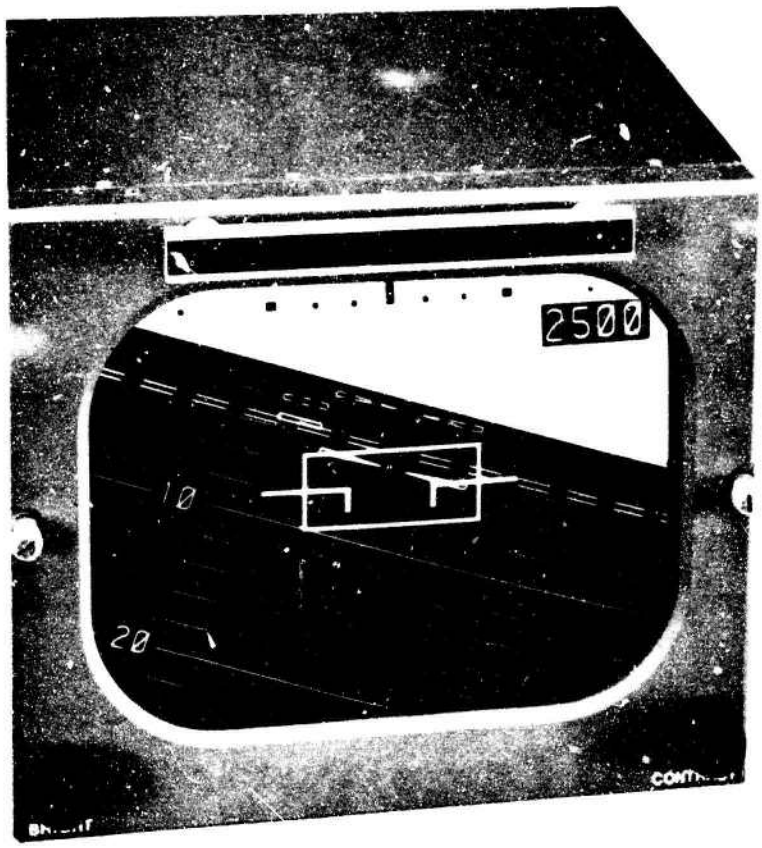



FIGURE 5. ELECTRONIC ATTITUDE DIRECTOR INDICATOR (EADI)

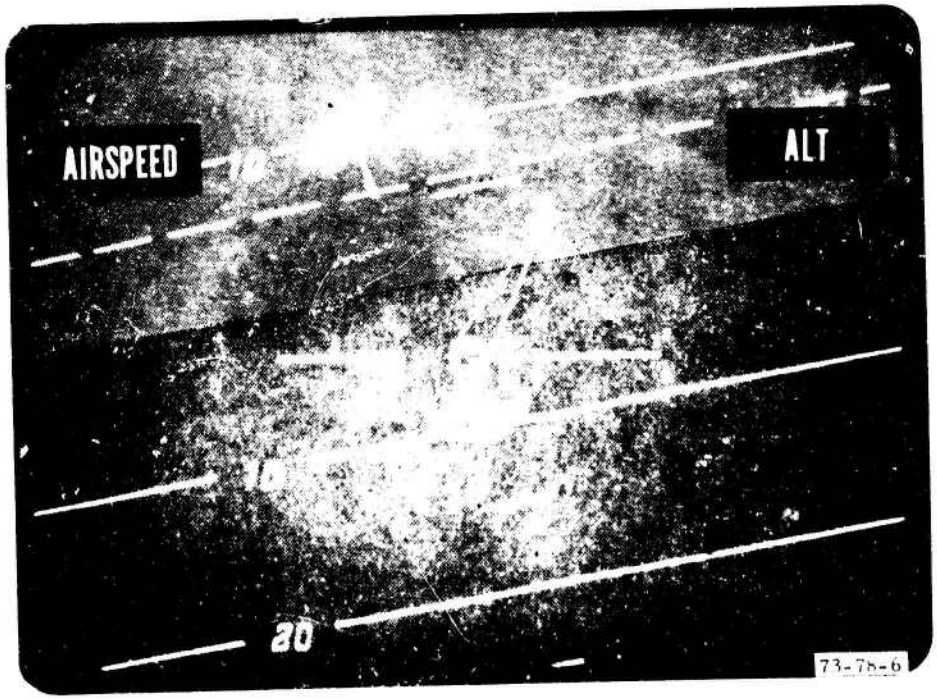



FIGURE 6. ELECTRONIC ATTITUDE DIRECTOR INDICATOR WITH FLIGHT PATH GUIDANCE

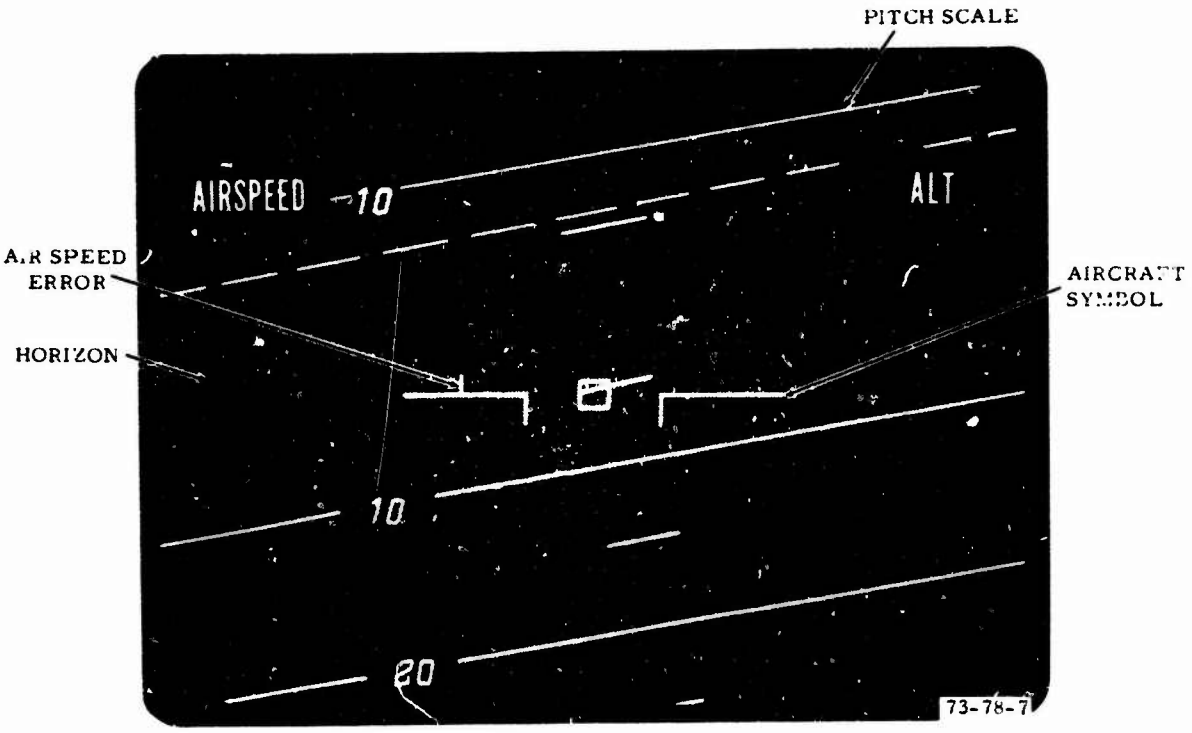



FIGURE 7. ELECTRONIC ATTITUDE DIRECTOR INDICATOR WITH FLIGHT DIRECTOR PRESENTATION

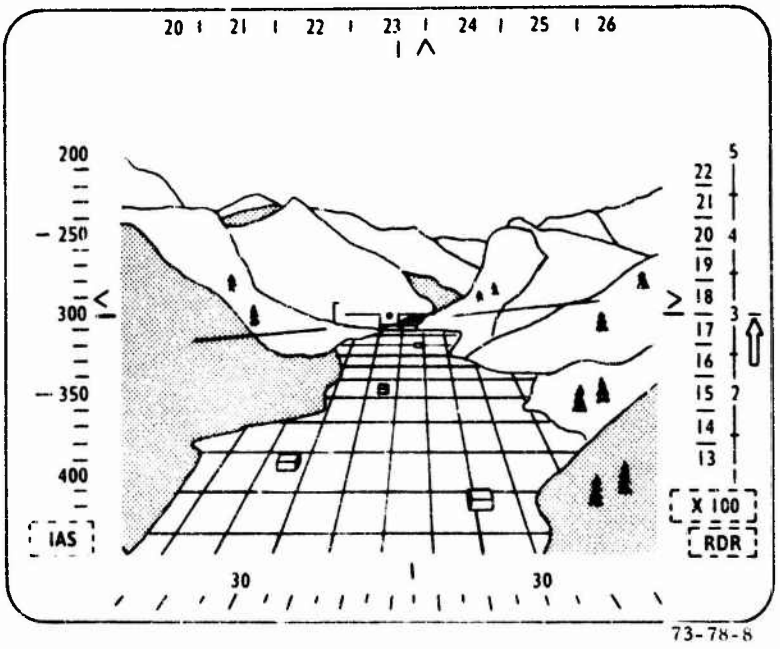



FIGURE 8. ELECTRONIC ATTITUDE DIRECTOR INDICATOR WITH TERRAIN CLEARANCE PRESENTATION

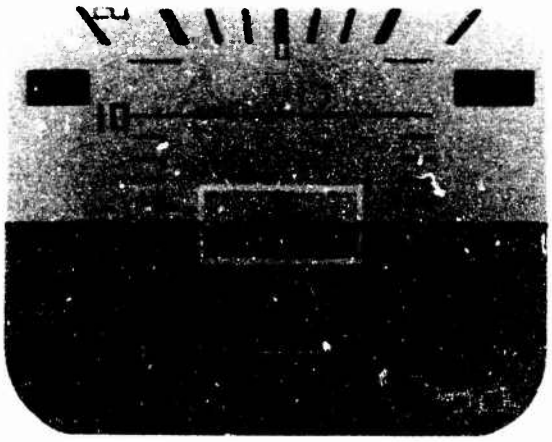


FIGURE 9. ELECTRONIC ATTITUDE DIRECTOR INDICATOR USING COLOR

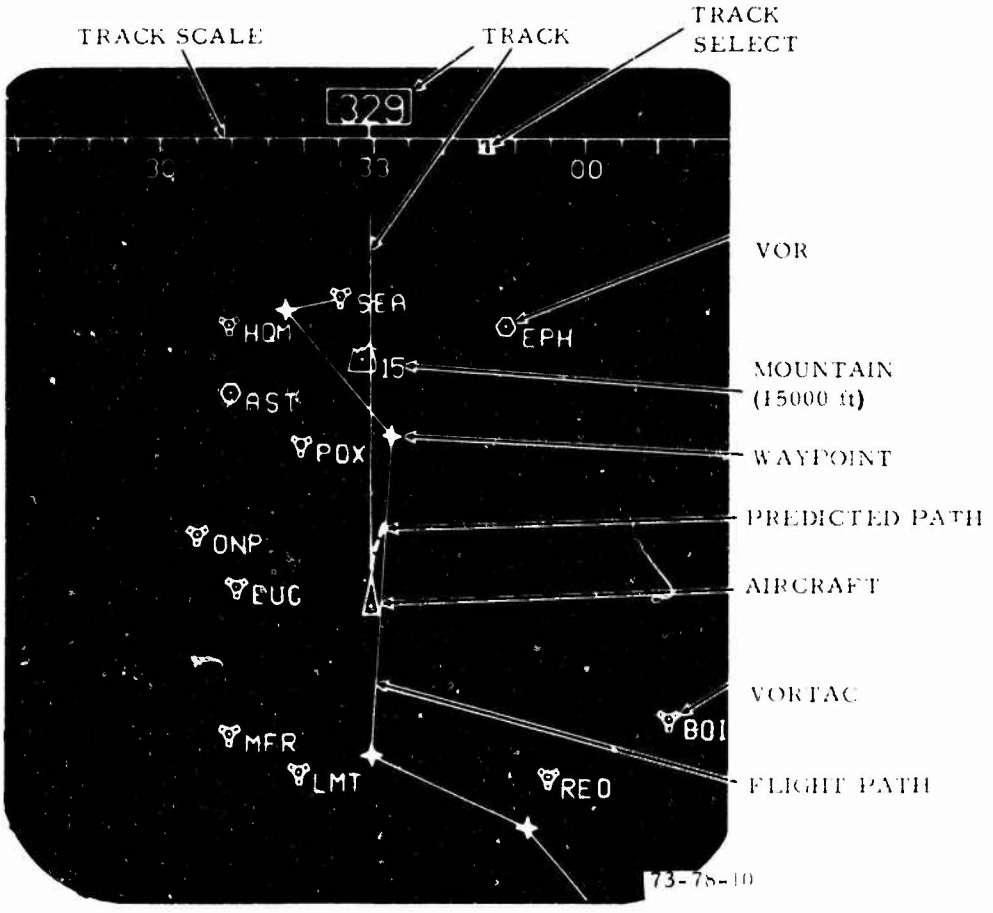



FIGURE 10. MULTIPLE FUNCTION DISPLAY FOR AREA NAVIGATION

In summary, the literature review and field survey indicated that the current primary efforts relating to EADI's are: (1) software concepts, (2) computer development, (3) symbol generation techniques, and (4) micro-modular development. Factors which either have not been explored, or have not been nor are not being investigated at any length, include: (1) problems induced by partial active or passive failures within the EADI system, (2) potential flight safety problems associated with establishing criteria for certification of software, especially if it is accessible for reprogramming in the field, (3) effects of electro-magnetic and electro-static potentials on critical components (i.e., memory) of the EADI system, and (4) certification criteria for symbol definitions.

## II. ELECTRONIC NAVIGATION GUIDANCE DISPLAYS.

Although the navigation task does affect pilot workload and involves flight path management and control, it is secondary to the stated objectives. The influence of such displays, if utilized by the pilot in accomplishing the metering and spacing in area navigation (RNAV), would bear on the terminal area problem. This aspect of these displays and their utilization in the total flight envelope (departure to arrival), are discussed in several publications noted in appendix B.

The documentation covers various types of concepts from the moving map to the stroke written CRT. The majority of the literature deals with the latter as an electronic horizontal situation indicator (HSI), but is generally termed a multiple function display (MFD), since in combination with a digital computer and other onboard sensors it could provide other information. While not documented in the literature, the navigation function could be time-shared, or through a priority system, replaced by propulsion information, checklist, discrete air traffic control (ATC) information (i.e., an adjunct to an advanced ATC system with a data link), annunciation of malfunctions, etc. Shown in figures 10 through 12 are several types of MFD's used as HSI's reported in the literature.

The literature and current experimental programs are addressed to the potential uses of such displays, but the impact on flight safety and pilot workload due to passive or active failures of such displays do not appear to be addressed. Also not covered in either the current experimental efforts or the documentation are technical criteria upon which certification of such display systems could be based.

The potential advantages of color-coding for the electronic horizontal situation displays are discussed in several documents including index No. 28.

The work being done in the electronic navigation guidance displays are similar to that summarized in the previous section covering EADIs. Other factors which require initial or additional exploration are: (1) advantages and limitations of time-sharing navigation, ATC, and engine performance information, (2) priority criteria for information displayed, (3) utilization of either or both electronic displays for annunciation, and (4) utilization of MFD/EADI as backup, one for the other.

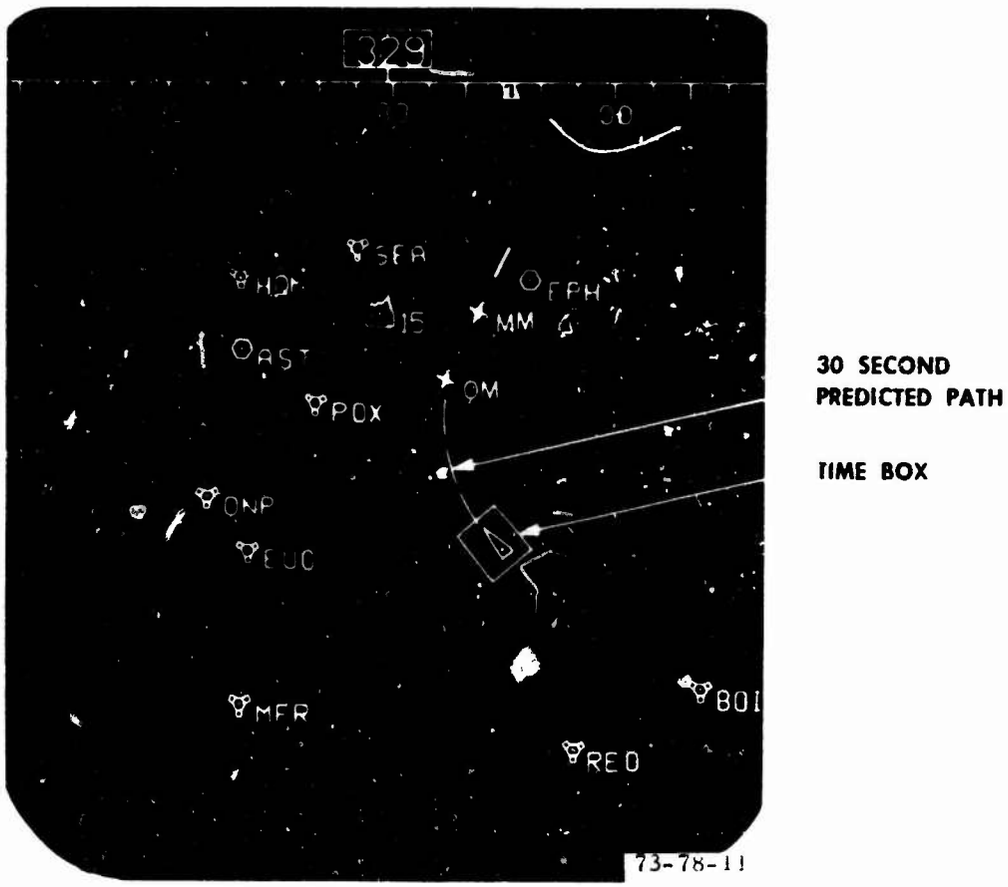



FIGURE 11. MULTIPLE FUNCTION DISPLAY FOR 4-D NAVIGATION

FIGURE 12. MULTIPLE FUNCTION DISPLAY FOR AREA NAVIGATION COLOR

An additional use of the multiple function display which is worthy of special notation is that of an ATC traffic situation display (TSD). This is the automatic display of air traffic information to the flight crew in accomplishing a station keeping function with respect to other aircraft. While not primary objective of the subject report, its potential importance to all-weather operations in the terminal enviornment is worthy of notation. Accordingly, references 2 through 9, which relate to TSD have been noted for special attention to the interested reader.

## III. HUMAN FACTORS.

Included within this grouping are those documents which deal with the effects on the human operator of: (1) the interaction between the form and quantity of information presented in a given display; (2) the interplay between various display concepts; (3) the interpretation of the information presented, and (4) the pilot's input to the flight control mechanisms. Another way of categorizing the documents contained in this group are: (1) those dealing with the display, (2) those relating to the human controller, and (3) those human factor considerations relating to the use of mechanized controllers.

Index No. 28 is a recent, comprehensive summary of the human factor considerations relating to displaying information. This document, which summarizes the results contained in 1,178 technical documents, breaks down the pertinent factors as follows:

1. Relationship of Design Consideration of a Model. This section covers: (1) display size considerations, (2) information coding, (3) alphanumeric considerations, (4) scale legibility, (5) factors affecting visual acuity, (6) flicker considerations, legibility based on contrast, and (7) environmental variables.

2. Display Size For Flight Control. The factors considered under this section include: (1) the noise, pip size, and imagery relating to the detection task, and (2) the design variables concerned with the continuous control task.

3. Information Coding. This chapter covers such factors as shape coding, color coding, and flash-rate coding. It should be pointed out that the color coding covered in this section is not necessarily real-world color, but rather, color contrasts, for the enhancement of information X display.

4. Alphanumeric Design. The factors considered herein include: (1) font of displays, (2) symbol size and form, (3) symbol spacing, (4) words, (5) edge-displayed symbology, (6) viewing angle, (7) symbol blur, (8) matrix symbol generation, and (9) solid-state matrix symbols.

5. Scale Legibility. The salient information incorporated are: (1) scale shape, (2) nonlinear scales, (3) numbering scale intervals and values, (4) stroke width of scale markings, and (5) circular and linear scale interpolation.

6. Factors Affecting Visual Acuity. Considerations covered include: (1) luminance level, (2) effects of contrast, (3) eye adaptation level, (4) exposure time and visual acuity, (5) spherical and chromatic aberration, (6) dynamic visual acuity, (7) retinal image location, and (8) point source of light.

7. Display System Resolution. Incorporated in this chapter are: (1) CRT image formation, spot size, channel bandwidth, and vertical and horizontal resolution, (2) solid-state display resolution, (3) visual acuity and resolution, (4) image quality, and (5) equipment quality.

8. Flicker Factors. Both observer characteristics (individual reaction, persistence of vision, etc.) and display parameters (refresh rate, light-to-dark ratio, phospher characteristics, etc.) are contained in this chapter.

9. Environmental Variables. Covered in this section are: (1) ambient illumination, (2) vibration, and (3) acceleration environmental factors as they relate to display information.

The recommendations contained in index No. 28 include:

1. The usefulness of color coding of displays (either real world color or color for acuity) should be evaluated flight task performance enhancement as opposed to its asthetic value. The use of color in EADI's could be a flight safety item in several portions of the flight profile, if its use degrades legibility. Nothing less than 100 percent legibility is acceptable.

2. Much of the literature indicates that flash coding is the least desirable of several dimensions of coding available. Its value for attention-gaining is well documented. Therefore, the use of this technique should be explored for annunciation of critical flight parameters (e.g., minimum decision height, approach to stall speed, etc.).

3. Evaluation of font or style of alphanumeric displays and symbology used on EADI's should be undertaken using both raster and stroke writing CRT's in varying environmental ambient conditions.

4. A review of the available literature indicates that there are practically no design-oriented contrast data available relating to electronically-generated flight data displays except that collected in a basic laboratory setting. The interaction of variations in real world ambient light conditions and dynamically moving symbology under actual flight stress conditions is unknown and should be identified. It should be noted that neither specific design criteria nor minimum flight safety operational criteria are identified.

The laboratory-only nature of human factors studies dealing with electronically-generated displays is further documented in index No. 91. The specifications of the systems documented in this article are targeted for simulator testing.

One article suggested variations in displayed information as a function of the particular portion of the flight profile. Thus, the possibility of organizing the displayed information to meet the constraints of the pilot's comprehension and utilization is suggested. Many of the studies sponsored by the military have been addressed to this in the sense of an assigned mission (e.g., attacking another aircraft, anti-aircraft missile avoidance, ground support bombing, etc.). However, there are no publications which deal with such considerations as they relate to civil aircraft operations.

## IV. ADVANCED FLIGHT CONTROLS.

A significant number of the publications within this group deal with the concept, laboratory breadboard, or simulator experimentation of analog, analog/digital hybrid, or digital flight control systems. Simulation tests using prototype flight hardware and the flight tests of any form of digital flight control systems are not reflected in the literature surveyed.

Among the more recent comprehensive publications relating to digital flight control concepts are reference 1 and index No. 83. The latter is primarily oriented toward the implementation of digital flight control concepts to advanced fighter aircraft technology. Both of these documents place preemphasis on hardware development, but equally, both open up flight safety factors and potential operational procedures which could impact current and future FAA certification and operational regulatory actions.

Implicit in the use of digital flight control technology is the cost effectiveness and flight safety aspects of such a system. Index No. 219 identifies the benefits which should be derived from such a system, including increases in range, pay-load, speed, ceiling, and reductions in power requirements and related fuel consumption. The advantages gained in performance are primarily based on the weight saving which would be realized through implementation of fly-by-wire concepts. A secondary saving in weight would be through the use of digital flight controls, thus allowing reductions in structure through load alleviation mode and maneuver load control concepts. These potential economic advantages of digital flight control systems certainly are important, but do not independently relate to the objectives of this survey.

Advanced flight control systems coupled to new display technology do provide the potential of enhancing flight safety through the reduction of pilot workload and improving tracking accuracy. This potential enhancement, as it relates to the approach and landing task, is noted in index No. 125, among others.

Index No. 83 suggests those technical questions which remain to be answered. Included in those questions and their relationship, the objectives of this literature review and analysis are:

1. Fundamental Digital Flight Control Criteria. Those criteria which are flight safety related would require explicit demonstration to a definable standard.

2. Digital Flight Control Computer Mechanization. The actual mechanization of the system including failure mode condition performance as it relates to the various approach and landing categories, requires definition.

3. Software Management. The criteria by which programs shall be certificated (e.g., hardwired, reprogrammable, etc.) must be determined.

4. Environmental Protection. The affects on the digital flight control system due to external ambient conditions (e.g., electromagnetic, electrostatic, temperature, etc.) have to be evaluated.

5. Flight Validation of a Preproduction System. As previously noted, the concept, laboratory, and simulation testing of breadboard or prototype systems have been accomplished. However, flight evaluation of a preproduction system has not been accomplished. Part of such a validation would include the definition of criteria and their acceptable performance and reliability limits.

V. APPROACH AND LANDING.

Listed in this group are all those publications which can be identified as pertaining, at least in part, to the aircraft approach and landing problem.

During this search and survey, other documents which are pertinent to this segment of the flight profile were also encountered. Included in such documents were papers presented at the all-weather operations panel in May/June 1973, references 10 to 18 inclusive.

The usefulness of sophisticated displays and flight control systems will be impacted by operational criteria, such as decision height/runway visual range relationships, criteria for various performance category aircraft, and ground-based flight guidance aids (ILS, MLS, etc.). These interrelationships can be seen in those approaches which have as their final "GO" state "SEE TO LAND." Those three words define the vast majority of encountered instrument flight conditions. Accordingly, unless the prerequiste of all instrument landing procedures is CAT III, the display and flight control systems must be amenable to the "SEE TO LAND" criteria or some variation thereof. Thus, such factors as glide path angle, cockpit cutoff angle, wind gusts, runway surface conditions, and aircraft's deceleration versus remaining usable runway may be factors in the display and flight control mechanization.

References 12, 15, and 17 suggest several possible mathematical expressions which deal with some of these variables, but none includes all and the literature does not reflect any flight test data which might provide some limited baseline information.

In summary, the publications identified in the group deal primarily with the approach and landing problem as it relates to existing pilot display systems, figure 4, used in conjunction with various types of ground-based navigation aids (i.e., ILS, MLS, and VOR). The potentials of the utilization of advanced flight control and display systems for such concepts as synthesizing an MLS curved approach by use of other existing ground-based navigation aids, or synthesizing an ILS using one or more existing navigation aids, is not reflected, nor are there reported efforts in this area.

## VI. TERMINAL ENVIRONMENT.

Literature included in this grouping include those relating to terminal area traffic density, ambient atmospheric factors, runway surface conditions, and surrounding terrain in close proximity to the runway.

The literature search did not produce any documents relating to flight control or display technology as influenced by, or influencing, the runway acceptance rate. However, some do treat the utilization of metering and spacing to optimize the flow of aircraft traffic within an arbitrarily defined runway environment, references 2 to 9 inclusive.

The significant difference is that other aspects of published research and current research efforts, identified through the field survey, are dedicated to unrestricted variations in other aspects of the terminal environment. Thus, while work has been done in aircraft path guidance in the air, during the landing roll and turnoff (index Nos. 15 and 258), the ability of the aircraft to operate in the existing runway environment, e.g., slippery surface, snow drifts, and fixed obstruction adjacent to the runway, between the threshold and end of the runway, are not treated. This lack of critical experimentation and flexibility in definition compromises many advantages of current flight control and display technology.

Index No. 15 clearly notes that, in civil aviation, both effectiveness and flight safety must be considered in the introduction and use of new "black boxes." The reality of using new technology is dictated by these factors and not by novelty, esthetic value, or purely supplementary to existing systems.

Ambient atmospheric factors above nominal threshold approach altitudes are discussed in many of the documents. However, the technical literature is limited, if not lacking, concerning such problems as gusts and crosswind compensation at altitudes below nominal threshold height and prior to touchdown.

Both of the preceding paragraphs deal with problems that would be directly influenced when integrated with the "SEE TO LAND" concepts.

Several publications cite the additional problem introduced by the wake turbulence generated by a preceding aircraft but the documentation does not reflect how this may be coped with by flight control or display technology.

Additional factors relating to the terminal area are the influence of the terminal environment on information acquired by the aircraft. Included in here are such things as:

1. Errors in aircraft-received flight-path guidance information due to aircraft and ground vehicular traffic.

2. Errors in aircraft-received flight-path guidance information due to weather conditions.

The sensitivity of ground-based flight-path guidance generators (e.g., ILS, MLS, VOR, etc.) due to the above have been, or are, under investigation. However, the prioritization of hierarchy structure of onboard evaluation of received information was not reflected in the literature reviewed during this survey. Thus, the criteria by which an advanced flight control system would determine selectivity due to an onboard sensor error, in a redundant system, is in the literature; such selectivity due to information error (parametric error) is not.

VII. PILOT AND FLIGHT OPERATIONAL PROCEDURES.

Recent reported undertakings in this area are primarily concerned with all weather landing, noise abatement, or more recently, pollution control.

References 10 to 18 are concerned with all weather landing. Some of the problems addressed, but not necessarily resolved, are (1) decision altitude or height vs. runway visual range (RVR), and (2) height loss allowance for DH calculations due to glide path angle, approach speed, aircraft dynamic response, or combinations thereof. Here too, the literature relates to these types of problems in connection with ILS. Thus the potential usage of digital flight control systems and CRT displays as they would influence these considerations are not documented in any of the literature reviewed. Also not covered are these factors as they relate to other potential ground based navigation aids used in conjunction with such advanced flight control systems and displays.

Experiments to evaluate the potential usage equipment like the FCD and ADEDS developed under DOT sponsorship for noise abatement operational procedures, are covered in the terminal configured program which is being undertaken by NASA, Langley Research Center. These experiments are designed to include some potential application to existing long and short-haul jet transport aircraft. Other portions of the proposed experimental efforts are for the development of pilot and flight operations procedures for the next generation commercial transport aircraft.

## ADDITIONAL COMMENTARY

The literature review and the related field survey resulted in other proposed experimentation. Since the discussion during the survey was informal, the subject matter or proposed studies are included without specific source identification.

One of the techniques employed in failure deduction such as in the FCD, is a comparision voting technique. A sensor or subassembly is evaluated by comparision to other redundant identical sensors or subassemblies. Thus, for example, if an angle-of-attack sensor differs from the other two angle-of-attack sensors, in a triple redundancy system, by a predefined limit, it is ignored and the FCD uses the average of the remaining two sensors for angle-of-attack. Another technique which could be employed is to compute the

angle-of-attack based on computed standard aircraft performance characteristics and other sensed perameters. The computed angle-of-attack could then be utilized for comparision and failure rating.

Another related factor is that there are a large number of sensor inputs to the aircraft in a flight control system for such tasks as auto-land. Each of these sensors have their own special characteristics. There are no reported successful investigations for determining the most satisfactory way to identify and monitor the priority characteristics for a given flight mode in a redundant system. The flight control developed under DOT sponsorship used an incremental digital computer, as opposed to the more familiar whole word computer. There are some specific advantages to this type, such as speed of problem solution, and some disadvantages. Due to the initial flexibility requirements imposed by the DOT study, the contractor produced a prototype system which could use either the incremental or whole word processor. The literature and field survey did not identify any current experiments related to evaluation of one technique versus the other as it relates to flight safety or versatility in the reduction of pilot workload.

The use of on-board digital computers and redundant sophisticated in-flight sensors opens up the field of annunciators relating to flight critical and flight safety items. The ability to provide priority coding for normal mode operations or other factors such as terrain clearance, potential conflicting traffic, and equipment malfunction due to having a programmable on-board digital computer, has not been fully explored.

Having the on-board capability for rapidly processing raw data from multiple sources increases the potential usefulness of existing ground-based navigation aids. Although not specifically covered in the literature, it may be possible to obtain significant reduction in IFR minimums and simultaneously increase flight safety through such capability. Equally influenced is the potential of increasing the usefulness of existing airports under IFR conditions with little or no additional increase in navigation aids.

## CONCLUSIONS

The following conclusions are drawn from the information denoted in the literature and the field survey.

1. The technology for the hardware and software requirements of digital flight control and electronic display systems have been developed to the extent necessary for use in aircraft.

2. The use of digital flight control and display system could increase effective use of the terminal area using existing ground-based navigation aides.

3. Pilot workload could be significantly reduced through use of digital flight control and display technology.

4. Enhancement of air traffic control through a more definitive display to the flight crew and more effective use of existing ground-based navigation aids may be possible through use of digital flight control and display systems.

5. Flight safety, through more precise navigation, could be enhanced through use of airborne digital computer processing of raw navigational information.

6. Current and proposed criteria for all types of IFR operations could be significantly influenced through the use of digital electronic display systems.

7. Criteria for safe implementation of digital flight control and display systems as influenced by both electromagnetic and electrostatic conditions require definition.

8. The factors relating to passive and active failure of both digital flight control and display systems, as they impact minimum descent altitude (MDA), decision height (DH), and runway visual range (RVR) requirements, have not been identified.

9. Human factors studies on the possible benefits of real-world color on display enhancement for flight safety are not identified.

10. Problems associated with transferring from CRT displays to secondary pointer and dial displays, necessitated by CRT failure, have not been investigated.

11. Actual documented experience, using existing display and flight control systems under real-world CAT-III type conditions, was not uncovered.

12. Clear definition for dealing with such factors as gusts, turbulence, decrab, etc., within the last 50 feet of height before touchdown, are not documented.

13. The use of EADI's, MFD's, and digital flight control systems, may provide large gains in economic flight operations, minimize ATC problems, and at the same time, enhance flight safety, especially in the terminal area.

## REFERENCES


1. Martin, A. J., McKinstry, R. G., and Veitengruber, J. E., Advanced Electronic Display System - System Function/Software Requirements, D6-25447, December 22, 1972.

2. Bush, R. W., Blatt, H., and Brady, F. X., A Cockpit Situation Display of Selected NAS/ARTS Data, Technical Note 1970-39, MIT, December 15, 1970.

3. Imrich, Thomas, Concept Development and Evaluation of Airborne Traffic Displays, FTL Report R71-2, June 1971.

4. Anderson, Robert Edward, Format Evaluation For an Airborne Air Traffic Situation Display, June 1971.

5. Bush, R. W., Blatt, H., and Brady, F. X. An Airborne Traffic Situation Display System, Technical Note 1971-19, MIT, June 23, 1971.

6. Connelly, Mark E., Rausch, Robert, Imrich, Thomas, and Anderson, Robert, A Cockpit Simulator For Air Traffic Control Research, Boston Computer Simulation Conference Week of July 19,1971.

6. Weiss, Herbert G., An Airborne Traffic Display System, MIT Lincoln Laboratory, November 1971.

8. Howell, Jack D., Simulator Evaluation of Pilot Assurance Derived from an Airborne Traffic Situation Display, Phase I, MIT, Report FAA-EM-72-3, February 1972.

9. Melanson, David, Simulator Evaluation of Pilot Assurance Derived from an Airborne Traffic Situation Display - Traffic Awareness Improvement Phase II, July 1973.

10. Kuznetsov, M. I., Decision Height/RVR Relationship, ICAO AWOP Working Paper WP/1, May/June, 1973.

11. Blake, D. A., DH/RVR Relationship - Height Loss Allowance For DH Calculation, ICAO AWOP Working Paper WP/3, May/June 1973.

12. Blake, D. A., A Method of Calculating a Minimum RVR For ILS Approaches, Category II, ICAO AWOP Working Paper WP/4, May/June 1973.

13. Anon, Decision Height - Visibility Correlation, ICAO AWOP Working Paper WP/14, May/June 1973.

14. Anon, Missed Approach Height Loss, ICAO AWOP Working Paper WP/83, Appendix A, May/June 1973.

15. Anon, Calculation of Height Loss in Overshoot, ICAO AWOP Working Paper WP/83, Appendix B, May/June 1973.

16. Spooner, A. H., Decision Height/Runway Visual Range and Their Relationship, and Definitions of Operational Performance for ILS, ICAO AWOP May/June 1973.

17. Blake, D. A., Decision Height/RVR Relationship - Operating Categories, ICAO AWOP Working Paper WP/5, May/June 1973.

18. Anon, Decision Height/Runway Visual Range and Their Relationship and Definitions of Operational Performance Categories for ILS, ICAO AWOP Working Paper WP/225, Oct/Nov 1973.

APPENDIX A

BIBLIOGRAPHY

1. ADVANCED ACTIVE CONTROLS TECHNOLOGY
Rainey, Gerald A., Langley Research Center.
Advanced active control concepts are described and their potential for providing improved characteristics for aircraft, along with an indication of the status of the technology in relation to its readiness for application, is given. The concepts considered are relaxed aerodynamic stability, maneuver load control, flutter suppression, fatigue damage reduction, and ride quality control.

2. ADVANCED CONTROL SYSTEM CONCEPTS
Smyth, R. K., Ostgaard, M. A., Rediess, A., Doetsch, K. H., Sutherland, J. P.; AGARD, September 1968, AD-701 546, AGARD-CP-58.
Survey of adaptive control applications to aerospace vehicles; case for adaptive control; theoretical perspective of adaptive control techniques and modern control theory; primary flight control circuit development from mechanical systems to an all-electric digital signalling system; fly-by-wire flight control systems; the impact of electronic displays on aircraft control; the place of adaptive control techniques in the future development of automatic flight control systems; adaptive control of flexible aircraft structural modes; a response regulation technique for self-adaptive control of flexible aircraft; flight test experience with adaptive control systems; self-adaptive maneuver demand control systems--some practical design considerations; safety and reliability for all-weather landing systems; the influence of system reliability of accident hazards due to poor handling qualities; VTOL IFR technology program; control function selection and monitoring.

3. ADVANCED CONTROLS TECHNOLOGY
The Boeing Company, January 1971, D3-8466.
Results of recent Boeing-Wichita analytical studies and flight demonstrations have shown the potential of advanced controls technology to significantly improve aircraft performance. Application of advanced control concepts during aircraft design can result in reduced weight, increased payload and range as well as improved ride and handling qualities.

4. ADVANCED FLIGHT CONTROL SYSTEM CONCEPTS FOR VTOL AIRCRAFT
Trueblood, Ralph B., Bryant, William B., Cattel, James J.
Massachusettes Institute of Technology, July 1970, AD-510 875L R-638.
This report describes the results obtained during Phase III of a research program to develop advanced flight control system concepts for helicopters and VTOL aircraft. For completeness, the report includes the pertinent results of the Phase I and II efforts together with summary descriptions of the individual phases.

5. ADVANCED FLIGHT CONTROL SYSTEMS POWER-BY-WIRE AND FLY-BY-WIRE
Schmitt, Vernon R., and Lorenzetti, Robert C., (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio). In: Vickers Aerospace Fluid Power Conference, 20th, Detroit, Mich., October 26, 27, 1970, Proceedings. (A71-39147 20-03)

Discussion of power-by-wire (PBW) actuators and fly-by-wire (FBW) flight controls. PBW is the transmission of power from the aircraft engine to the control surface actuator by electrical rather than hydraulic means. FBW is an electrical closed-loop feedback control system which makes aircraft motion, rather than surface position, the controlled variable. The mechanical linkages between the control stick and the control surface acutators are replaced by multiple physically dispersed electrical signal wires. Various systems now under study or development, or in actual use are described.

6. ADVANCED MANNED STRATEGIC AIRCRAFT (AMSA). TASK 5-7. CONTROL DISPLAY REPORT
Sorensen, A., Boeing Company, Seattle Washington, Military Aircraft Product Development, Report No. D6-25023, June 1967, AD-389 360L.

This document contains the final technical report for the display/control study accomplished as part of AMSA Task S-7. Contained herein are detailed descriptions of the functional development of the Boeing Display/Control Configuration. The descriptions are supplemented by mockup and detailed panel photographs. Also included are comparisons of the IBM, Autonetics, and Boeing aft station concepts. These comparisons are based on mechanization technique, information and response requirements. Photographs are supplied to assist in visualizing the differences.

7. ADVANCED TECHNOLOGY TRANSPORT CONFIGURATION
Williams, B., (Boeing Company, Commercial Airplane Group, Seattle, Wash.). American Institute of Aeronautics and Astronautics, Aircraft Design, Flight Test, and Operations Meeting, 4th, Los Angeles, Calif., August 7-9, 1972, Paper 72-756.

Consideration of the compromises involved in advanced transport aircraft designs for Mach numbers approaching 1.0, to develop an environmentally acceptable and economically viable commercial transport. The impact of configuration constraints on a baseline aircraft is discussed, and details are given on the development of the aircraft from a wind tunnel model. The subjects covered also include the configuration cycle, aerodynamic and configuration concepts, full-scale aircraft characteristics, and an alternate aircraft configuration.

8. ADVANCES IN HELICOPTER AVIONICS
Nethaway, BSc CEng, AFRAeS, Royal Aircraft Establishments, Farnborough, Vol. 76, November 1972, Aeronautical Journal.

9. ADVANCES IN V/STOL COCKPIT INFORMATION
Dougherty - Strother, D., AGARD Conference Proceedings, No. 55, 1968, Paper No. 26.

10. AIRCRAFT DISPLAYS FOR STEEP ANGLE APPROACHES
Wolf, J. D., Hoppe, R. B., 1970, JANAIR Report 681215.
The primary objective of the program was to investigate aircraft display requirements for steep-angle approaches and landings with 1975-1980 era tactical rotary-wing and V/STOL aircraft. Alternative display formats were developed and empirically evaluated by means of real-time man-in-the-loop simulation techniques. In addition, approach angle and profile characteristics were systematically varied to ascertain their effects on task performance. Interpreted within the constraints imposed upon by the simulations, results of the study indicated that manually controlled IFR steep-angle approaches and landings are possible with all display formats evaluated.

11. AIRCRAFT DYNAMICS AND AUTOMATIC CONTROL
McRuer, Duane, Ashkenas, Irving, Graham, Dunstan, Systems Technology,Inc., August 1968, TR 129-1.

12. AIRCRAFT FLIGHT CONTROL SYSTEMS FIELD SAFETY EXPERIENCE
Bielka, R. P., Kavaloka, A. P., Johnson, W. L., Reel, R. E.,Boeing Company, Seattle Washington Research and Engineering Division, May 1972, AD-894 814L.
This report contains field safety and failure information on flight controls and related systems for the F-11A, F-4D, C-141 and B-52G/H aircraft. More than three-and-one-half million maintenance actions, 1,460 degrading failures, 302 hazardous conditions, and 5 years of accident experience were analyzed for lessons learned which could have application toward updating specifications and/or research. Plans applicable to new flight control system design such as fly-by-wire, basic data sources included accident/incident reports, safety publications, emergency unsatisfactory reports.

13. AIRCRAFT LANDING CONTROL AUTOMATION
Belogorodskii, S. L., Moscow, Izdatel'stvo Transport, 1972, in Russian.
Operational principles of radio beacons and associated communications equipment used to generate instrument landing trajectories are examined along with problems involving the dynamics of automatic and semiautomatic flight control systems. Functional diagrams are given for Soviet and western systems providing automatic control of landing-phase operations, and emphasis is placed on methods and hardware used to assure safety in the autopilot flight mode. Particular topics considered include minimum landing requirements, aspects of flight control in the presence of characteristic disturbances, and flight status display systems.

14. AIRCRAFT LANDINGS, DDC
AD-523 400, DDC-TAS-72-49, November 1972.
This bibliography contains confidential and unclassified references on aircraft landings. These references deal with carrier landings, instrument landings, approach, night landings, landing aids, landing lights, display systems, human factors, control systems, glide path systems, carrier controlled radar, ground-controlled radar and radar landing control. Computer-generated indexes of corporate author-monitoring agency, subject, title, and personal author are included.

15. AIRCRAFT LANDING SYSTEMS CONFERENCE PROCEEDINGS
AGARD AD-714 925, AGARD-CP-59-70, September 1970.
An international airline views automatic landing systems; psychological and procedural aspects related to ILS approaches and landings in visibilities less than 1200 feet; new developments in landing systems; automatic landing system optimization using inertial navigation data and modern control theory; importance of speed control relative to longitudinal touchdown dispersion; and new guidance developments for all-weather landing. Development of airborne hardware for automatic landing systems; post 1970 scanning beam approach and landing; landing VTOL aircraft in adverse conditions and some possible solutions; automatic landing systems are here; aided inertial flight test experiments; the development of automatic landing for B5A operation; experience gained by B.A.C. and Elliot in the development and service use of automatic landing systems; the autopilot for the C-141 all-weather landing system; direct lift control for approach and landing.

16. AIRCRAFT PERFORMANCE BENEFITS FROM MODERN CONTROL SYSTEMS TECHNOLOGY
Holloway, R. B., Burris, P. M. (Boeing Company, Wichita, Kansas), and Johannes, R. P., (USAF, Wright-Patterson AFB, Ohio). American Institute of Aeronautics and Astronautics, July 14-16, 1969, Paper 69-767.
In conventional approaches to aircraft design, the flight control system is designed to meet specified handling requirements after the configuration is optimized to meet the mission performance requirements. The performance benefits which accrue by considering the control system design throughout the configuration studies are discussed. The approach employed to integrate control techniques and their impact on the design, and the performance benefits expected are elements of the work. Concepts to be examined include relaxation of inherent static stability, ride quality control, flutter margin control and maneuver load control.

17. AIRCRAFT PERFORMANCE BENEFITS FROM MODERN CONTROL SYSTEMS TECHNOLOGY
Holloway, R. B., Burris, P. M., and Johannes, R. P., Controls Systems Technology, Journal of Aircraft, Vol. 7, No. 6, p. 550, November - December 1970.

18. AIRCRAFT PERFORMANCE ENHANCEMENT THROUGH AUTOMATIC CONTROL
Johannes, Robert P., Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio.

This program was originated as a result of the recognition that the trend in aircraft vehicle technology is toward ever increasing dependence on control system functions to achieve the desired mission performance capability. The need to develop automatic control technology to this trend was the driving factor. The objective of the CCV program is to provide flight validation of specific functions which can enhance the mission performance of aircraft. In addition to flight test validation, the practical mechanization of control systems which will perform the desired functions will provide the basis for CCV control function design criteria.

19. AIRCRAFT SIMULATION APPLICATION TO THE DEVELOPMENT OF THE CONCORDE PROJECT
Pinet, Jean, (Societe Nationale Industrielle Aerospatiale, Toulouse, France). American Institute of Aeronautics and Astronautics.

Consideration of simulation as the required solution for study of the man-machine coexistence, particularly for handling studies where the introduction of man, as a sophisticated transfer function in the mathematical computations, is not yet at a sufficiently advanced stage. For this study, the fixed-cabin simulator in Paris, the variable stability Mirage IIIB, the BAC Bristol ground-based simulator, and mainly, the Aerospatiale Toulouse ground-based simulator were used. Results are described in detail.

20. AIR FORCE EVALUATION OF THE B-52G AND H PROTOTYPE STABILITY AUGMENTATION AND FLIGHT CONTROL SYSTEM
Gobert, D. O., Bowline,J. D., AFFTC, FTC-TR-67-30, February 1968.

21. AIRPLANE AND SYSTEMS CONFIGURATIONS DEVELOPED FOR THE NOISE ABATEMENT LANDING APPROACH TASK, Phase 3, final report, Bleeg, Robert J. and Willich, Wayne, March 1969, NASA-CR-73309.

The Boeing 367-80 airplane (707/KC-135 prototype) was test flown to investigate the effectiveness of various systems for reducing pilot workload and maintaining tracking accuracy during noise abatement landing approaches. Preliminary studies showed that an increased dependence on automatic systems would be necessary to enable the pilots to fly noise abatement approaches at workload levels and accuracies comparable to conventional approaches. Further evaluations of specific systems developed for this task showed that a significant reduction in workload accompanied by improved accuracy in tracking unconventional descent paths was realized with certain combinations of systems aids.

22. AIR TRAFFIC NAVIGATION DISPLAY CONSIDERATIONS FOR THE DESIGN OF AN ONBOARD AIR TRAFFIC SITUATION DISPLAY
Anderson, R. E., Curry, R. E., Weiss, H. G., Connelly, M. E., and Imrich, T., NASA, 7th Ann. Conf. on Manual Control, 1972, p 61-72. Refs. N73-10104 01-05.

The basic concept of remoting information to the cockpit is used to design and develop a computerized airborne traffic situation display device that automatically selects and presents segments of a controller's scope to the aircraft pilot via a narrow band digital data link. These data are integrated with aircraft heading and navigation information to provide a display useful in congested airspace. The display can include alphanumerical symbols, air route maps, and controller instructions.

23. AIR TRANSPORT 1969(VOZDUSHNYI TRANSPORT 1969)
Pil'chman, I. I., and Nozdrin, V. I., Moscow, Izdatel'stvo, VINITI, 1970, in Russian.

The development of air traffic control systems and air transport automatic landing systems in the U.S. and Western Europe is summarized. Information display systems are described, as well as automated air traffic control systems and various electronic devices for controlling air traffic. The present state of development of automatic landing systems is reviewed, automatic landing systems produced in Great Britain, the U.S., and France are evaluated, and certain helicopter and V/STOL landing systems are investigated. The automation of air traffic after landing and while taxiing on the airfield is considered.

24. ALL-WEATHER CARRIER LANDING SYSTEM AIRBORNE SUBSYSTEM, GENERAL REQUIREMENTS FOR, NASC, AR-40, May 1, 1969.

25. ALL-WEATHER LANDING FLIGHT DIRECTOR AND FAULT WARNING DISPLAY SIMULATOR STUDIES
Vreuls, D., Gainer, C. A., Semple, C. A., and Monroe, R. D., Human Factors Society, Annual Symposium, 5th, Los Angeles, Calif., June 1968, Proceedings. (A69-10448 01-02.)

Discussion of all-weather landing, human-factors studies conducted in a fixed-base, six-degree-of-freedom research simulation of a Boeing 707-720B aircraft. Flight director systems and elements contained in the display were subjected to empirical test in an envisioned Category III-G environment. For the Boeing 707 dynamics, unacceptable manual landing performance was found. A prototype fault warning display was tested and found to be inadequate. The display was changed on the basis of pilot preference and performance, and considerable improvement in fault direction performance emerged. Low-altitude go-around and decision rules for Category III operations were examined. It was found that the system could be configured, and simplified rules could be used to help the pilot take the safest course of action. Some general fault-warning display design principles resulted.

26. ALL-WEATHER LANDING SYSTEM, VOL. 1, RESULTS OF FLIGHT
Hoopes, L. H., Weisner, G., Lockheed Georgia Co. Marietta, Report No. LGR-ER-8206, November 1968, AD-866 208L.
The category IIIB program was conducted to test and evaluate the C-141A all-weather landing system with the test results to be used as aid in establishing FAA category IIIB landing weather minima performance criteria.

27. ANALOG SIMULATION OF AUTOMATIC GLIDE SLOPE CONTROL USING WING LIFT SPOILERS AS DIRECT LIFT CONTROL.
Lloyd, Robert C., James, K., Naval Postgraduate School Monterey, Calif., June 1968, AD-855 529.
The use of wing lift spoilers as a means of changing lift without changing angle-of-attack was studied for use in the landing approach task. The vehicle used was the F-8 type fighter. Automatic glide slope controllers were proposed using an elevator glide slope coupler in conjunction with an automatic power compensator for comparison with an automatic direct lift control system. The system gains were optimized for gust disturbances and initial offsets from glide slope. An analog computer simulation program including a manual control phase was used to determine arbitrary measures of effectiveness of the proposed systems.

28. ANALYSIS OF HUMAN FACTORS DATA FOR ELECTRONIC FLIGHT DISPLAY SYSTEMS
Semple, Clarence A. Jr., Heapy, Raymond J., Conway, Ernest J. Jr., and Burnette, Keith T. 1st Lt/USAF Manned Systems Sciences, Inc., Northridge, Calif. Report No. AFFDL-TR-70-174, January 1971.
This report presents the results of a review of 1178 technical documents dealing with human factors considerations in electronic flight display systems. Design-oriented human factors data are presented for the following families of design considerations: display size, information coding, alphanumerics, scale legibility, visual acuity, display system resolution, flicker contrast ratio requirements, and environmental variables including ambient illumination, vibration and acceleration. Quantitative, design-oriented functional relationships are emphasized. Research recommendations are made where existing data were found inadequate for design use. A model is presented for organizing the variables impacting upon human performance as a function of electronic flight display system design.

29. AN ANALYSIS OF LONGITUDINAL CONTROL DURING LANDING APPROACH
Norihiro, Goto (Tokyo, University, Tokyo, Japan). Japan Society for Aeronautical and Space Sciences, Transactions, Vol. 13 no. 22, 1970.
Investigation of the characteristics of the back side operation using single and multiloop analyses. The problem of flight in the back side of the drag-velocity curve - i.e., one of the important problems in the landing approach - is examined assuming that it is a stability problem of the closed loop feedback control system where the pilot and the aircrafft are regarded as elements. An analysis of this problem is made using the closed loop system analysis technique. It is shown that the system characteristics on the back side

can be remarkably improved if the airspeed-control-with-throttle loop is added to the altitude-control-with-stick loop, and it is also shown that the lag in the throttle loop influences the system characteristics harmfully. A way of controlling the flight path on the back side is proposed as the result of the analysis.

30. ANALYSIS OF PILOT SURVEY ON V/STOL APPROACHES AND LANDING
Honeywell, Inc., Janair Report 681215, 1970.

31. ANALYSIS AND PRELIMINARY DESIGN OF AN ADVANCED TECHNOLOGY TRANSPORT AIRCRAFT FLIGHT CONTROL SYSTEM
Vol. I Technical Proposal, Lear Siegler, Inc., January 15, 1973.
This proposal presents the Lear Siegler-Astronics approach to the analysis and preliminary design of an advanced technology transport aircraft flight control system. Techniques are presented for taking advantage of recent and expected future developments in digital computer technology to perform new automatic control functions which will permit lighter and higher performance airframe designs while improving passenger comfort. Safety and the impact of introducing the new systems into routine airline operations are also considered. Methodology for deriving an optimum system configuration is described. A detailed description of the tasks involved in deriving an optimum system is given in Section 3. A discussion of various technical approaches to the most significant problem areas is presented in Section 4, along with a list of problems likely to be encountered. A summary of LSI's experience in the flight control field is given in Section 5. Particularly appropriate to the advanced technology transport program is the recent experience on the L-1011 automatic landing system development and the Navy DIGIFLIC program. The L-1011 autoland system is fail-operational and certified to Category IIIA. The DIGIFLIC program consists of a study for using a digital processor as the main computational element in an advanced flight control system. Qualification of personnel to be assigned to the program are described in Section 6. Detailed resumes are attached at the end of the proposal.

32. ANALYSIS OF V/STOL FLIGHT CONTROL SYSTEM CONCEPTS AS RELATED TO OPERATIONAL EFFECTIVENESS
Hoffman, Dale P., Ramsden, Walt S., Modiest, L. J., et al, AFFDL TR-68-120, March 1969.
A general methodology is reported for determining the interrelationships among flight control system concepts, maintenance philosophies, and operating policies as related to air vehicles possessing V/STOL capabilities. The principal characteristics of interest are those associated with flight safety and operational effectiveness. The methodology is developed through the selection of two particular V/STOL vehicle configurations representing typical tactical fighter and heavy transport designs. Fighter strike and infantry supply missions are developed in the context of coordinated deployment and support of an air mobile infantry brigade. These mission profiles and the two vehicle configurations are used as the basis for evaluating the flight safety/operational effectiveness tradeoff characteristics.

33. THE APPLICATION OF CORRELATION ILS TECHNIQUES TO TERMINAL AREA TRAFFIC CONTROL
Benjamin, J., This Journal, 22 October 1969.
Discussion of an ILS based on hyperbolic geometry and correlation detection and its possible applications in traffic control on terminal areas. The topics considered include the coverage, the accuracy and the rate of sensitivity variations of this technique as well as the role of the pilots in its implementation. The possible applications include an increased runway utilization, the exploitation of upward-looking systems, the use of vertical phase fields and of stacks and race track guidance, and the ILS reflection monitoring.

34. APPLICATION OF THE HEAD-UP DISPLAY/HUD/TO A COMMERCIAL JET TRANSPORT
Naish, J. M., (Douglas Aircraft Co., Long Beach, Calif.), Journal of Aircraft, vol. 9, Aug. 1972.
Previous work with HUD is extended by solving problems of installation in a commercial jet transport, and by demonstrating a high order of accuracy in manual control. Spatial aspects of the symbol format are organized to accord with principles promoting a balanced flow of information from the pilot's superimposed visual fields. Alternate installations are compared in DC-9 flight tests, an overhead mounting being found less prone to glare effects. Temporal aspects of the format are optimized by determining empirical relationships between gains and performance measures, for one test pilot and conditions are chosen which enable subsequent users consistently to demonstrate equivalence between manual and automatic methods of flight control. Consequently, a new basis is suggested for evaluating an all-weather approach system.

35. APPROACH GUIDANCE TO CIRCULAR FLIGHT PATHS
Journal of Aircraft, Vol. No. 2, February 1971.

36. AREA NAVIGATION SYSTEMS AND DISPLAYS
Wright, Frank F., Beckman, William R., (Lockheed-California Co., Burbank, Calif.), and Newman, T. J.,(AMBAC Industries, Inc., Arma Div., Garden City, N.Y.). Society of Automotive Engineers, National Air Transportation Meeting, Atlanta, Georgia, May 10-13, 1971. Paper 710457.

37. ATC AND LANDING AIDS FOR VTOL AIRCRAFT
Jones, S. S. D., Phillips, C. M., RAS - Paper to 2-day convention on Short-Range Transport, 1969.
Study of the terminal-area navigation and guidance problems which will be raised by the introduction of VTOL intercity transport aircraft. It is shown that the necessary area-coverage navigation facilities are within the state of the art but that a new approach-and-landing guidance system must be developed. The radio guidance system is described. It is pointed out that much thought has to be given to the aircraft control system and to the interaction between that system and the guidance system.

38. AUTOMATED LANDING SYSTEM
Popik, M. J., Sperry Rand Engineering Review, Vol. 24, No. 2, 1971.

39. AUTOMATIC LANDING SYSTEM 727 AIRPLANE
Templeman, J. E., (Boeing Co., Renton Wash.) and Parker, R. H., (Sperry Rand Corp., Sperry Phoenix, Ariz.). American Institute of Aeronautics and Astronautics, Aug. 14-16, 1967, Paper 67-573.
Description of the evolution of the Boeing 727 automatic flight control system with respect to its use in obtaining progressively lower operational weather minima for the airlines. The overall landing system is examined, and details of the dual-pitch channels of the automatic pilot are explained. Following a discussion of the 727 automatic-landing certification program, the future role and form of the automatic flight-control system are assessed.

40. AUTOMATIC LANDING SYSTEMS FOR ALL-WEATHER OPERATION BY CIVIL TRANSPORT AIRCRAFT,
Sullings, F. J., (British Overseas Airways Corp., London England) and Waller, P., (British European Airways, London, England), American Institute of Aeronautics and Astronautics, Royal Aeronautical Society, and Canadian Aeronautics and Space Institute, Anglo-American Aeronautical Conference, 10th, Los Angeles, Calif., Oct. 18-20, 1967, AIAA Paper 67-757.
Discussion of the introduction of scheduled automatic landing systems into standard in-service aircraft. The effects of introduction of automatic landing systems on a commercial airline are described, with special attention to the certification program, the formulation of certification requirements, and development of an operable system. The salient features of maintaining the Smith's flight control system are outlined and automatic landing certification for future aircraft is briefly discussed.

41. AUTOMATIC LANDING SYSTEMS MECHANIZATION - SERIES OR PARALLEL SERVOS?
Hoffman, Dale P. and Kawana, Harry (North American Aviation, Inc., Los Angeles Div., Los Angeles, Calif.) IN: Aerospace Vehicle Flight Control Conference, Los Angeles, Calif., July 13-15, 1965, Proceedings. A66-10661 01-21.
Review of several studies and their results, conducted in an effort to determine the most advantageous form of outer loop control mechanization for use in high-performance flight control systems. It is indicated that the series servo concept has considerable merit in contrast to the similar parallel servo mechanization. Results of both analytical and hardware tests with pilot-in-the-loop evaluation in the area of system performance, failure transients, malfunction protection, and physical characteristics have shown that for all autopilot functions and particularly for such critical outer loop functions as automatic landing systems, the series servo system mechanization is superior or equivalent to the parallel servo in all respects.

42. BELL COMMERCIAL AUTOMATIC FLIGHT CONTROL SYSTEM DESIGN AND TEST.
Erhart, R. G., (Bell Helicopter Co., Fort Worth, Tex.), Society of Experimental Test Pilots, Technical Review, Vol. 11, No. 3, 1973.

The philosophy of the design of a helicopter automatic flight control system (AFCS) is discussed, and the testing and development of the commercial AFCS is summarized. The problem is complicated because helicopter stability is a difficult design problem. Due to the range of airspeed the control power has to be high, and there are no appreciable aerodynamic forces to give "feel" to the flight control system. The stability and control augmentation system (SCAS) can be considered as a fast rate, limited authority system, while the attitude retention unit (ARU) is a slower rate, full authority, parallel system. A major portion of the flight testing was used to optimize gains and adjust the circuits to allow small delays before starting the parallel actuators in motion.

43. BIBLIOGRAPHY OF THE JOINT ARMY-NAVY AIRCRAFT INSTRUMENTAION RESEARCH PROGRAM
Joint Army-Navy Aircraft Instrumentation Research Project, Washington, D. C., Report No. JANAIR-720101, AD-903 890L, August 1972, AD-903 890L.

Displays for terrain avoidance/terrain following; integrated cockpit research program; displays for helicopter formation flight; displays for VTOL steep angle of approach; helicopter lift margin performance display; displays and controls for search and rescue aircraft; aircraft optimum multiple flight path displays; geographic orientation of aircraft pilots; theory of manual control for displays; aircraft head-up displays; integrated electronic aircraft displays; auditory displays; cockpit geometry evaluation; radar display media; navigation systems; low-airspeed sensor; subsystem interconnect techniques; and general.

44. A "BUILDING BLOCK" APPROACH TO INTEGRATED NAVIGATION DISPLAYS
Brown, Kenneth A. (International Telephone and Telegraph Corp., (ITT) Gilfillan, Inc., Los Angeles, Calif.). IN: International Air Transport Association, Technical Conference, 16th, Miami, Fla., April 22-30, 1965, Working Papers. Vol. 1 (nos. 1-70). A66-17667 07-21,Montreal, International Air Transport Association, 1965. 15 pp.

Assessment of building blocks that had their beginnings in a pictorial navigation display designed to project a servo-driven microfilm map onto a 5.5 in. by 7.5 in. rear projection screen. The display unit was packaged in a 9 in. by 7.5 in. by 9.5 in. box, and weighed less than 16 lb. Since then, continuous improvements have been made in display brightness, optical resolution, and microchart technology, which were incorporated in two horizontal situation displays. One of the systems is described. Designed for use in a V/STOL aircraft, it consists of the display unit, the control panel, and a remote amplifier-power supply unit. Parallel to the development of the map drum type of display, an advanced integrated horizontal situation display was constructed; this added new features to the catalog of building blocks. All these blocks are being combined in an advanced integrated navigation display now in fabrication.

The compact size, micromap drum with multiple scales and reference data, and folded optics of the USAF and NASA displays, are combined with the image rotation, multiple shadow reticles, and electronically generated symbols superimposed over the map from the JANAIR display, plus the optional use of the integral CRT as a radar indicator or television monitor. The major characteristics of this display system are tabulated.

45. C-5A CATEGORY I ENGINEERING FLIGHT TEST AUTOMATIC FLIGHT CONTROL SYSTEM TEST RESULTS
Kascak, A. J., Lockheed-Georgia Co., Marietta, Report No. LGIT19-1-20-Vol 2, June 1972, AD-904 506L.

Development and demonstration tests were conducted on the C-5A autoland to optimize performance and demonstrate compliance with specification requirements. Volume 1 discusses all autopilot modes except those associated with ILS approaches or autoland which are covered in vol. 2.

46. CATHODE-RAY TUBE CENTERED HSI
Astronautics Corp. of America, Milwaukee, Wis.,Sobocinski, R., Wright-Patterson AFB, Ohio AF Flight Dyn. Lab. May 1968, AFFDL-TR-68-71; AD-839574.

The study demonstrated that the electro-mechanical elements in the center section of a Horizontal Situation Indicator (HSI) could be successfully replaced by electronically generated symbols on a cathode-ray tube, thus allowing the HSI to be used as a multi-mode display for future requirements of the Air Force. The course pointer, vertical deviation bar, horizontal deviation bar, and the TO/FROM indications were generated by digitally programming an Up/Down counter from both the X and Y axis. The outputs were converted to CRT sweep voltages by a digital to analog converter. The generated symbol set was rotated with respect to aircraft heading by resolving the X,Y sweep voltages. A flyable prototype was successfully constructed.

47. THE CHANGING WORLD OF THE PILOT IN THE NEXT DECADE - V/STOL AIRCRAFT OPERATIONS
Reeder, J. P., HFSNS Paper, October 1970.

48. COCKPIT EQUIPMENT
Schaffer, Richard E., Sperry Rand Engineering Review, Vol. 24, No. 3, 1971.

In this, the era of wide-bodied jet aircraft, each carrying several hundred passengers at near-sonic speed, effective flight path management is more important than ever. More accurate, more versatile, and more sophisticated sensing, computing, and control devices have been developed over the past decade. These tools extend the capabilities of the aircraft to new levels of operational dependability, safety, and economy. But, the assimilation of this expanded capability in the cockpit confronts the designer with a dual challenge; not only must he provide all the information necessary to control

an immensely complex vehicle, but he must also achieve this with a degree of integrity never before realized and at reduced crew stress levels. These objectives demand the consolidation of all flight data and control functions into as simple and intelligible a display arrangement as possible.

49. COCKPIT WARNING SYSTEM COMPARATIVE STUDY
Bate, Almon J., AMRL, February 1968.

50. COLOR CATHODE-RAY INSTRUMENTS ENHANCE DISPLAY SYSTEMS
Trichet, Jean-Claude, Foreign Technology Division Wright-Patterson AFB, Ohio, Report No. FTD-HC-23-1104-72 July 1972, AD-904 137L
This article discusses in detail the problems involved in adapting picture tube technology to use on flight decks, and notes several recently developed solutions that have made this possible. In particular, the article cites research done by the firm Thomson-CSF on the use of color picture tubes. This firm has realized some variable penetration tubes that have two photoemissive layers of different colors. Each, excited by electrons with different energy levels. By modulating the acceleration voltage of the electron beam, four different colors may be created: red, green, yellow, and orange.

51. COMBAT CAPABILITIES AND VERSATILITY THROUGH CCV
Bennett, D. H. McDonnell Aircraft Company, and Johannes, R. P., Flight Dynamics Laboratory, Dept. of the Air Force (Society of Automotive Engineers, National Aerospace Engineering and Manufacturing Meeting, San Diego, California, October 2-5, 1972).
Advanced design studies indicate that use of "control configured vehicle" (CCV) concepts can provide improvements in combat capability and versatility. These benefits will be evidenced by improved performance and survivability, as well as by new maneuvering capabilities not available to pilots of current aircraft. The fly-by-wire (FBW) techniques, utilized to enable CCV, also provide the potential for improved flying qualities. The end result of applying these concepts in the preliminary design stages can be a lighter weight fighter aircraft to do a given job better.

52. COMMAND AUGMENTATION - DIGITAL FLIGHT CONTROL EVALUATION
Neebe, Fred C., (General Electric Co., Avionic Controls Dept., Binghamton, N. Y.). Institute of Electrical and Electronics Engineers, National Aerospace Electronics Conference, 21st, Dayton, Ohio, May 19-21, 1969, Proceedings A69-34056 17-09.
Development of a digital control computer using the most advanced computer techniques and microelectronics and specifically tailored to the flight control task. Completely solid-state, this variable incremental computer is packaged in a single unit which includes all power supplies, converters, interface units, and switching interlocks. It has the speed to perform all the stability augmentation functions of high-performance aircraft and helicopters and the capacity to perform all of the pilot relief functions. It can generate complex path control programs such as those required for minimum fuel expenditure for VTOL landing. Reserve capacity can be used for special self-test problems and new types of flight control functions.

53. A COMPUTER-GENERATED DISPLAY TO ISOLATE ESSENTIAL VISUAL CUES IN LANDING
Hummel, B. H., Williges, B. H., and Roscoe, S. N., (Illinois, University, Urbana, Ill.), Proceedings of the Sixteenth Annual Meeting, Los Angeles, Calif., October 17-19, 1972. (A73-16701 05-05) Santa Monica, Calif., Human Factors Society, Inc., 1972.

54. CONCEPT PAPER FOR AN INTEGRATED FLIGHT CONTROL AND NAVIGATION SYSTEM FOR THE EUROPLANE PROGRAM
Lear Siegler, Inc., Astronics Division, March 29, 1973.
This document is organized to first provide a summary of proposed concepts, followed by a discussion of current technological trends and possible candidate systems. During the February 7, 1973, informal discussions between Astronics and Europlane personnel, the Europlane team described the preliminary avionics concept for the aircraft. This concept included two digital navigation computers and three digital flight control computers. Astronics believes it is more cost effective to integrate the navigation and flight control functions into common digital computers, thereby more fully utilizing the capabilities of the digital computations. However, it may be worthwhile to consider the use of presently available hardware for high-integrity functions, such as autoland, where the development and certification costs are high. For example, the present L-1011 autoland system could be used on the Europlane aircraft, minimizing the total safety analysis effort required for certification. The other flight control functions could be integrated with the navigation computations in common digital computers.

55. CONTROL EQUIPMENT OF AIRCRAFT
Kukhon, Iu. I. and II'inskii, N. N., Moscow, Voenizdat, 1972, in Russian.
This book is based on Soviet and western published work on aircraft control systems. Radio communication and navigation systems, automatic guidance and landing systems, homing and radar tracking of aircraft are discussed in detail. The topics include data transmission through radio channels, atmospheric interferences in radio communications equipment for target detection and identification, radio and light signal systems for near-airport flight control, radio beacon aircraft locating and tracking techniques, and automatic homing on air and ground targets.

56. CONTROL PROBLEMS IN THE CASE OF VTOL AIRCRAFT WITH SPECIAL ALLOWANCE FOR MAN AS PART OF THE CONTROL SYSTEM
Schweizer, G. (Dornier-System GmbH, Friedrichshafen, West Germany) and Staufenbiel, R. (Vereinigte Flugtechnische Werke GmbH, Bremen, West Germany). Luftfahrttechnik Raumfahrttechnik, vol. 15, Nov. 1969, In German.
Discussion of the man-machine interface and its improvement in the control of VTOL aircraft and in problems of adaptation of stabilization systems to aircraft control. Methods of generating moments in the case of VTOL aircraft are considered, and man-machine relations during manually controlled hovering flight are examined. The detection of deviations of the controlled parameters from the desired values is discussed.

57. CONTROL PROBLEMS IN VTOL AIRCRAFT TAKING PARTICULAR ACCOUNT OF MAN AS A LINK IN THE CONTROL LOOP
Schweizer, G., Staufenbiel, R, Luftfahrttechnik Raumfahrttechnik, 1969.
Study of the means of improving control characteristics in VTOL aircraft. The various possibilities of phase lead generation, the stabilization systems applicable to VTOL aircraft, and the means usable in controlling translational motions during transition from hovering to aerodynamic flight are evaluated as aids toward better flight characteristics and man-machine interaction. A review of solutions to problems of matching stabilization systems with flight control systems is presented, taking into account reliability factors in flight-control and automatic-control systems.

58. CONTROL STUDY FOR ADVANCED SUPERSONIC TRANSPORT
Honeywell Inc., Systems and Research Division, Research Department, November 1, 1972.
The DIGIFLIC study consisted of six major technical areas: Control law synthesis; Redundancy and self-test provisions; Digitization procedures and performance; Computer variational parameters; Airborne computer programming and simulation; Implementation specification.

59. CONTROL TECHNIQUE AND FLIGHT QUALITY OF NEW GENERATION AIRCRAFT
Wanner, J. C., (Delegation Ministerielle pour l'Armement, Paris, France), (Association Francaise des Ingenieurs et Techniciens de l'Aeronautique et de l'Espace and the Royal Aeronautical Society, Journee Louis Bleriot, 24th, London, England, April 22, 1971), L'Aeronautique et l'Astronautique, No. 31, 1971. In French.
Investigations have shown the necessity of reducing crew workloads in order to improve flight safety of military and civil aircraft. The study led to a definition of the various components of a modern cockpit: a head-up display featuring the velocity vector, potential climb angle, horizon, and synthetic runway; a head-down display giving the necessary data concerning the flight phases when airborne (climb, cruise, descent, and approach); and a ministick and autopilot to handle the aircraft, with a gust alleviation device to improve passenger and crew comfort.

60. CONTROL THEORY RESEARCH (FINAL SCIENTIFIC REPORT)
March 1, 1970, February 29, 1972, Ackermann, Jurgen E., Kreisselmeier, Gerhard, Deutsche Forschungs-and Versuchsanstalt fur Luft-und Raumfahrt, West Germany, N73-14251 May 1972.
The report contains a summary of research performed by the control systems department at the Institute for Dynamic of Flight Systems of DFVLR during the period from March 1, 1970 until February 29, 1972.

61. CONTROL WHEEL CONSOLES FOR CONTROL-DISPLAY MODEL SELECTION SWITCHING
Krueger, Gerald P., Bunker-Ramo Corp., AD-845 476 TR-68-142, Nov. 1968.
Three console-switching configurations were developed and flight tested. The preliminary results of the testing indicate that the location of switches on the consoles will be particularly useful to the pilot in accomplishing the instrument landing.

62. CRITICAL ANALYSIS OF B-52 STABILITY AUGMENTATION AND FLIGHT CONTROL SYSTEMS FOR IMPROVED STRUCTURAL LIFE. PART I. INITIAL FEASIBILITY STUDY. VOL. I.
Strand, D. E., Boeing Co , Wichita, Kansas; Wichita Division, Report No. D3-6434-1-REV-C, Oct. 1965, AD-891 634L.
The results of the initial feasibility conducted under Part I of "Critical Analysis of B-52 Stability Augmentation and Flight Control Systems for Improved Structural Life" are reported in four volumes. D3-6434-1 (interim report) reports the work accomplished on the yaw axis stability augmentation study. D3-6434-2 Contains the results of the roll axis analysis. D3-6434-3 contains the pitch axis analysis. D3-6434-4 contains the results of the flexible analog study and the selection of the stability augmentation system.

63. DESIGN AND DEVELOPMENT OF THE PRIMARY FLY-BY-WIRE FLIGHT CONTROL SYSTEM FOR THE XV-4B V/STOL RESEARCH AIRCRAFT
Jackson, V. R. and Patch, D. E., (General Electric Co., Aerospace Group Aircraft Equipment Div., Avionics Controls Dept., Binghamton, N. Y.), American Institute of Aeronautics and Astronautics, Aug. 12-14, 1968, Paper 68-818.
Description of the design, analysis, and flight simulation of the primary fly-by-wire flight control system for the XV-4B V/STOL research aircraft. Redundance features include triplex fly-by-wire and a pilot select mechanical back-up. Fail-operational performance and maximum use of flight-proven equipment were the primary program objectives. High rate gains and responsive controls provide essentially invariant angular rate maneuvering throughout the V/STOL flight envelope without gain changing or control blending. It is concluded that automatic control technology provides a basis for effective solution of the complex flight control problems encountered in V/STOL aircraft.

64. DESIGN CRITERIA FOR HIGH-AUTHORITY CLOSED-LOOP PRIMARY FLIGHT CONTROL SYSTEMS
Hendrick, R. C., Rasmussen, R. F., Honeywell Inc., Minneapolis, Minn. Government and Aeronautical Products Division, Report No. 21572-FR. Z9080-3041, AD-903 862L, August 1972.
The study consisted of eight parts, including a survey of operational problems. A review of system-gain changing (Requirements and Techniques), stabilization criteria for high-frequency control modes, and analysis of stall/spin maneuvers, a catalog of dominant performance characteristics which affect flying qualities, an analysis of system/airframe compatibility testing.

65. DESIGN CRITERIA FOR HIGH-AUTHORITY CLOSED-LOOP PRIMARY FLIGHT CONTROL SYSTEMS
Hendrick, R. C., Bailey, A. J., Edinger, L. D., et al, Howell Inc., Air Force Flight Dynamic Laboratory, Report No. AFFDL-TR-71-78, Aug. 1972.

66. DESIGN OF ELASTIC MODE SUPPRESSION SYSTEMS FOR RIDE QUALITY IMPROVEMENT AND APPLICATION TO AN SST
Edinger, L. D., 1967, Paper No. 67-571 AIAA.
An analytical technique is presented for design of systems to actively control the structural bending modes to improve the ride quality on flexible aircraft. The technique specified a set of requirements for the sensor configuration and filtering for a system which provides corrective control through the conventional aerodynamic control surfaces. Vehicle data required only in a frequency-response format, thus facilitating the inclusion of unsteady aerodynamics. Application of the technique to a large supersonic transport is described. Gust-response data on the SST indicated that the lower-frequency symmetric structural modes contributed up to 60 percent of the rms acceleration at the pilot's station. Results of the study showed that a system designed by the synthesis technique essentially achieved the performance objective of a 50 percent reduction in the rms acceleration level at the pilot's and other critical vehicle stations. This application of the synthesis technique to the SST problem showed it to be an effective design tool.

67. DESIGN AND EVALUATION OF MINIATURE CONTROL SURFACE ACTUATION SYSTEMS FOR AEROELASTIC MODELS
Bergmann, Gerald E., Sevart, Francis D., Boeing Co. March 19-20,1973, AIAA Pater No. 73-323.
Miniature control surface actuation systems with wide bandpass performance have been developed for two airplane aeroelastic wind tunnel models. Analysis, design and test results are presented for: (1) electromechanical systems for the elevator, aileron, canard and flaperon control surfaces of a 1/30 scale B-52 model, and (2) electrohydraulic systems for the trailing edge and leading edge aileron control surfaces of a 1/17 scale semispan delta wing model. The electromechanical systems utilize dc torque motors with position and rate feedback to achieve a bandpass capability of 50 Hz. A rotary vane hydraulic actuator (weighing less than 3 ounces) and servovalve compensated with position and load pressure feedback have demonstrated a band pass performance of over 100 Hz.

68. DESIGN OF FIXED GAIN COMPENSATOR SYSTEM FOR THE LONGITUDINAL AXIS OF THE C-141 FLY-BY-WIRE AIRCRAFT
Kwasigroh, Larry D., A.F. Institute of Technology, March 1973, AD-760 763.
The report presents an attempt to design a fixed gain control system for the longitudinal axis of the C-141-fly-by-wire aircraft. Classical control theory using root locus and frequency response (bode) techniques was used throughout the design process. It was found that a quadratic over quadratic compensator

in the forward path of the C* control loop improved the system response even with the origial discreter gains with slightly relaxed constraints on the C* performance (*envelope was originally designed for fighter aircraft). A single fixed gain in the C* loop produced acceptable C* category 3 responses. An additional quadratic over quadratic compensator was designed for the pitch attitude control loop; however, the acceptability of the attitude response with a fixed gain is questionable.

69. DESIGN AND FLIGHT EXPERIENCE WITH A DIGITAL FLY-BY-WIRE CONTROL SYSTEM IN AN F-8 AIRPLANE
Deets, Dwain A. and Szalai, Kenneth J., September 24-26, 1973, AGARD 17th Guidance and Control Panels Symposium on Advances in Control Systems, Geilo, Norway.

A digital fly-by-wire flight control system was designed, built, and for the first time flown in an airplane. The system, which uses components from the Apollo guidance system, is installed in an F-8 airplane as the primary control system. A lunar module guidance computer is the central element in the three-axis, single-channel, multimode, digital control system. A triplex electrical analog system which provides unaugmented control of the airplane is the only backup to the digital system.

70. DESIGN AND FLIGHT EXPERIENCE WITH A DIGITAL FLY-BY-WIRE CONTROL SYSTEM USING APOLLO GUIDANCE SYSTEM HARDWARE ON AN F-8 AIRCRAFT
Deets, D. A. and Szalai, Kenneth, J., (NASA, Flight Research Center, Systems Analysis Branch, Edwards, Calif.), American Institute of Aeronautics and Astronautics, Guidance and Control Conference, Stanford, Calif,. Aug. 14-16, 1972, Paper 72-881.

This paper discusses the design and initial flight tests of the first digital fly-by-wire system to be flown in an aircraft. The system, which used components from the Apollo guidance system, was installed in an F-8 aircraft. A lunar module guidance computer is the central element in the three-axis, single-channel, multimode, digital, primary control system. An electrohydraulic triplex system providing unaugmented control of the F-8 aircraft is the only backup to the digital system. Emphasis is placed on the digital system in its role as a control augmentor, a logic processor, and a failure detector. A sampled-data design synthesis example is included to demonstrate the role of various analytical and simulation methods. The use of a digital system to implememt conventional control laws was shown to be practical for flight. Logic functions coded as an integral part of the control laws were found to be advantageous. Verification of software required an extensive effort, but confidence in the software was achieved. Initial flight results showed highly successful system operation, although quantization of pilot's stick and trim were areas of minor concern from the piloting standpoint.

71. A DESIGN PROCEDURE AND HANDLING QUALITY CRITERIA FOR LATERAL-DIRECTIONAL FLIGHT CONTROL SYSTEMS

Stein, G. and Henke, A. H., February 1971, Honeywell-AFFDL-TR-70-152.

A study to develop improved design criteria for primary flight controls which feature feedback techniques is reported. The study consisted of eight parts, including a survey of operational problems, a review of system-gain changing (requirements and techniques), stabilization criteria for high-frequency control modes, an analysis of stall/spin maneuvers, a catalog of dominant performance characteristics which affect flying qualities, an analysis of system/airframe compatibility testing, definition of criteria for built-in test equipment, and a catalog of flight control actuator designs. Operational problems include high angle-of-attack stability and potential control loss. A math model of a spinning F-4 was used to study basic effects and associated control criteria. Nominal control laws in pitch and yaw tended to be beneficial for departure inhibition; roll control degraded controllability. Spin recovery demands full surface deployment without detraction by feedback. The controllability limit for spin recovery was defined. The compatibility test analysis featured closed-loop simulation of structural response. Compensation for surface aerodynamics and special airframe support to avoid bending mode distortion were justified. Criteria for built-in test equipment in redundant flight controls to produce adequate flight safety and mission reliability were expressed in terms of test thoroughness, latent failure probabilities, and false indication rate. Test quality was shown to have a highly significant effect on system reliability that becomes more critical with the number of redundant channels and system life.

72. DESIGNS TO REDUCE AIRCRAFT FLIGHT CONTROL VULNERABILITY

Taylor, Frederick R, Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio, Flight Control Division, Report No. AFFDL/FGL-TM-71-3, September 1971, AD-900 992L.

This report summarizes the current status of tactical aircraft flight control system vulnerability based, on combat experience in sea (southeast Asia) specific survivability deficiencies are identified. Design concepts and technology than can reduce flight control system vulnerability in current and future aircraft are presented.

73. THE DESIGN OF STABILITY AUGMENTATION SYSTEMS FOR DECOUPLING AIRCRAFT RESPONSES

Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio, Ph. D. Thesis - Purdue Univ. Final Report, Jan. 1970 - Dec. 1971, Pope, Rhail E., June 1972, NASA-CR-130543; AD-747017; AFFDL-TR-72 63.

Tactical aircraft with STOL capability exhibit undesirable coupled response during the landing phase of flight. A simplified method for designing a stability augmentation system which eliminates the coupling effects is demonstrated. The method is based on Gilbert's decoupling theory which utilizes a feedback control law to obtain a set of single input, single output subsystems. The augmentaion system can be designed to provide either command rate or command angle authority in the three rotational axes. Analyses

is facilitated through the use of two computer programs, the first of which determines the class of control laws which will decouple a system. The second computer program determines, through transient response analysis, the values of the transfer function parameters required to satisfy response criteria. The results of a piloted simulation which analyzed several decoupled configurations is also presented.

74. DEVELOPMENT OF DC-10 AUTOMATIC LANDING MONITOR
Harenberg, H. L., Jr.; and Shannon, J. H., SAE Paper No. 690672, 1969

75. DEVELOPMENT AND EVALUATION OF A FLIGHT DIRECTOR SYSTEM FOR INSTRUMENT LANDINGS
Lamb, Joe A, May 1972, AD-748244; ARL-72-11/AFOSR-72-6.
The research evaluates comparatively, in a simulated instrument landing system, four different configurations of a flight director display using command heading and command flight path angle. The four configurations include moving horizon display, moving aircraft display, frequency-separated display, and kinalog display. ILS localizer tracking performance with any of the experimental displays was superior to that with the conventional cross-pointer flight-path display.

76. DEVELOPMENT AND EVALUATION OF A TWO-COLOR ELECTROLUMINESCENT V/STOL HOVER DISPLAY
Fuller, P. R., (Lear Siegler, Inc., Instrument Div., Grand Rapids, Mich.), IN: SOCIETY FOR INFORMATION DISPLAY, NATIONAL SYMPOSIUM ON INFORMATION DISPLAY
8th, SAN FRANCISCO, CALIF., MAY 25-27, 1967.

77. DEVELOPMENT AND FLIGHT TEST OF A DIGITAL FLY-BY-WIRE F-8 AIRPLANE
Peterson, Bruce A., Krier, Gary E. and Jarvis, Calvin R., Society of Experimental Test Pilot's Symposium, September 28-30, 1972. Beverly Hills, Calif.
Digital fly-by-wire control technology has long been proposed as a solution to many of the complex control problems stemming from the expansion of aircraft operational envelopes. A recognized need exists to develop more advanced flight control systems for such future vehicles as the space shuttle (SSV), the supersonic transport (SST), short haul aircraft (such as VSTOL and STOL), and advanced fighters and helicopters. By incorporating fly-by-wire technology, the performance of these aircraft could be optimized without having to trade off basic aerodynamic stability. If fly-by-wire looks attractive for a vehicle, full advantage should be taken of it. For example, the aircraft can be designed initially as a control-configured vehicle (CCV), or its design can utilize active controls technology (ACT) concepts. Trim drag associated with large stability margins could be eliminated, and complex control laws could be programmed into a computer to gain maximum performance from the vehicle.

78. DEVELOPMENT OF A GYRO-LESS DIGITAL FLIGHT DIRECTOR
Horwitz, David L., Ohio Univ., Athens, Dept. of Electrical Engineering, Oct. 1972, AD-754028.

This research presents a new type of digital flight director which is free of gyroscopic references. This digital flight director (controller or compensator) is derived by two methods, the (root locus) trial and error method and Truxal's Method. The first method showed the feasibility of a gyro-less controller. Using the second method, a digital flight director is obtained that offers precise aircraft control on a defined route. The derivation and testing of these controllers are discussed in detail in the report.

79. THE DEVELOPMENT OF AN INTEGRATED FLIGHT GUIDANCE AND CONTROL SYSTEM FOR MODERN HIGH-PERFORMANCE AIRCRAFT
Schumann, H. G. and Staufenbiel, R. (Vereinigte Flugtechnische Werke GmbH, Bremen, West Germany). Deutsche Gesellschaft fur Luft und Raumfahrt, Jahrestagung, Bremen. West Germany, Sept. 22-24, 1969, Paper 41, in German.

Discussion of the development of a "fly-by-wire" system for aircraft in which errors are automatically eliminated. The system was designed in connection with development work for VTOL aircraft. Basic investigations regarding the electronic and electrohydraulic control components are discussed. The design of a model which was tested successfully in 100 experimental flights is described. Further developments are considered which led to the first prototype of the device.

80. DEVELOPMENT OF STOL AND, A VERSATILE NAVIGATION, GUIDANCE AND CONTROL SYSTEM
Hansen, G. M., Young, L. S. (NASA, Ames Research Center, Moffett Field, Calif.), Rouse, W. E., and Osder, S. S. (Sperry Rand Corp., Sperry Flight Systems Div., Phoenix, Ariz.). American Institute of Aeronautics and Astronautics, Los Angeles, Calif., Aug. 7-9, 1972, Paper 72-789.

STOLAND has been developed to perform navigation, guidance, control, and flight management experiments in advanced V/STOL aircraft. An integrated digital concept using modern avionics components was selected as the simplest approach to maximizing versatility and growth potential. Unique flexibility has been obtained by use of a single, general-purpose digital computer for all navigation, guidance, control, and displays computation. Modularity of the software insures easy change of experiments. The general-purpose computer is integrated with flexible pilot controls and with both electromechanical and CRT displays for maximum cockpit versatility. A complex hierarchy of control modes with safety monitors and interlocks has been provided.

81. DFCS DESIGN REPORT III
Sowada, D. J. and Gaabo, R. J., Government and Aeronautical Products Division, March 1973, Honeywell.

The report describes and documents the software and hardware that exists for the breadboard system. A general study of control law mechanizations is also included. Other general DFCS implementation considerations that were defined in conjunction with the triplex design--such as self-test and sensor/actuator monitoring--were later picked up and incorporated in "Navy Digital Flight Control System Development," Final Report, December 1972, Honeywell Document 21857-FR, and in "Digital Flight Control System Requirements for Tactical Fighters," Final Report to be issued later this year. These subjects are not repeated in this report.

82. DIGITAL FLIGHT CONTROL SYSTEM (DFCS) INTERFACE DEFINITIONS
Smith, F. L., Government and Aeronautical Products Division, November 1972, Honeywell.

The initial work that was done was directed towards simplex interface definitions between the Electronics Control Assembly (ECA), which contains the digital processor, and the balance of the system. The items that were considered include analog sensor inputs, DADS (Arinc Characteristics 575 and 576) inputs, Radar Altimeter digital inputs, and analog servo outputs. Subsequent work was devoted to redundant interfaces. The complexity of the interface is directly proportional to the difference in degree of replication on either side of the interface. If the difference is such that one is an integral multiple of the other, then the early work done on simplex mechanizations is directly applicable. The bulk of the redundant interface work done is concerned with the non-integral multiple cases such as pentad/triplex, quadruplex/triplex, duplex/triplex, triplex/duplex, and triplex/quadruples. An approach to a digital servo loop was also defined during the most recent efforts.

83. DIGITAL FLIGHT CONTROL TECHNOLOGY ROADMAP
Blatt, Paul E., Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, September 1973, Report No. AFFDL-FGL-TM-73-65.

Long-range program planning for digital flight control technology validation is based upon a technical roadmap establishing essential requirements, tests, and criteria which must be developed to confidently and economically apply digital flight controls benefically to advanced weapon systems. End objective of the Air Force Flight Dynamics Laboratory's exploratory and advanced development programs for digital flight controls is the total multimode aircraft design and control flexibility that digital controls impart to concepts such as the Advanced Fighter Technology Integrator (AFTI). Secondary objectives are to establish realistic performance-cost-time tradeoffs as to the extent that digital controls should replace analog controls for future weapon system applications. The roadmap is subdivided into Primary Digital flight controls, Multiplexing, Displays, and Function Integration groupings. Relationships of basic exploratory development to digital system transition to advanced developments, and final systems application are clearly evident. Relationships between the Tactical Advanced Digital Control System (TADS) ADP and the Digital Avionic Information System (DAIS) are

clarified. Areas requiring additional program investigation have been identified. The technology roadmap scheme is a useful management tool for broad programs. A summary of on-going digital flight control flight test programs is also included in the report.

84. DIGITAL FLY-BY-WIRE NEARS LAUNCH
Arnold, William F., Aerospace Editor.
Fueled by continuing advances in computers and large-scale-integration technology, Government and industry researchers are developing new digital fly-by-wire (DFBW) flight-control systems. Developers predict that when DFBW systems are ready later this decade, they will lead to cheaper and more responsive flight control in aircraft that, though lighter, will carry the same payloads as previous planes.

85. A DIGITALLY-ADDRESSED FLAT PANEL CART
Goede, W. F., June 1973, Northrop Corporation,
Principles of operating and special operational features of a digitally addressed flat panel electron beam display are discussed. Special emphasis is given to explaining methods of simplifying and optimizing the display structure for a given application, and techniques for implementing color and inherent storage to the structure. In addition, a fairly detailed analysis of the display power requirements is given, along with calculations for a specific display. Also covered are the operating characteristics of several prototype displays, and comments pertaining to life, manufacturability, and environmental characteristics.

86. DIRECT LIFT CONTROL FOR THE LAMS B-52
Nelson, Gary L., and Lorenzetti, Robert C., AF Institute of Tech., June 1968, AD-831 091, TR-68-134.
A DLC (Direct Lift Control) system was designed for the LAMS B-52 test aircraft using optimization theory. Spoilers, symmetric ailerons, and elevator respond to normal longitudinal column movements achieving incremental rates of climb up to 500 FPM from trim without pitching the aircraft. DLC reduces normal acceleration 50 percent, both in and out of turbulence, and improves airspeed control in precision maneuvering tasks: approach and landing, in-flight refueling, and terrain following. The closed-loop DLC controller, consisting of fixed-gain normal acceleration, pitch angle, and pitch rate feedbacks to the three control surface servos, was demonstrated by a piloted 6° of freedom analog simulation.

87. DISPLAYS FOR APPROACH AND LANDING OF V/STOL AIRCRAFT
Advisory Group for Aerospace Research and Development, Paris (France), Nov. 1972, AGARD-AR-51.
An analysis of the display systems required for approach and landing of V/STOL aircraft was conducted. The various factors considered in the analysis are (1) operational factors and ground environment, (2) guidance

requirements, (3) relation between control and display sophistication, (4) information requirements, (5) human factors engineering, and (6) current display devices. Diagrams of proposed instrument panels and display devices are included.

88. DISPLAY INSTRUMENTATION FOR V/STOL AIRCRAFT IN LANDING
Van Houtte, N. A. J., NASA Report CR-112779, 1970.
A V/STOL aircraft (of the tilt-engine type) was simulated and flown from cruise altitude to touchdown with severe wind disturbance, descending along glideslopes of 4.47°, 8.87°, and 17.3°. A general display program was written to display a skeleton scenery, consisting of lines connecting the runway boundaries, the glideslope lines, and several distance indicating poles. The piloting task consisted of staying in level flight until intercept of the glideslope, then in tracking the glideslope to hover, and in landing the aircraft with minimum impact velocity and maximum accuracy. The task was quite difficult, because of the lack of stability augmentation. The value of the perspective glideslope is shown in the ease of performing coordinated maneuvers, the consistency of touchdowns, accuracy of tracking the glidelslope, the learning curve, and the effectiveness of the representation of the integrated real world outside picture.

89. DISPLAYS FOR APPROACH AND LANDING OF V/STOL AIRCRAFT
AGARD, AGARD Advisory Report No. 51, Nov. 1972.
With the increased number of parameters requiring pilot attention, the potential gains in both performance and safety from presenting the information in the cleanest and simplest fashion are much greater in the VSTOL case than in conventional aircraft. The mass of information to be absorbed by the pilot, usually indifferent axes, poses peculiar problems in the integration of information and implies the use of combined displays. The design of which should be as simple as possible while still providing the essential functions. Whether the information is presented head-up or head-down depends on other circumstances, e.g., the existence of a head-up display for mission purposes.

90. DISPLAY SYSTEMS FOR VERTICAL TAKEOFF TRANSPORT AIRCRAFT
Francis, B. C., 1971, IEE Conference on Displays, Proceedings No. 80.
A V/STOL simulator study, carried out on the Hatfield fixed base simulation facility, is described in which the operational requirements of an aircraft flying profiles anywhere between the very shallow angles typical of conventional aircraft up to the limiting case vertical ascent and descent were investigated. A comparison of the head-up display VTOL and STOL studies indicates that properly processed director information need not be intimately related to quantitative information. A thorough assessment of the display concept showed that it was possible to provide the pilot of even a very complex aircraft with much of the information in a form that he would require to perform an accurate and safe landing.

91. EADI/MFD ID PROGRAM

Schuck, J. W., Government and Aeronautical Products Div., Honeywell Jan. 1973.

To accomplish the development of this display system, several tasks were accomplished. Previously developed display hardware was modified to incorporate the specific requirements for this application. The H316-DE interface hardware was designed and built, the H316-Boeing interface hardware was designed and built, the H316 Data Multiplex Control (DMC) and high spped arithmetic options were obtained and installed, and the H316 was programmed to provide the necessary data processing and formatting.

92. EFFICIENT FLIGHT MANAGEMENT - A STEP FORWARD IN FLIGHT SAFETY

Marmisolle-Daguerre, E. (Sperry Rand France, Puteaux, Hauts-de-Seine, France). International Conference, Paris, France, June 26-30, 1972, Reports, Volume 1, (A73-32426 15-21) Paris, Editions Chiron, 1972.

Following a review of early blind flying instrumentation and procedures, present-day devices are described and discussed. The Sperry zero reader, a pioneer flight director system, was developed to relieve the pilot's burden. The Sperry Integrated Instrument System arrived in time for the first generation of jet transports. The most critical instrument for short-term flight management is the attitude direction indicator. Horizontal situation indicators provide a semipictorial display of ground track data. The radio magnetic indicator has undergone considerable change in adapting to technological progress. The instrument comparison monitor is an integrity assessment tool. A useful device for easing crew workload is the thrust rating system. Some future devices such as advanced cathode-ray tube displays are discussed.

93. ELECTRICAL INTERCONNECTIONS FOR FLY-BY-WIRE FLIGHT CONTROL SYSTEMS

The Boeing Co. October 1970, AFFDL-TR-70-134.

An aircraft with a fly-by-wire (FBW) flight control system will be completely dependent on the integrity and reliability of its electrical systems. Since FBW is a relatively new concept, there is no military specification that addresses the overall wiring and connector requirements of a purely electrical flight control system. Aircraft electrical designers are, in general, not familiar with the concepts of dispersed redundancy and elimination of single-failure points that must be an integral part of a FBW design. An investigation of current and proposed wiring and connector hardware and techniques was conducted by reviewing: FBW technical literature; wire and connector specifications, test data and failure; military and commercial specifications, standards and handbooks; and by discussions with several aircraft, spacecraft and launch vehicle manufacturers. It was concluded that; hardware and techniques for the high reliability requirements of FBW exist at present or are in an advance development stage, the FBW wiring requirements must be defined early in the aircraft design with adequate routing priorities, and special manufacturing and maintenance controls are required. The recommendations provided in this report are based mainly on Apollo vehicle techniques and hardware, proposed techniques and hardware for the SST stability augmentation system and on information from the Air Force "Survivable Flight Control System" program.

94. ELECTRONICS IN ALL-WEATHER OPERATIONS
Wood, K. A., United Kingdom Symposium, Sept. 1969, Electronics for Civil Aviation Unit.

This paper is intended to review the use of electronics in one area of Civil Aviation activities, namely All-Weather Operations. It sets out to review this subject broadly and to show the wide variety and large electronic content in the many systems associated with the total All-Weather Operations system. It is not intended to cover in detail any particular aspects; this is better left to those who are closely associated with developments in the individual areas concerned and some references to other papers are listed at the end of the paper.

95. ELECTRONIC ATTITUDE DIRECTOR DEVELOPMENT FOR THE SST
Annin, Gordin, Instrumentation in the Aerospace Industry (ISA), Vol. 17, 1970.

Simulator testing of proposed supersonic transport configurations during 1964 and 1965 demonstrated the need for improved attitude displays. Efforts to develop landing approach capability for category II weather for contemporay turbojets in that time period resulted in pilot complaints regarding the content, quality, and organization of critical monitoring information. To cope with these problems, experimental displays employing CRT stroke writing were developed and evaluated on the SST simulator. Television capability in a head-down concept was added to the basic symbol format so that the pilot could use flightpath information superimposed on an image of approach terrain. All-weather sensors, such as Microvision, have been incorporated on an experimental basis. Engineering prototype electronic attitude director indicators (EADI) now flying employ techniques whereby the symbols are generated during the raster scan. The U.S. supersonic transport scheduled for certification in 1978 is expected to incorporate an advanced version of the EADI.

96. ELECTRONIC ATTITUDE DISPLAY INDICATORS
May, James W. (M), Sept. 25-27, 1969, Technical Review, Vol. 9, No. 4, Sept.13th Symposium Proceedings.

The Electronic Attitude Director Indicator (EADI) offers a solution that is capable of combining, in one instrument, the indications of a half dozen or more separate instruments. Furthermore, because of the versatility of the EADI display medium, symbols and formats can be duplicated for changes on the display surface. Through mode switching, it is possible to achieve different combinations of instruments for different modes or phases of flight or to change scaling as the flight situation may require.

97. ELECTRONIC FLIGHT CONTROL GETTING SET TO TAKEOFF
Sutherland, P. and Hendrick, R. C., Honeywell Inc., Aerospace Division, Minneapolis, Minn.

Fly-by-wire systems are flexible, indifferent to the expansion and contraction caused by changes in temperature, need no lubrication or bearing points, can be looped in hairpin turns, and best of all, easily can be made redundant. The main concern of would-be users, however, is not whether FBW is at all better than conventional systems, but how much better it is. In general, the conclusions seem to be: 1. The weight of an FBW system for a tactical aircraft would be about 60 percent less than that of a conventional system, for a large helicopter about 80 percent less. 2. It would occupy about 150 fewer cubic feet in a bomber or jetliner. 3. It would need 10 percent manhours of maintenance in a bomber or jetliner. 4. Its design and installation per large aircraft would take up to 5,000 fewer manhours, and effect major cost savings.

98. ENHANCEMENT OF HUMAN EFFECTIVENESS IN SYSTEM DESIGN, TRAINING, AND OPERATION
Annual Progress Report, 1 June 1971 - 31 May 1972, Hopkins, Charles O., July 15, 1972, N73-14098.

Progress is reported on the following research tasks: Radar signal detection through real-time visual time compression; All-weather landing enhancement through display frequency separation; Reorganization of manual flight control dynamics; Target acquisition in real-time aerial reconnaissance; Residual attention and risk-taking behavior under operational stress; Essential visual cues for contact flight operations; Predictive validity of ground-based flight checks; Transfer effectiveness functions for ground and airborne flight trainers.

99. EVALUATION OF A CLOSED-CIRCUIT TELEVISION DISPLAY IN LANDING OPERATIONS WITH A HELICOPTER
Gracey, W., Sommer, R. W., and Tibbs, D. F., NASA TND-4313, 1968.

100. EVALUATION OF A CONTACT-ANALOG DISPLAY IN LANDING APPROACHES WITH A HELICOPTER
Sommer, R. W., and Dunham, R. E., NASA TND-5241, 1969.

101. EVALUATION OF FLIGHT DIRECTOR ELEMENTS-RISING RUNWAY, EXPANDED LOCALIZER, AND ROLLOUT STEERING DURING SIMULATED CATEGORY 3-C MANUAL AND SPLIT-AXIS LANDINGS
Vreuls, D., Barneby, S. F., Brown, J. E., and Nichols, D. E., February 1968, Bunker-Ramo Corp., AD-672568.

A total of 19 commercial airline pilots flew a total of 684 ILS approaches through rollout without visual cues in a fixed base research simulation of a Boeing 707-720B (Stir). Results indicated that both longitudinal and lateral plane performance deteriorated when the expanded localizer operated. With the expanded localizer off, the rising runway improved full manual touchdown performance when it came into view at 200 feet of wheel height (47 percent successful). Pitch manual split-axis landings were best when the rising

runway came into view at 100 feet (66 percent successful). Vertical plane manual performance was excellent through 50 feet of altitude, but the flare caused problems. Data are presented to show why the flare computation was not compatible with the human pilot, and the need for improved flare computation for human pilot use is discussed. Roll manual split-axis touchdowns were 73 percent successful: manual lateral control was not tight enough to consistently land the simulator on the runway, autopilot roll-axis control to touchdown was the major determinant of rollout success.

102. EVALUATION OF AN INTEGRATED FLIGHT DISPLAY FOR THE MANUAL IFR-LANDING OF VTOL AIRCRAFT
Kornstadt, H. J., Pfennigstorf, J., AGARD, Paper to Conference on Guidance and Control Displays, October 1971.

103. EVALUATION OF A MOVING-GRAPH INSTRUMENT DISPLAY FOR LANDING APPROACHES WITH A HELICOPTER
Dunham, R. E. and Sommer, R. W., NASA TND-6025, 1970.

104. EVALUATION OF A VTOL FLIGHT-DIRECTOR CONCEPT DURING CONSTANT-SPEED INSTRUMENT APPROACHES
Kelly, J. R., Niessen, F. R., and Sommer, R. W., NASA TND-5860, June 1970.

105. EVOLUTION OF THE ELECTRONIC HEAD-UP DISPLAY
Aviation Review, Sept. 1972.
The electronic head-up display (HUD) is the result of a number of evolutionary steps from the lead-computing electromechanical reflector sight. The HUD is based on the versatility and adaptability of the cathode ray tube and the electronic computer. Modern HUD systems have a digital system of symbol generation to give system flexibility, high reliability over a wide temperature range, inherent redundancy, and low weight and minimum volume.

106. EXPERIMENTAL DISPLAY REFERENCED FLIGHT CONTROL SYSTEM WITH AUTOMATIC TAKEOFF ROTATION AND CLIMBOUT
Woloshen, John R. Bendix Corp., October 1971, AD-752 547, Report No. 7211-360.
The report describes a pilot-in-the-loop display referenced flight control system for automatic longitudinal control of an aircraft during takeoff ground roll, rotation and climbout. The takeoff control system configuration uses the display referenced flight control system described in AFFDL TR-71-90, A KC-135 as the test aircraft, and the KC-135 rotate go-around system described in Air Force T. O. KC-135 (K) A-2-11 as the longitudinal steering signal source. The integration of the rotate go-around steering signal into the display referenced flight control system to satisfy the KC-135 aircraft takeoff dynamics is presented. Also the technique of providing a pilot-in-the-loop capability through pilot control force steering during the takeoff maneuver is discussed.

107. EXPERIMENTAL ELECTRONIC CIRCUITS FOR AN INTEGRATED MANOEUVRE DEMAND FLIGHT CONTROL SYSTEM
Shipp, P. J., Royal Aircraft Establishment, Farnborough (England), July 1970, Report No. RAI-TR-70128, AD-882 916.

A description is given of the design of the experimental electronic system for the integrated maneuver Demand Flight Control System in the Hunter MK.12 aircraft at R.A.E. Problems arising from the use of redundancy in the form of multiplex systems using current state-of-the-art electronics are discussed and test results are included.

108. AN EXPERIMENTAL EVALUATION OF AIRCRAFT DISPLAYS FOR IFR STEEP ANGLE APPROACHES
Wolf, J. D. and Cundari, F., Paper to IEEE - GMMS - ERS International Symposium on MMS, Dept. 1969.

109. EXPERIMENTAL TESTING OF FLIGHT-CONTROL HEAD-UP DISPLAYS
Berjal, M,. (Compagnie Nationale Air France, Orly, Val-de-Marne, France). International Conference, Paris, France, June 26-30, 1972, Reports. Volume 2, (A7332426 15-21) Paris, Editions Chiron, 1972, In French.

Discussion of the results of a series of flight tests performed since 1965 upon five flight-control head-up display systems developed in France. The test purposes, system design, equipment installation particulars, and obtained results pertaining to each test series are reviewed, along with the merits of each system tested. Some targets for future research are pointed out.

110. AN EXPLORATORY STUDY OF FLYING QUALITIES OF VERY LARGE SUBSONIC TRANSPORT AIRCRAFT IN LANDING APPROACH
Mooij, H. A., and de Boer, W. P. (Nationaal Luchtvaartlaboratorium, Amsterdam, Netherlands). International Council of the Aeronautical Sciences, Congress, 8th, Amsterdam, Netherlands, Aug. 28-Sept. 2, 1972, Paper 72-07.

For two hypothetical subsonic jet transports with aircraft weights of two and eight times those of our contemporary jumbo jets, estimated characteristic parameters for the handling qualities are presented and discussed in the light of contemporary regulations. Controllability in vertical windshear and maneuver performance for lateral-directional control during the lateral offset maneuver are discussed. The need for command augmentation flight control systems and direct lift control is clearly established.

111. FACTORS IN STOL FLIGHT CONTROL CONFIGURATION
Harris, William P. A.(Boeing Co.,Seattle, Wash.). American Institute of Aeronautics and Astronautics, Annual Meeting and Technical Display, 8th, Washington, D.C., Oct. 25-28, 1971, Paper 71-993.

The STOL flight control problem is discussed in relationship to its unique operational requirements. A survey is made of the historic growth of control system techniques, and their implementation, in order to put into

perspective the STOL position. The danger of regarding STOL position. The danger of regarding STOL control as a simple extension of CTOL technique is discussed, and in contrast, the concept of task orientation and configuration is developed as pertinent to the STOL problem. Reference is made to current control system technology and analytical tools, and thoughts are presented on future trends. The need for a composite approach to control implementation is emphasized.

112. FIGHTER FLIGHT CONTROL SYSTEM DESIGN CONSIDERATIONS
Nardi, L. U., AIAA Fighter Aircraft Conference, St. Louis, Missouri, March 5-7, 1970, AIAA Paper No. 70-515.

A preliminary design effort is reviewed to present the system requirements, configuration characteristics, and technology applications which are significant in fighter flight control system design. Criteria to provide maximum combat effectiveness, safety, and survivability in the design without excessive program cost or risk are included. The impact of studies in the areas of stability and conttol, precision flying, control actuation, hydraulic power, safety, redundancy, and emergency modes on the selection of specific flight control system design features is highlighted, and the resultant preliminary design is summarized. It is concluded that effective, safe, and survivable control of the fighter aircraft can be accomplished within the current technololgy and that attention to vehicle design can minimize flight control system cost and complexity.

113. FLIGHT CONTROL
Reuter, W., Schweizer, G., and Seelmann, H., December 1971, VDI-Z, Vol. 113, A72-16736.

Review of advances made in the last decade in the development of flight control systems and suggestion of future trends in this field. The role of the onboard computer in integrating the functions of all subsystems is noted, including some possible improvements achievable through the use of a decentralized computer arrangement. The possibility of further improvement in instrumentation, stabilization and flight control systems (particularly for helicopters), and landing systems is discussed, and some features of inertial navigation and flight simulation are noted.

114. FLIGHT CONTROLS
Schweizer, Gerhard and Seelmann, Hans, VDI Zeitschrift, vol. 108, no 12, 1966, In German.

Review and bibliography of the past developments and present status of flight control systems, automatic landing devices, and inertial navigation with gyros. In order for SST's to become operational on commercial flights, improved flight controls will be required. Adaptive controls of the type installed on the U.S. X-15 experimental aircraft will find increasing application. The mass-produced F-111 fighter craft is equipped with such automated controls. The introduction of VTOL aircraft will require a new type of landing

system; the future lies in the development of predictive controls and self-learning systems. The role of man as part of a closed-loop control circuit is considered. The very great increase in the reliability factor of electronic computing devices brought about by module and integrated circuit techniques more than offsets the increase in complexity of such equipment.

115. FLIGHT-CONTROL HEAD-UP DISPLAY
Martin, M., IN: Electronics and civil aviation; International Conference Paris France, June 26-30, 1972, Reports, Volume 2, (A73-32426 15-21) Paris, Editions Chiron, 1972, In French.
Discussion of the assessed advantages of a flight-control head-up display providing information on the velocity vector, angle of attack, potential slope, and real or synthetic ground reference data. Two types of equipment are discussed; a simple one for flight by visual observation in good visibility, and a complex one for instrument-based flight.

116. FLIGHT CONTROLS DAMP BIG AIRCRAFT BENDING,
Reprinted from Control Engineering, Vol. 14, No. 9, Sept. 1967.
A flight control system suitable for future large aircraft is now under development and test by Wright-Patterson AFB. A modified B-52, heavily instrumented to record the response of the huge air frame to in-flight gust loads, serves as the test vehicle. The advanced control techniques employed are yielding notable improvements: structural fatique reductions of more than 50 percent, better handling and manuevering qualities, and a "boulevard" ride.

117. FLIGHT CONTROL SYSTEM MECHNAIZATION.
Bird, D. K. (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio). IN: NAECON '72, Proceedings of the National Aerospace Electronics Conference, Dayton, Ohio, May 15-17, 1972. (A72-35551 17-02) New York, Institute of Electrical and Electronics Engineers, Inc., 1972.
The expansion of the required flight regime for new airplanes as well as other requirements relating to both direct and indirect performance benefits has increased the criticality of flight control systems. Although the use of fly-by-wire techniques is a powerful tool for increasing flight control system performance, the total use of these techniques does not appear practical for some time. For this reason, a need exists to be as sure as possible that the present generation of hybrid electrical-mechanical systems are mechanized and integrated on a total system basis for maximum performance, reliability, safety, and maintainability. This paper discusses some of the present hybrid mechanical electrical mechanizing techniques, problem areas, and presents a somewhat unique design approach to mechanize a system. This concept features the use of aerodynamic summing to separate the electrical summing functions within the system.

118. A FLIGHT CONTROL SYSTEM PROVIDING A SIMPLE-TO-FLY, CONSTANT ATTITUDE AIRCRAFT
Smetana, Frederick, O. (North Carolina State University, Raleigh, N.C.), Society of Automotive Engineers, Wichita, Kan., Mar. 24-26, 1971. Paper 710393.

Most light aircraft accidents occur during landing and takeoff because at these times the pilot must operate controls frequently and precisely and with more than average force. These operations are further complicated by the nose-high attitude of the aircraft, which interferes with a normal visual control reference. The purpose of the studies reported here was to design an aircraft that would fly at zero pitch angle and would require a minimum of pilot commands for satisfactory operation. Preliminary investigation showed that it would be possible to modify and existing airplane by providing a three-component control system, new wing with Fowler flaps for lift modulation, and additional longitudinal control power. The details of these modifications are described fully in this paper.

119. A FLIGHT CONTROL SYSTEM FOR STOL AIRCRAFT
Schanzer, G., Geratetechnick, Bodenseewerk, 1973, Uberlingen, Federal Republic of Germany, Interavia.

The deterioration of flight characteristics combined with the increased demands on approach and landing procedures (steep, curved and slow) can be overcome by means of a suitable flight control system. Such an installation would enable full use to be made of STOL aircraft performance capabilities as well as permitting advantage to be taken of the future MLS (Microwave Landing System) ability to provide curved approach path guidance, especially under IFR conditions.

120. FLIGHT CONTROL TECHNIQUES FOR ADVANCED COMMERCIAL TRANSPORTS
Doniger, J. and Beckman, D., AIAA, 9th Annual Meeting and Technical Display, Wash. D.C., Jan. 8-10, 1973, Paper 73-30, A73-17618.

The basic design goals of commercial aircraft are to provide lower structural weight and/or longer fatigue life, smoother pilot handling and passenger ride qualities, lower drag at the same or higher cruise speeds, and improved efficiency in the cockpit and in the traffic control environment. Among the most significant aircraft design features that can be used to accomplish the design goals are reduced free airframe stability margins, the use of active controls to provide structural fatigue alleviation and to improve ride qualities, and the use of integrated navigation, air data, and flight guidance controls and displays. The architecture and organziation of an integrated control and guidance systems that provides these features is described.

121. FLIGHT DIRECTOR DESIGN FOR STOL AIRCRAFT
Seitz, W. R. and Goodson, R. E., (Purdue University, Lafayetter, Ind.) American Society of Mechanical Engineers, Washington, D. C., Nov. 28 - Dec. 2, 1971, Paper 71-WA/Aut-9.

All-weather capabilities for aircraft depend heavily on precision guidance during the landing-approach maneuver, particularly in turbulent, low visibility conditions. Whether or not this type of maneuver can be accomplished by a pilot in zero-zero conditions by reference to instruments alone, with the consistent accuracy required, is a subject of some debate. A recent FAA study, described here, has concluded that present-day flight director systems do not allow pilots to demonstrate accuracy comparable to automatic systems. For the FAA study, intended to explore ways of giving the pilot information necessary to perform as well as an autopilot, a fixed-base flight simulator was built to observe pilot/director/aircraft performance in an approach down to touchdown, including a flare and decrab maneuver. Optimal control theory and the theory of manual control were used to find the feedback gains required to drive the display symbols.

122. A FLIGHT EVALUATION OF CURVED LANDING APPROACHES
McMurtry, T. C., Gee, S. W., and Barber, M. R. (USAF, Flight Research Center, Edwards AFB, Calif.), Society of Experimental Test Pilots, Technical Review, vol. 11, no. 3, 1973.

A potential solution to some of the operational problems of STOL aircraft operations in the terminal area lies in the capability of making curved landing approaches under both visual and instrument flight conditions. Tests are described which were conducted with a twin-engine, light weight, general aviation aircraft. The advanced control system mode utilized during the curved approaches was an attitude command control system. Four curved patterns were investigated using a steep glide slope: two display configurations, and two flight control modes. When using the flight director display, curved approaches were not significantly different in difficulty and workload than straight approaches.

123. FLIGHT EVALUATIONS OF THE EFFECT OF ADVANCED CONTROL SYSTEMS AND DISPLAYS ON THE HANDLING QUALITIES OF A GENERAL AVIATION AIRPLANE
Loschke, P. C., Barber, M. R., Jarvis, C. R., and Envoldson, E. K., (NASA, Flight Research Center, Edwards, Calif.), Society of Automotive Engineers, National Business Aircraft Meeting, Wichita, Kan., Mar. 15-17, 1972, Paper 720316.

Flight tests have shown that, by means of improved displays and advanced control systems, it is possible to transform a typical light airplane into a flying machine that borders on being perfect from a handling-qualities standpoint. A flight-director display and an attitude-command control system used in combination transformed a vehicle with poor handling qualities during ILS approaches in turbulent air into a vehicle with extremely good handling qualities. The attitude-command control system alos improved the ride qualities of the airplaine. A rate-command control system was less beneficial than an attitude-command control system. Although this paper deals primarily with general aviation aircraft, the results presented pertain to other types of aircraft. Short-takeoff-and-landing (STOL) aircraft would

be a natural application of the control systems because, as a result of their low speeds, they encounter many of the handling-qualities problems noted on light aircraft. The improved ride qualities should be of interest to all airline operations, and for STOL aircraft in particular, because of their prolonged exposure to low-altitude turbulence.

124. FLIGHT INVESTIGATION OF METHODS FOR IMPLEMENTING NOISE-ABATEMENT LANDING APPROACHES
Quigley, Hervey C., Innis, Robert C., and Fry, Emmett B. NASA SP-189, 1968.

125. A FLIGHT INVESTIGATION OF SYSTEMS DEVELOPED FOR REDUCING PILOT WORKLOAD AND IMPROVING TRACKING ACCURACY DURING NOISE-ABATEMENT LANDING APPROACHES
Flora, C. C., Driechbaum, G. K. L., and Willich, W., October 1969,, NASA, CR-1427.

Preliminary results of a two-phase flight test program conducted at the NASA AMES R. Center showed that steeper than normal approaches could not be performed at the same pilot workload level without improvements in the path guidance system flight instrument displays and automatic flight controls. The results of further flight evaluations showed that when the pilot was given an appropriate combination of systems aids he was able to perform steep, Z-beam or decelerating approaches with workloads and accuracies, comparable to those of conventional approaches.

126. FLIGHT INVESTIGATION OF VTOL CONTROL AND DISPLAY CONCEPT FOR PERFORMING DECELERATING APPROACHES TO AN INSTRUMENT HOVER
Garren, J. F., Kelley, J. R., Summer, R. W., and DiCarlo, D. J., Feb. 1971, NASA TN D-6108.

127. FLIGHT MANAGEMENT CONCEPTS
Gannett, James R. (Boeing Co., Seattle, Wash.). Airline Pilots Association Seattle, Wash., July 9-11, 1968, Proceedings, (A69-20449 08-14), Chicago, Air Line Pilots Association, 1968.

Discussion of the guidelines for improved flight deck equipment in future aircraft. The pilot of a modern-day airliner must have information relative to the aircraft's situation, rate of progress with respect to its objectives, and any problems that may develop. It does not appear desirable that all aspects of the operation be full automated because of the danger that unsatisfactory performance will not be detected early enough. In going over all the required and desired improvements related to flight management, it is apparent that more use must be made of the systems approach.

128. FLIGHT PATH CONTROL SYSTEM CONCEPT, EVALUATION AND APPLICATION
Ostheimer, Jr., A. J. (United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn.) and Meth, M. A., (U.S. Naval Air Systems Command, Automatic Flight Control Section, Wash. D.C.), American Institute of Aeronautics and Astronautics, San Diego, Calif., April 29-May 1, 1968, Paper 68-484.

The paper presents the concept, flight test results, and possible future applications of a Flight Path Control System which has been tested on a Navy SH-3A sonar dipping antisubmarine warfare (ASW) helicopter. The system reduces pilot workload, improves navigation accuracy, reduces dip-to-dip cycle time, increases tactical effectiveness, and provides the basis for improved ASW tactics. The concept combines the navigation and flight control functions by the utilization of existing sensors which include Doppler radar, radar altitude, altitude-heading reference, vehicle acceleration, and true airspeed. Flight path equations are solved to provide for automatic wind-oriented hover-to-hover flight. This includes transitions to cruise, coordinated turns, bearing hold, velocity hold, altitude hold, transitions to hover, and precision hover over the desired dip locations. Initial flight test results have domonstrated the system feasibility with unique on-site flexibility. Numerous future applications of this integrated concept are envisioned for all types of aircraft.

129. FLIGHT RESEARCH CENTER FLY-BY-WIRE FLIGHT-TEST PROGRAM
Gee, Shu W, and Burke, Melvin E., Proceedings of the Space Shuttle Integrated Electronics Conference, vol I, May 11-13, 1971, NASA TMX-58063.

Equipping the space shuttle vehicle with a digital fly-by-wire flight control system is discussed. The past and present space programs have demonstrated performance and reliability of such a system in a space environment; however, only limited actual flight data in an atomospheric environment are available on which to base confidence in the performance of such a system. A echnology development program is underway that should provide information on the performance of digital fly-by-wire systems for aerodynamic control. This program, which utilizes an F-8C aircraft as a flight-test vehicle, is being conducted in two phases. Phase 1 is the development and flight testing of a single-channel digital system with a triple redundant direct electrical backup system. Phase 2 is the development and flight testing of a redundant all digital fly-by-wire system. The mechanical flight control system will be deactivated for this program.

130. FLIGHT SYSTEMS, FLIGHT DECK DISPLAY AND AUTOMATIC FLIGHT CONTROL
Howard, R. W. (Elliott Flight Automation, Ltd., Rochester, Kent, England). V/STOL in Civil Aviation; British Air Line Pilots Association, London, England, November 24-26, 1970.

Discussion of the application of existing controls, instruments, and displays to the takeoff and landing operation of a V/STOL. The flying control system is considered to be essentially a problem of applications engineering rather than one requiring some new breakthrough in systems or hardware technology. Electronic displays have the ability to present data in any form or combination on any suitable display surface.

131. FLIGHT TEST RESULTS OF A TRAILING EDGE FLAP DESIGNED FOR DIRECT LIFT CONTROL
Taylor, Richard C., NASA CR-1426.

132. FLIGHT TESTING STRUCTURAL PERFORMANCE OF THE LAMS FLIGHT CONTROL SYSTEM
Burris, P M., Dempster, J. B. (Boeing Co., Wichita Branch, Wichita, Kan.), and Johannes, R. P. (USAF, Wright-Patterson AFB Ohio) American Institute of Aeronautics and Astronautics, Los Angeles, Calif., Mar. 25-27, 1968 Paper 68-244.
Presentation of a flight demonstration technique which permits evaluation of advanced flight control systems that provide gust load alleviation and structural mode stabilization for large flexible aircraft. Structural performance parameters considered are fatigue damage rates, maximum expected stresses, and ride qualities. Flight test results are presented, verifying the test approach and indicating the degree of success expected in the flight demonstration phase of the Load Alleviation and Mode Stabilization (LAMS) program. The test approach is to acquire aircraft response data in turbulence and compare them with theoretically determined responses. The random nature of atmospheric turbulence necessitates analysis and experimental data to be derived by statistical techniques. General descriptions of the LAMS program, flight control system configuration, test aircraft instrumentation, and analytical approach are also presented to give some insight into the factors affecting selection of the flight test techniques.

133. FLIGHT TESTS UNDER IFR WITH A STOL TRANSPORT AIRCRAFT
Innis, R. C., Holzhauser, C. A., and Gallant, R. P., 1968, NASA TND-4939.
A STOL transport was studies in instrument flight. This aircraft was flown on 7 1/2° and 2 1/2° ILS approaches. It could be flown comfortably and accurately on the 7 1/2° ILS at 60 knots to 200 ft. above the runway. The descent and deceleration capabilities were more than adequate in the approach and landing configuration, but were not sufficient in the preapproach configuration. The handling characteristics during instrument flight were generally satisfactory, except for moderate heading excursions at low speeds and moderate angle-of-attack excursions at the rear center of gravity. These characteristics, while not satisfactory, were acceptable and are considered general problems of STOL aircraft operations.

134. FLY-BY-WIRE
Bumby, E., in NASA. Lewis Res. Center Space Transportation System Technol. Symp. Vol. 6, July 1970, NASA TM-X 52876.
The major design problems involved in designing a fly-by-wire flight control system for space shuttle vehicles are considered. Projected implementations integrate the fly-by-wire function without the automatic flight control system. Available data indicate that a quadruple-redundant configuration is required to provide the reliability of the mechanical system which the fly-by-wire system replaces.

135. FLY-BY-WIRE FOR COMBAT AIRCRAFT FLIGHT INTERNATIONAL
Aug. 23, 1973, Vol. 104, No. 3363.

136. FLY-BY-WIRE CONTROL SYSTEM
Millard, D. J., FIMechE, FRAeS.
An aircraft set of Dowty Boulton Paul Power controls comprises six elevon units, two rudders and three relay units, figure 2. It will be seen that the pilots' controls operate on three relay or booster units which help to drive the long mechanical control runs to the main power units located at the control surfaces. In addition, the pilots' controls operate position synchros which produce electrical signals which, when amplied are used to command the main power units electrically. In this mode of control, which is the normal one, the mechanical input system is declutched from the power control unit. The relay units are also capable of receiving electrical signals from the automatic pilot. Auto-pilot command of the surface units is through control of the relay units by either one of its two electrical signalling systems.

137. FLY-BY-WIRE FLIGHT CONTROL SYSTEMS
Sutherland, J. P., August 1967, A.F. Flight Dynamics Lab, AD-830 861.
The purpose of this paper is to provide the reader with an introduction to fly-by-wire and an outline of state-of-the-art fly-by-wire flight control systems is given. The evolution of fly-by-wire is discussed. The advantages of fly-by-wire over mechanical systems are listed. Current fly-by-wire techniques are outlined, and a brief review of the Air Force Flight Dynamics Laboratory. Proposed in-house and contracted fly-by-wire development programs is given.

138. THE FLY-BY-WIRE SYSTEMS APPROACH TO AIRCRAFT FLYING QUALITIES
Kisslinger, R. L. (McDonnel Aircraft Co., St. Louis, Mo.) and Lorensetti, R. C. (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio). In: NAECON '72; Proceedings of the National Aerospace Electronics Conference, Dayton, Ohio, May 15-17, 1972. (A72-35551 17-02) New York, Institute of Electrical and Electronics Engineers, Inc., 1972, A72-35575.

139. FLY-BY-WIRE TECHNOLOGY
Emfinger, J., and Flannigan, J.,(Sperry Rand Corp., Sperry Flight Systems Div., Phoenix, Ariz.). American Institute of Aeronautics and Astronautics, Guidlance and Control Conference, Standford, Calif, Aug. 14-16, 1972, Paper 72-882.
The requirements and equipment characteristics of a production electronic primary flight control system are predicted based upon current state-of-the art trends. Current Air Force (680J) and NASA (F-8) fly-by-wire programs are described with particular attention given to the requirements placed on these programs which heavily influenced equipment physical characteristics.

Typical production equipment charactristics are then developed based upon a postulated set of requirements, which eliminate constraints associated with a flight test program.

140. FLY-BY-WIRE TECHNIQUES
Emfiger, Jack E., and Miller, Frederic L., Sperry Phoenix Co., July 1967, AD-820 427, Report LJ-1201-0723, AFFDL TR-67-53.

Manual Flight Control Systems are described in which the sole means of control between the pilot's station and the control actuator is in the form of electrical signals. No mechanical control links are used in the system. Such a system is defined as a fly-by-wire control system, because of the growing number and severity of problems in mechanical control systems, particularly in large and high speed aircraft. Fly-by-wire systems are evolving out of necessity. Fly-by-wire control is shown to provide many advantages over conventional mechanical flight control systems. Principally, they are reduced weight and volume, improved control performance, reduced design effort and maintenance time, and the feasibility of standardizing flight control systems. System design requirements and tradeoffs are discussed such as the types of components used, control signal format, method of transmitting signals, actuator configurations, degrees of redundancy, failure detection, techniques, and artificial feel mechanization. Examples are given of the application of fly-by-wire control to various classes of aircraft, the primary benefits derived depend on the class of aircraft.

141. FUTURE NAVAL AIRCRAFT SUBSYSTEM/AADC INTERFACE DEFINITION FOR OPERATIONAL AND OBC REQUIREMENTS (VOL. 1)
Bogin, Warren W., Butler, William, I, Eng, Fook W., and McDonough, Leonard P., Gurmman Aerspace Corp., Bethpage, N.Y., April 72, Report No. D-545, vol. 1, AD-907 1746.

This report describes the functional interface between the advanced avionic digital computer (AADC) and the subsystem of a future naval fighter used in a combat escort mission.

142. THE FUTURE OF ELECTRONIC DISPLAYS
Joint RAeS/IEE Symposium Proceedings, February 23, 1972, Hearne and Hussey, D. W.

143. GUIDANCE AND CONTROL PHILOSOPHY FOR ALL-WEATHER LANDING
Jones, S. S. D., Jan. 21, 1970.

This paper, which was presented at an Institute meeting held in London, suggests a range of philosophical implications which result from the interaction of guidance and control systems in the context of all-weather landing of fixed-wing aircraft. It then attempts to deduce the considerations which must be applied to the approach to the engineering solution to the guidance and control problem.

144. A G&C REDUNDANCY MANAGEMENT CONCEPT FOR SPACE SHUTTLE VEHICLES
Ingalls, E. L. and Shoquit, R. R., (Honeywell, Inc., Minneapolis, Minn.), American Institute of Aeronautics and Astronautics, Guidance, Control and Flight Mechanic Conference, Hofstra University, Hempstead, N.Y., Aug. 16-18, 1971, Paper 71-946, A71-37187.

A solution to the problem of providing automatic redundancy management for the Space Shuttle Guidance, Navigation and Control (GN and C) system using a fly-by-wire control technique ais developed. The solution utilizes digital techniques controlled by a data management computer to detect and correct in-flight failures. Study results are presented that show a fail operational/ fail safe is the most cost effective redundancy level. The characteristics and requirements of each GN and C device, including the computers, are analyzed to develop first failure and second failure detection and correction procedures to provide fail operational/fail safe redundancy. Logic diagrams showing the sequency of computer action required to execute the redundancy functions are developed.

145. HEAD-UP DISPLAY FOR AIRLINES
Cane, Peter, Smiths Industries Ltd.

Head-Up Display is a method of presenting to the pilot the information he requires for the flight mode in progress, superimposed on his view of the terrain ahead. The display is focused at infinity, allowing the pilot to scan it and the outside world simultaneously without re-focusing his eyes. The Operational Adviser, Aviation Division of Smiths Industries discusses the application of Head-Up Display to commercial flying, with special reference to the HUD System manufactured by their subsidiary company Specto Avionics Ltd. Further observations on the transport applications of HUD will be made in an extensive survey, All-Weather Landing, to be published in Shell Aviation News No. 364.

146. HEAD-UP DISPLAY STUDY
Opittek, E. W. Hughes Aircraft Co., July 1973, TR AFAL-TR-73-215.

A study of the requirements for and the design of an advanced head-up display (HUD) was conducted. The requirements, based on use in an advanced close air support fighter, included wide field of view (60-x 45-degree), and high brightness ( 8,000 fL). The requirements analysis was supported by interviews with pilot users of head-up displays in the field. It was concluded that conventional HUD techniques (cathode ray tubes, thick lenses, etc.) could not be practically used to meet these requirements. Accordingly, an advanced design utilizing holographic optics and liquid crystal display techniques was conceived and evaluated. The holographic lens provides the combiner and collimator functions. The liquid crystal matrix display provides modulation of the light from a collimated arc light source to provide either sensor or symbol video. Using these components, several alternate configurations capable of meeting the requirements were derived. The A-10 aircraft was selected as a candidate for the installation due to its large canopy and over the nose visibility. As part of the study program, a demonstrator was developed to indicate how the holographic lens/combiner and reflective liquid crystal can be used together as a see through display. Also a half size mockup of the baseline cockpit configuration was fabricated.

147. HELICOPTER ALL-WEATHER OPERATION - EQUIPMENT FOR THE TRANSPORT ROLE
Curties, M. C., The Aeronautical Journal, 1972, 1968.

148. HELICOPTER COCKPIT INSTRUMENTATION SYSTEM (HCIS)
Witte, G. E., Douglas Aircraft Co., Inc., Long Beach, Calif.
May 1964, AD-455 594.
The hardware phase of the helicopter cockpit instrumentation system is being accomplished. Detail design parameters and interface requirements have been established. Manufacture of equipment has begun for an integrated pictorial display, a digital computer, display generator, vertical and horizontal television displays and sensors, (i.e., velocity, attitude, altitude, directional, terrain avoidance, etc.) are being integrated into a display system. The system being implemented in a Bell 204B helicopter.

149. HELICOPTER IFR FLIGHT PATH CONTROL SYSTEM
AGARD, June 1971, Paper to conference on Helicopter Guidance and Control Systems.

150. HIGHLY RELIABLE VERTICAL DISPLAY SYSTEM
NADC, Oct. 1972.
This study develops the requirements for a highly reliable cathode ray tube type of Vertical Display System (VDS) for use in Advanced Navy All-Weather Aircraft of the 1980's. First the operational requirements study identified the detailed information required for the VDS. The performance requirements section converts the general operational requirements into specific mechanization requirements. Mechanization tradeoffs then evaluate specific candidate designs and selects the optimum design mechanization for the VDS. A Reliability Analysis is also performed and aids in making the hardware tradeoffs. A TV type (resonant) indicator is selected to be optimum for the VDS application along with an in-raster or digital television symbol generator. Also two candidate digital scan converter PPI to TV mechanizations are recommended for further evaluation.

151. HLH PRIMARY FLIGHT CONTROL SYSTEM DESIGN
Sanford, Richard W., Venuti, Peter R., and Wood, Derek (Boeing Co., Vertol Div., Phila. Pa.). American Helicopter Society, Washington, D.C., May 19-21, 1971.
Demonstration that the most attractive primary flight control system for the Heavy Lift Helicopter (HLH) is a fly-by-wire electrical analog of the conventional mechanical control linkage. This type of system can be mechanized using known techniques, and in many cases identifiable components. It is pointed out that the only remaining step required for acceptance of this fly-by-wire system is contrstruction and flight demonstration of a complete operational prototype.

152. HOLOGRAPHY IN AN AIRBORNE DISPLAY SYSTEM
Harris, T. J., Schools, R. S., Sincerbox, G. T. (IBM Corp. Development Div., Poughkeepsie, N. Y.), Hanna, D., and DeLay D. (IBM Corp., Federal Systems Div. Oswego, N.Y.). Information Display, vol 7. Apr. 1970.
Discussion of a method of adapting holography to form a dynamic display, and in particular a dynamic head-up display, to aid pilots making aircraft carrier deck landings during conditions of restricted visibility. The system is based on the ability of holography to store three-dimensional information on a two-dimensional recording media. This feature of holography is used to provide all the perspective views of a carrier necessary to simulate a carrier landing approach.

153. HUMAN ENGINEERING FOR THE AIR FORCE CONTROL DISPLAY PROGRAM
June 25, 1969 - June 24, 1972, Bunker-Ramo Corp., Westlake Village, Calif., Electronic Systems Div., Snyder, Thomas A. and McTee, A. C., Wright-Patterson AFB, Ohio AFFDL, June 1972.
A research program which addresses each of two interface problems to be considered in the conduct of advanced control-display research within the system context, namely, the manager/information systems interface and the pilot/aircraft interface. Activities included an investigation to explore the potential of an on-line terminal with a CRT and printer. The Control-Display Information Program is directed toward developing a properly designed search and retrieval system utilizing the computer to its fullest potential, in addition to maintaining the day-to-day operation of satisfying the technical information requirements of control-display researchers.

154. HUMAN ENGINEERING PILOT FACTORS PROGRAM
Swartz, W. F., Bunder-Ramo Corp., Canoga Park, Calif., Report No. HEGRI 64, AD-455 013, September 1964.
The primary purpose of the pilot factors program is to have the flying community evaluate a number of advanced control-display concept to insure that timely pilot generated data are available. Such a program requires the inter-disciplinary talents of the pilot, the design engineer, the human factors specialist, and the skilled service engineer, to mention a few, for successful execution. Various aspects of the program are presented in the report.

155. IDENTIFICATION AND OPTIMIZATION OF AIRCRAFT DYNAMICS
Narendra, D. S. (Yale University, New Haven, Conn.) and Tripathi, S. S. (Quinnipiac College, Hamden, Conn.), Journal of Aircraft, vol. 10, Apr. 1973.
A technique is described for the design of an adaptive controller for multivariable systems and is based on recently developed methods for identification and optimization. An application of the method to a helicopter system with time-varying parameters is considered in detail. The response of the adaptive system is compared with the corresponding response of a system with a fixed controller and a system using optimal control. The comparison reveals the almost optimal character of the adaptive system.

156. IFR STEEP ANGLE APPROACH: EFFECTS OF SYSTEM NOISE AIRCRAFT CONTROL AUGMENTATION VARIABLES
Wolf, James D. and Barrett, Mike F., July 1970, Honeywell, Inc., St. Paul, Minn. Research Dept.

The objective of this study was to investigate, by means of real-time man-in-the-loop simulation techniques, piloting performance as influenced by approach-signal degradation and aircraft control-augmentation variables during IFR Steep-angle approaches and landings with vertical-lift aircraft. Simulation evaluations also included aircraft-type, display-format, approach-angle, and display-quickening variables to increase the generality of study results. Variable-velocity simulations of Bell UH-1 and Ryan XV-5 aircraft were utilized as test vehicles. Interpreted within the constraints imposed by the simulations, study results indicated that increased filtering of measurement noise is beneficial during approach but may have a degrading effect during hovering flight. Generally, both flight-path error and pilot control activity increased with increased measurement noise. With one exception data trends also indicated improved performance with aircraft outer-loop control augmentation.

157. THE IMPACT OF ELECTRONIC DISPLAYS ON AIRCRAFT CONTROL
Lawry, P., 1970, AGARD Committee Paper 58.

158. INERTIAL SYSTEMS AS SENSORS FOR FLIGHT CONTROL
Collinson, R. P. G. (Elliot Flight Automation, Ltd., Rochester, Kent, England). International Air Transport Association, Technical Conference, Miami, Fla., April 22-30, 1965, Working Papers, vol. 1, Nos. 1-70. A66-17667 07-21.

Examination of the use of a Schuler-tuned inertial system as a flight sensor. It is pointed out that it offers,considerable advantages over existing sensors, providing the requirements of reliability and failure survival velocity, by the complementary filtering of inertially and barometrically derived vertical velocity, is treated briefly. Control of the translational velocity of a VTOL aircraft during hover phase is considered, and mention is made of the combination of ILS and inertial information for automatic landing.

159. IN-FLIGHT INVESTIGATION OF AN UNAUGMENTED CLASS III AIRCRAFT IN THE LANDING APPROACH TASK, PHASE I - LATERAL-DIRECTIONAL (FINAL TR)
Wasserman, Richard, Eckhart, Franklin F., and Ledder, Howard J., Cornell Aeronautical Lab, Inc., January 1972, AD-744 831.

An in-flight research program on the handlin qualities of Class III airplanes in the landing approach was conducted using the USAF/CAL Total In-Flight Simulator (TIFS) airplane. The Phase I research program discussed in the report consisted of an investigation of lateral-directional handling quailities. A baseline configuration was defined by a set of stability and control derivatives provided by the Air Force. The experiment was based on the evaluation of this configuration and other configurations defined by changes in stability and control derivatives from the baseline values. Seventeen different configurations were evaluated utilizing 3 different pilots. A total of thirty-six evaluations were performed.

160. AN IN-FLIGHT INVESTIGATION OF LATERAL-DIRECTIONAL DYNAMICS FOR THE LANDING APPROACH
Hall, Warren G., Boothe, Edward M., October 1970, CAL., Inc., AFFDL-TR-70-145.

Lateral-directional handling qualities and roll control power requirements for executive jet and military Class II Airplanes in the landing approach flight phase were investigated in the USAF/CAL variable stability T-33 airplane. Particular emphasis was placed on the effects of crosswinds and turbulence. Simulated IFR ILS approaches and VFR offset and crosswind approaches were made. Specifically, two Dutch roll frequencies, three Dutch roll damping ratios, three roll-to-sideslip ratios and three roll mode time constants were investigated. It was found that lateral-directional dynamics do not establish a limiting cross wind value; however they do determine the ease or difficulty with which a cross wind approach can be accomplished. Roll control power requirements were determined from actual control usage data obtained throughout the evaluation program. In addition, a number of configurations were reevaluated with limited roll control power to determine minimum acceptable levels. Available roll control power can establish a limiting crosswind component. A number of configurations were evaluated with a stick controller in place of the normally used wheel controller to determine if the type of controller affected the lateral-directional dynamics for acceptable handling qualities. No difference was found to exist. A detailed comparison with MIL-F-8785B(ASG) requirements is included and generally shows the present requirements to be too conservative in the landing approach flight phase.

161. IN-FLIGHT INVESTIGATION FOR AN UNAUGMENTED CLASS III AIRPLANE IN THE LANDING APPROACH TASK. PHASE II - LONGITUDINAL STUDY
Wasserman, R., et al, AFFDL-TR-71-164, Vol. II, January 1972.

162. THE INFLUENCE OF A PREDICTION DISPLAY ON THE HUMAN TRANSFER CHARACTERISTICS.
Dey, D. (Berlin, Technische Universitat, Berlin, West Germany). Proceedings of the Advanced Study Institute, Berchtesgaden, West Germany, March 15-20, 1971, A72-41402 21-06.

A quasi-linear human operator model is proposed to describe the effect of a prediction display on the transfer characteristics of a human operator at stick controls. It is shown that a prediction display diminishes the mean square value of a human control deviations in manual attitude stabilization of a hovering VTOL aircraft.

163. INFORMATION TRANSFER IN ALL-WEATHER OPERATION
Naish, J. M., Shell Aviation News No. 394, 1971.

An attempt is made to broaden the basis for evaluating an aircraft all-weather flight system. The influence of the pilot on overall reliability is considered in terms of the balance of supply and demand in the information process of the complete man-machine system. A more efficient transfer is possible if the man has the same kind of access to information as does the automatic flight control system, and if he is allowed to use his equivalent capabilities.

Operations of monitoring, decision making, and giving concurrent attention to several matters are improved by reducing the times needed to transfer attention, as is possible with the Head-Up Display (HUD). The same means can be used to give reassurance about the ease of a rapid takeover, of being able to check on the external environment, and of retaining flight skill. These improvements are applicable in the development of all-weather operations.

164. INITIAL ASSESSMENT OF THE AUTOLAND PERFORMANCE
Brown, S. J. W., Aeroplane and Armanent Experimental Establishment Boscombe Down (England), Report No. AAEE-NOTE-2021, AD-886 611.
An initial assessment has been made of the performance of the autolanding system in the Belfast. The results have been compared with the design aims of the system, but at this stage, no account has been taken of equipment tolerance variations, and only a limited range of wind and aircraft loading conditions has been tested. Subject to the incorporation of certain modifications it was considered that the development of the system should be continued to the stage "B" release standard.

165. INSTRUMENT CAPABILITIES SURVEY HELICOPTER PIFAX PROGRAM CDG-PF-8.
Hartwig, James A., Instrument Pilot Instructor School, Randolph AFBTEX, Report No. IPIS-TN-71-1, April 1971, AD-885 289.
A questionnaire was distributed to USAF helicopter pilots to determine present operational capabilities, and to identify deficiencies affecting their ability to accomplish their unique flight profile in a weather/low visibility environment. This information is to be used to assist in determining the requirements for, and direction of, future control/display/guidance research. A sampling of this survey indicates that: helicopter pilots fly 50 percent fewer instrument hours than fixed-wing pilots; USAF helicopter units require higher VFR minimums than the other military services; new instrument displays and associated systems might increase mission effectiveness up to 75 percent.

166. INSTRUMENT-PANEL ELECTRONIC DISPLAY SYSTEM
Coussediere, M. Electronics and Civil Aviation: International Conference. Paris, France, June 26-30, 1972. Reports, Vol. 2, (A73-32426 15-21) Paris, Editions Chiron, 1972, in French.
The electronic display design desiderata generated by present and future aircraft performance trends are discussed, along with presently mastered or developing techniques and technologies that hold promise to fulfill these desiderata. Current instrument panel design philosophy is reviewed and illustrated by specific design accomplishments.

167. AN INTEGRATED APPROACH TO THE STEEP DESCENT PROBLEM
Scott, Jr, Charles M. (Sperry Rand Corp., Sperry Div., Sperry Flight Systems Div., Phoenix, Ariz. American Helicopter Society, Washington, D.C., May 8-10.

Over the past three years, the Sperr Flight Systems Division has been developing two complementary systems which will add immeasurably to the capability of VTOL vehicles in the area of steep descents. One system (the Hover Augmentation System or HAS) utilizes new automatic flight control concepts which greatly improve the vehicle handling characteristics, especially during steep descents. The second (the Remote Area-Terminal System or RATS) provides a simple, pilot-selectable vertical path with which to guide the aircraft to a desired landing area. These systems do not interface directly; however, since we are working toward component improvements in both airborne and ground areas rather than in only one problem area, the program is termed "an integrated approach."

168. AN INTEGRATED DISPLAY CONCEPT FOR HELICOPTERS AND VTOL AIRCRAFT
Dukes, Theodor A. (Princeton University, School of Engineering and Applied Science, Dept. of Aerospace and Mechanical Sciences, Instrumentation and Control Laboratory, Princeton, N.J.). American Helicopter Society, Washington, D.C., May 14-16, 1969, Paper 314.
Introduction of an integrated trajectory error display (ITED) concept for accurate flight path control of helicopters and VTOL aircraft. Four principles govern the display synthesis - integration of all necessary multiloop control information on a single display; true deviations from desired values are to be displayed; control motion oriented arrangement of the symbols; and systematic arrangement of position, velocity, and acceleration information. The basic display developed from these principles and its application to helicopter station keeping are described in detail. The display combines position errors, error rates, aircraft attitudes, and additional auxilliary information into a single presentation so that scanning to other instruments is minimized. The basic symbolism and arrangement can be augmented for other display modes to cover any flight path control requirement. Specific versions for terrain avoidance, terrain following, and landing are suggested. The common aspects of accurate flight path control are emphasized throughout, and various ways of applying a flight path command in different display modes are discussed.

169. INTEGRATED DISPLAY PRINCIPLES AND SOME APPLICATIONS TO V/STOL AIRCRAFT
Young, L. R., AGARD - Paper to Conference on Guidance and Control Displays, Oct. 1971.

170. INTEGRATED INFORMATION PRESENTATION AND CONTROL SYSTEM STUDY, VOL. 1, SYSTEM DEVELOPMENT CONCEPTS
Zipoy, D. R. and Premselaar, S., Boeing Co., Seattle Wash. Military Airplane Systems Division, August 1970, AD-876 624

A cockpit concept for a tactical fighter aircraft of the 1975-1980 time period was developed to significantly reduce pilot workload, within the context of the study. A composite mission profile and scenario are presented to define the operational requirements for the system concept. Airplane configuration and performance are described, and the characteristics and capabilities of the on-board avionics are summarized. A full-sized, single-place cockpit mockup and three interior configurations have been fabricated to reflect study results and to serve as evaluation tools.

171. AN INTERIM NOTE ON THE DEVELOPMENT OF A BLIND GROUND ROLL SYSTEM IN A COMET 3B AIRCRAFT,

Burgan, M. L., Royal Aircraft Estab., AD-846 507, Report RAI-TR-68119.

Flight tests have been conducted to evaluate an experimental blind ground roll system suitable for completing a blind landing. The system tested was manually operated and consisted of an azimuth director fed by ILS localizer, compass and yaw rate signals. Speed and distance information was also displayed the pilot. The sensing device being a wheel speed pick-off. The tests showed that pilots were capable of producing good azimuth performance both following a normal automatic landing and also in the presence of some extremely unfavourable starting conditions, using the ground roll director following an automatic landing. The standard deviation of lateral displacement reduced steadily from about 10 feet at 105 knots to about 5 feet when the aircraft stopped rolling.

172. INTERPRETABILITY OF SYMBOLS IN A HEAD-UP DISPLAY

Berstrom, Bengt SAAB, Linkoping, Sweden

An aircraft in operation may be regarded as a rather complicated man-machine system. There have been several attempts to describe the role of the human component in such systems. Usually, the human operator is pictured as a data transmission and processing link inserted between the displays and controls of a machine. An input is transformed into a signal, which is displayed as a pointer reading or a pattern of lights. This information is assimilated by the pilot and transformed into responses such as moving the control stick. The responses generate control signals that in turn affect the system outputs: the control surfaces. In systems of this kind--the closed-loop type--the output works back upon the displays, so that they reflect the pilot's response. It may seem obvious that a simulator set-up or an experimental situation intended to study pilot behaviour should employ these dynamic, closed-loop characteristics. Some problems, however, may very well be pursued in more or less static tests. The purpose of this paper is to demonstrate a few such problems, and give a brief review of the corresponding experimental results.

173. INTRODUCTION AN SUMMARY (LAMS)

Johannes, R. P. (USAF, Flight Dynamics Laboratories, Wright-Patterson AFB, Ohio). LAMS - A technology to control aircraft structural modes; Institute of Electrical and Electronics Engineers, Case Studies in System Control, Institute of Technology, Atlanta, Ga., June 23, 1970, Proceedings A71-11658 02-02.

Discussion of the present stage of a R & D program initiated in 1966 at the Air Force Flight Dynamics Laboratory to demonstrate the capability of an advanced flight control system to alleviate gust loads and to control structural modes on a large flexible aircraft using conventional aerodynamic control surfaces. The major elements of thes program are described as (1) establishment of performance criteria applicable at all phases of the program, (2) analysis of the B-52 to select the control techniques to be developed, (3) demonstration of the applicability of analytical techniques by applying them to the C-5A, (4) production of an operable LAMS-FCS, (5) conversion of an existing B-52 to an appropriate test bed to demonstrate the LAMS-FCS, and (6) demonstration of the performance of the LAMS-FCS during flight through a turbulence. The results of various tests conducted within this program are evaluated, noting the positive turbulence test results for fatigue damage rates, maximum expected stress, and rms accelerations.

174. AN INVESTIGATION OF ADVANCED PILOTS VERTICAL DISPLAY TECHNIQUES
McDade, John L., Northrop Corp., AD-755 739, NORT-71-295-2, Jan. 1973.

The report summarizes the results of a one-year investigation of advanced vertical display techniques. The purpose of the study was to appraise the relative merits of nonconventional display techniques for their potential application aboard a 1985 era naval all-weather day/night attack aircraft. The vertical display system (VDS) must present situation, command, and multisensor (radar, FLIR and TV) information to the pilot and systems requirements were defined including informative, functional and human factors, and VDS performance and design criteria were established. Two mission plans and scenarios were prepared to cover a wide range of aircraft flight conditions and weapon delivery modes to exercise the various avionics sensor systems and establish the worst case or most demanding VDS information and design requirements. A weighting factor tradeoff analysis was conducted to determine the optimum scanning standards and the system design specifications for a complete VDS digisplay system. A preliminary design for the recommended VDS was prepared and a series of simulation tests were conducted to verify the performance and flyability of the recommended design.

175. INVESTIGATION OF DATA RATE REQUIREMENTS FOR LOW VISIBILITY APPROACH WITH A SCANNING BEAM LANDING GUIDANCE SYSTEM
Dillow, J. D., Stolz, P. R., and Zuckerman, M. D. (USAF, Institute of Technology,) Joint Automatic Control Conference, 13th, Standford, Calif., August 16-18, 1972. A72-38226 19-10 N.Y., American Institute of Aeronautics and Astronautics.

Data rate requirements for low visibility approach with a sample data measurement of glideslope deviation is investigated analytically. Approach performance is defined by specifying certain allowable deviations in the aircraft motion variables which are acceptable for continuation of the landing at a 100 foot decision altitude. The landing approach process is modeled by a system of linear-Gaussian differential equations which account for aircraft dynamics, atmospheric disturbances, guidance errors and data rate. The flight

control system is modeled by a state estimator and an optimal state feedback control law. Performance as a function of data rate was computed using DC-8 and CH-53A dynamics and considering variations in the atmospheric environment, guidance errors, control authorities, control points, and on-board sensors.

176. AN INVESTIGATION OF DIRECT SIDEFORCE CONTROL FOR IMPROVING MANEUVER CAPABILITY OF ATTACK AIRCRAFT
The Boeing Co., AD 888 983L D180-14004-1, October 1971.
The feasibility of employing direct sideforce control devices (DSFC) to enhance the maneuverability and weapon delivery accuracy of high-speed attack aircraft has been investigated. Linear analysis, piloted simulation, and an implementation study were performed. Pilot-in-the-loop analyses show that connecting the direct sideforce controller to the pilot's aileron and rudder controls, combined with heading rate and side acceleration feedback, is the best method for integrating the DSFC into the control system. By decoupling the airplane's lateral and directional motions and using DSFC, rapid heading changes can be made with the rudder pedals alone, without rolling and sideslipping the airplane. The flight simulation clearly demonstrates the airplane's improved close-in maneuvering and target tracking capability with the DSFC. Very substantial circular error probable (CEP) improvements over the basic airplane without sideforce control were achieved. The implementation study shows that deflecting a dedicated aerodynamic control surface ahead of the center of gravity, in conjunction with the rudder, to balance the yawing moment, produces the desired sideforce most efficiently.

177. AN INVESTIGATION OF THE NEED FOR IMPROVED DISPLAYS IN HEAVY-LIFT HELICOPTERS.
Sherbert, A. T., AHS, 26th ANF, Preprint No. 432, 1970.
Discussion of the cockpit display problems of present-day heavy-lift helicopters. Helicopters designed to transport large external loads have associated with them two types of display problems; (1) cockpit display problems which are common to present-day helicopters, regardless of size or mission; and (2) display problems which are peculiar to the external load-handling operations associated with heavy-lift helicopters. A review of these problems is followed by a description of an experimental program designed to assist in quantifying these problems and identifying feasible solutions. Thus, this program is to provide a data bank which can be used by engineers and human factor analysts to gain better understanding of helicopter display problems. This data bank will be available to substitute for expensive and time-consuming flight investigation of visual cues each time such information is required. Analysis of the film accumulated on this program is expected to provide information which can be used in support of crew station trade studies. Such studies will encompass aircrew station visibility and instrument panel layout.

178. JB-47F FLY-BY-WIRE FLIGHT TEST PROGRAM
Jenney, Gavin D., Hydraulic Research and MFG Co., Burbank, Calif. September 1969, AD-861 640

The report presents a description of the research investigation on a fly-by-wire control system applied to a B-47 test aircraft. The investigation is primarily confined to the pitch axis of the test aircraft and is divided into three phases, Phase I system operation is based on using an electrical non-redundant primary flight control system with control inputs being generated by the normal control motion. Phase II system operation is based upon adding a side stick controller, pitch rate and nose acceleration feedback, and electrical roll axis control to the Phase I system. Phase III incorporates a 4 channel redundant actuator with hydraulic logic into the Phase II system. Flight test of the Phase I system was completed with over 40 flight hours, including touch and go landing being accumulated on the fly-by-wire system by four different test pilots.

179. LABORATORY LANDING,
Lockheed-Georgia Quarterly, vol. 6, June 1969.

Discussion of a research laboratory study of a STOL aircraft landing. Design engineers are working on preliminary concepts involved in modifying a Lockheed C-130 Hercules as an STOL aircraft. As part of the pilot's view during a landing approach on a STOL runway was developed. The landing site selected was LaGuardia Field in New York City.

180. LAMS B-52 FLIGHT EXPERIMENTS IN DIRECT LIFT CONTROL
Lee, J.A., and Johannes, R. P., (USAF, Wright Patterson AFB, Ohio). Society of Automotive Engineers, New York, N. Y., Apr. 21-24, 1969, Paper 690406.

Results of a limited flight evaluation of Direct Lift Control (DLC) on a modified B-52 aircraft. The evaluation was made in conjunction with concluding flights of the Load Alleviation and Mode Stabilization (LAMS) Program and represents the first flight testing of a blended closed loop DLC system on an aircraft of this size and weight. By allowing the pitch and heave motions in the longitudinal axis to be decoupled, the system provided positive control of altitude displacements while holding the pitch attitude constant. In both ILS approaches and aerial refueling tasks, controllability was significantly improved and pilot workload was reduced.

181. LAMS FLIGHT CONTROL SYSTEM ANALYSIS AND DESIGN
Thompson, G. O., (Boeing Co., Wichita, Kan.) LAMS A Technology To Control Aircraft Structural Modes;Institute of Electrical and Electronics Engineers, Georgia Institute of Technology, Atlanta Ga., June 23, 1970. Proceedings A71-1165802-02.

Analysis of the design features of LAMS' flight control systems aimed at the reduction of turbulence induced fatigue damage rates in the B-52 and C-5A aircraft. The B-52 and C-5A mathematical models used in structural performance and stability analysis are discussed. Problem identification, system synthesis, and performance evaluation are considered as basic elements of the analytical technique used in the study. Block diagrams are given for B-52 and C-5A LAMS flight control systems.

182. LAMS FLIGHT DEMONSTRATION

Dempster, J. B., (Boeing Co., Wichita, Kan.) LAMS A Technology To Control Aircraft Structural Modes; Institute of Electrical and Electronics Engineers, Georgia Institute of Technology, Atlanta, Ga., June 23, 1970. Proceedinga A71-11658 02 02.

Discussion of the results of the flight demonstration phase of the LAMS program, designed to validate the analytical techniques used in the system design by comparing test data with analytical performance predictions. It is shown that the LAMS test vehicle with powered controls with or without the Baseline SAS has an adequate flutter boundary. Repeatable sinwave and step function transients were introduced into the control surfaces at selected frequencies and amplitudes to verify the functional operation of the control systems. Transient testing data were used to define open and closed loop responses of the aircraft and its systems.

183. LAMS - A TECHNOLOGY TO CONTROL AIRCRAFT STRUCTURAL MODES

Johannes, R. P.; Thompson, G. O.; Kass, G. J.; Dempster, J. B., IEEE Professional Group on Automatic Control, June, 1970.

Introduction and Summary (LAMS), R. P. Johannes (USAF, Flight Dynamics Laboratories, Wright-Patterson AFB, Ohio), p. 2-12. (See A71-11659 02-02) LAMS flight control system analysis and design. Thompson, G. O. (Boeing Co., Wichita, Kan.), p. 13-41. (See A71-11660 02-02). LAMS test vehicle modification and system tests. Kass, G. J. (Boeing Co., Wichita, Kan.), p. 42-96. (See A71-11661 02-02) LAMS flight demonstration. Dempster, J. B. (Boeing Co., Wichita, Kan.), p. 97-125. (See A71-11662 02-02) Conclusions, Johannes R.P. (USAF, Flight Dynamics Laboratories, Wright-Patterson AFB, Ohio), p. 126.

184. LAMS TEST VEHICLE MODIFICATION AND SYSTEM TESTS

Kass, G. J. (Boeing Co., Wichita Kan.). In: LAMS A Technology to Control Aircraft Structural Modes; Institute of Electrical and Electronics Engineers, Georgia Institute of Technology, Atlanta, Ga., June 23, 1970. Proceedings, A71-116588 02-02.

Discussion of the B-52 test vehicle modification and instrumentation used in the flight demonstration phase of the LAMS vehicle and system test program. The modified features of the B-52 test vehicle include structural changes in the aft fuselage and vertical tail section, a gust probe installed in the vehicle nose, new hydraulic activators to the elevators, ailerons and rudder, a new servo valve for spoiler panels, a fly by wire pilot station, a copilot station converted into a safety monitor station, and a bomb nav station modified to a flight engineer station. System and component evaluations performed within the framework of this program are reviewed.

185. LANDING GUIDANCE FOR VTOL AIRCRAFT
Hunter, I. M., Nethaway, J. E. BAPA Proceedings of a Technical Symposium on V/STOL in Civil Aviation, 1970.

Description of a system which offers a very precise short-range three-dimen sional surveillance system and ground computer to evaluate the optimum VTOL aircraft maneuver with a minimum of airborne complexity. It is shown that the use of the computer offers very great flexibility including multiple flight paths, multiple aircraft types, and freedom of choice of equipment site. as well as redundancy and integrity. The control system of the aircraft is likely to be electrically signalled, possibly with a mechanical backup, and will probably incorporate a failure-survival autostabilizer. The pilot's display system will be extremely important because the pilot may be unable to see the landing pad for the greater part of the transition and hover.

186. LANDING VTOL AIRCRAFT IN ADVERSE CONDITIONS & SOME POSSIBLE SOLUTIONS
Walters, D.J. Paper to AGARD Guidance & Control Panel Symposum on Aircraft Landing Systems, 1969.

187. LANDING VTOL AIRCRAFT IN ALL WEATHER
Grochowski, F. Dornier-Post No. 2-3, pp. 12-15, 1968.

188. LINEAR OPTIMAL THEORY APPLIED TO ACTIVE STRUCTURAL BENDING CONTROL
Smith, R. E. & Lum, E. L. J. of A., Vol. 5, 479-486 Sept.1968

189. LONGITUDINAL ANALYSIS OF TWO CCV DESIGN CONCEPTS
Kujawski, Capt. B. T., Jenkins, Jerry E., and Eckholdt, Capt. D.C., Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, AIAA, Paper No. 71-786, July 1971.

The analyses of relaxed static stability (RSS) and maneuver load control (MLC) presented in AIAA paper 70-926 are extended in this paper. This investigation treats the longitudinal control requirements due to simultaneous application of these concepts. The same dynamic response criterion used in the previous paper is applied to a fighter-type aircraft, with the exception that the duration of the maneuver is selected based on the short period response requirements for acceptable handling qualities. The approach to MLC was modified to include directly the effects on induced drag. This provided improved capability to investigate the trade-offs between wing-root-bending alleviation, drag, and longitudinal trim change. As a result of the new approach, improved solutions were found for the bomber configuration previously investigated.

190. MANUAL AND AUTOMATIC LANDING SYSTEM TERMINAL CONTROL THEORY, SYSTEM INTEGRATION CONCEPTS. FLIGHT TEST RESULTS, AND FUTURE DEVELOPMENTS
Farnum, D. D. Montooth, J., Advisory Group for Aeronautical Research and Development Paris (France), January, 63, AD-427 674

The theory and operation are described of the APN-114 automatic and manual all-weather landing system. Results of flight test programs utilizing the Convair TF-102A and the Boeing 70780, are presentedd. Possible system building blocks, including advantages and disadvantages, are noted. Also, areas which require additional research and development are briefly discussed.

191. MANUAL DIGITAL POSITIONING IN 2 AXES - A COMPARISON OF JOYSTICK AND TRACK BALL CONTROLS
Technology for man 72; Proceedings, Human Factors Society, Inc., Los Angeles, Calif., October 17-19, 1972. A73-16701 05-05, Santa Monica, Calif.

A series of experiments comparing various configurations of joystick and track ball controls operating in rate and position modes are described. Data are presented on optimizing a given control configuration and on comparative of the optimized controls. Test results using the best configuration of each type of control showed times-to-position values of 2.5 to 4.0 seconds for target displacements of 300 steps and from 2.9 to 4.8 seconds for displacements of 900 steps.

192. A METHOD FOR ESTABLISHING INSTRUMENT APPROACH LIMITATIONS FOR HELICOPTERS
Fisher, I. A. A & AEE Note 2031, 1970

193. MORE NOTES ON THE ESTABLISHMENT OF AIRCRAFT APPROACH LIMITATIONS FOR HELICOPTERS
Charles, M., Fisher, I. A., Gregory, J. D. L., A & AEE Note 2038, 1970.

194. MULTIPLE LOOP CONTROL OF THE F-8C DURING A POWER APPROACH, PHASE II - ANALOG SIMULATION WITH PILOT MODEL
Gross, Gary L., Naval Air Development Center Aero Mechanics, Division AD-843 018L Rept. NADC-AM-6831 Oct. 1963.

The use of an automatic multiple integrated controller (AMIC) should provide more precise airplane control, and reduce pilot workload in critical flight modes such as carrier landing approaches. The AMIC system will integrate two, or possibly three, of the longitudinal controls available to the pilot (elevator, flaps, throttle) for single stick control. This report is the second phase in an attempt to isolate longitudinal control problems and also to establich criteria to implement automatic control devices, an analog computer was used to simulate the F-AC airplane with the mathematical pilot model in multiple closed loop. Non-integrated control in the power approach configuration. The results of this study have provided valuable insight for the development of AMIC system. Which should logically follow.

195. MULTIPLEX ELECTROHYDRAULIC SYSTEM FOR FLY-BY-WIRE ACTUATORS, WITH MAJORITY VOTING AND PRESSURE LOGIC
Himmler, C. R., Fluid Power Symposium, 2nd, University of Surrey, Guildford, Surrey, England, January 4-7, 1971, Proceedings. Cranfield, Beds, England, British Hydromechanics Research Association, 1971, A72-22151 08-03.

The double-triplex hydraulic system described satisfies specifications regarding static and dynamic accuracy, resistance to vibrations, and behavior in the case of failure. The unit consists of a tandem cylinder and two triplicate electrohydraulic pressure transducers. Each module of the unit controls a power stage with an independent hydraulic supply. A redundant active/standby switch is used to switch from one system to the other. A hydraulic majority system with three hydraulic outputs was developed. A frequency response analysis is discussed together with aspects of the tests conducted with the new system.

196. NASA FLIGHT RESEARCH CENTER FLY-BY-WIRE FLIGHT TEST PROGRAM
Shu W. Gee and Burke, Melvin E. Proc. of the Space Shuttle Integrated Electron. Conf., Vol. 1 1971 N71-33051 20-31.

Equipping the space shuttle vehicle with a digital fly-by-wire flight control system is discussed. The past and present space programs have demonstrated performance and reliability of such a system in a space environment: only limited actual flight data in an atmospheric environment are available on which to base confidence in the performance of such a system. A technology development program is underway that should provide information on the performance of digital fly-by-wire systems for aerodynamic control. This program, which utilizes an F-8C aircraft as a flight-test vehicle, is being conducted in two phases. Phase 1 is the development and flight testing of a single-channel digital system with a triple redundant direct electrical backup system. Phase 2 is the development and flight testing of a redundant all digital fly-by-wire system will be deactivated for this program.

197. NASA GETS SHUTTLE 'LANDING' DATA
Elson, Benjamin M. Aviation Week & Space Technology, Sept. 25, 1972.

Unpowered automatic approaches and landings made from 40,000 ft. in a Convair 990 are providing National Aeronautics and Space Administration with data on space shuttle terminal area navigation, guidance and control problems, and a foretaste of landing the shuttle without airbreathing engines. The shuttle landing simulations are being conducted by the NASA Ames Research Center to determine the shuttle's requirements for ground navigation aids. NASA's 990 research airplane is configured for these tests to approximate shuttle aerodynamics and equipped with a digital avionics.

198. NATIONAL SUPERSONIC TRANSPORT PROGRAM CONTROL DISPLAY PILOT FACTORS PROGRAM, INSTRUMENT PILOT INSTRUCTOR SCHOOL RANDOLPH AFB TEX
Dec. 63 AD-441 953.

Intervening levels of control between full manual and full automatic were examined to determine the compatibility of the human pilot with an automatic flight control system using force wheel steering as the link between the two elements. Two identically equipped T-39 aircraft were utilized in the inflight examination. Twenty-six pilots representing commercial airlines, FAA, and the USAF flew every possible combination of the two levels of control in pitch, and three levels of control in roll. A total of five times; two times were for training and three times for record. The standard T-39 panel. Featuring the USAF flight director display, was used. The profile consisted of the ILS final approach. All approaches were made under the hood. Standardized briefings and procedures were utilized.

199. NAVIGATION GUIDANCE, & CONTROL SYSTEMS FOR V/STOL AIRCRAFT ORDER
Stephen, S., Rouse, William E:, Young, Lou S. Sperry Technology Vol 1 No. 3, 1973.

The development of digital autopilots and integrated avionics systems, applicable to many classes of vehicles and missions, was undertaken by Sperry Flight Systems in the mid-sixties. The first application of the system was planned for automatic flight control in the U.S. supersonic transport; the termination of that program, however, thwarted any flight experience. The second application, which has additional navigation and energy management functions, is an airborne simulator of the space shuttle vehicle. The latter system underwent a series of successful flight tests in a CV-990 aircraft under contract with NASA. The third application, which has new electronic displays, air data computation, and time-constrained guidance (i.e., specified position and altitude at a specified time), is in the DOT/NASA STOLAMD test program.

200. NAVY DIGITAL FLIGHT CONTROL SYSTEM DEVELOPMENT
Borow, M. S.; Grabo, R. J.; Hendrick, R. C.; Konar, A.F. et al. Naval Air Development Center Report No. 21857-FR Sept. 1, 1970 to Sept. 30, 1972.

201. A NEW CONCEPT IN AUTOMATIC FLIGHT CONTROL
Abrams, Charles R. Naval Air Development Center, Aero Mech. Dept. AD-850 1256 Rept. NADC-AM - 6904 Feb. 1969.

This report defines a new concept in automatic flight control: that is a single controller that will provide suitable stability augmentation and pilot assist functions for all aircraft within a given class, and, in addition, be physically interchangeable among aircraft with minimum modification. The implications of adaptability and versatility are decreased costs. Improved maintainability, reduced logistic problems and high reliability. The most prominent problem areas are the signal, actuator and primary flight control interfaces that are inherent in different aircraft. These problems are not unsolvable, and may be minimized or eliminated if provisions for an adaptable system are incorporated into the initial airplane design processes.

202. NEW CONTROLS TO SHAPE FUTURE AIRCRAFT
Yaffee, Michael L. Wright-Patterson Air Force Base, Ohio, Aviation Week and Space Technology, October 16, 1972.

Basically, the CCV concept involves application of advanced flight control technology, such as the static stability compensation system, to aircraft while they are still in the design stage. These new control systems can replace and enhance to a significant degree many of the control functions now performed by pilots and conventional control surfaces. They also will enable aircraft to make maneuvers such as side steps that couldn't be done before.

203. NEW DEVELOPMENTS IN SCANNING BEAM LANDING GUIDANCE SYSTEMS, WRIGHT PATTERNSON AIRFORCE BASE, Litchford, G. B., Report AFFDL-TR-69-107, December 1969.

The methodology and rationale for establishing significant design features of a new, radio-landing system are described. Multiple, microwave scanning beams define the precise coordinates of the touchdown conditions and permit a wide selection of curved flared, or other flight path geometries that terminate in a safe landing condition. By time-sequencing wide-beams (scanning wide sectors) with narrow-beams (scanning narrow sectors), a coarse-fine solution to a vexing system design problem is offered. Precision guidance (for flareout, touchdown and rollout) is provided as well as wide sector proportional guidance data for noise abatement flight paths, steep angle approaches, and curved lateral paths. Users have the choice in the proposed systems signal formats of a low-cost implementation as well as a very sophisticated implementation that would be commensurate with high-performance jet aircraft. Typical design trade-offs of (1) C and K sub u band. (2) CW narrow-band data. (3) future channelization needs. (4) variable sampling rates, (5) guidance accuracies, and (6) the overall integrity of the system are analyzed. Several examples are given to illustrate the proposed methodology for arriving at a new signals in space standard for a common civil-miltary landing system illustrated are several configurations of the basic system exemplifying various user demands, aircraft types, costly lighting aids, safety levels, and redundancy of radio guidance.

204. A NEW GUIDANCE SYSTEM FOR APPROACH & LANDING
RTCA Document No. Do-148 prepared by SC-117, Dec. 18, 1970

205. NEW METHODS IN ADAPTIVE FLIGHT CONTROL
Hofman, L. G. & Best, J. J. NASA, CR-1152, Sept. 68 IV.

The adaptive control function technique is applied to design a remarkably simple adaptive lateral stability augmentation system for a hypothetical manned, lifting-body entry vehicle. This system is proven stable under certain ideal conditions. The general principles of the adaptive control function technique are summarized and used to motivate the steps in the design for this specific multivontrol-point application. The basic operating principle is that sums of properly modulated conventional linear feedforward and feedback signals

provide the control functions needed to obtain specified responses in a number of output variables of a linear controlled element. System performance is demonstrated via computer simulation. Data show the adaptive system highly capable of coping with the unstable nature of the vehicle as well as those nonideal effects (time-varying vehicle-vehicle model mismatch, disturbance inputs, outer control loops, and noise suppression filtering) not considered in the analytical design. A comparison of the gains set by the adaptive system, with those selected by a competent aircraft flight control system analyst as optimum, confirms in still another way the reasonable performance of this system.

206. NF-8D VARIABLE STABILITY PROGRAM
Burton, R. A. (U.S. Naval Air Test Center, Flight Test Div., Patuxent River, Md.) (Society of Flight Test Engineers), Saint Mary's College of Maryland, Saint Mary's City, Md., August 31-September 2, 1971, Technical Papers. A72-16652 05-21, A72-16660.
Description of the procedures used in the ground/inflight calibrations of the Variable Stability System (VSS) installed in NF-8D BuNo 147041, with comments on the relative merits of ground vs inflight calibration procedures. The procedures represent a technique which can successfully be used to identify the various elements of an automatic flight control system. Both the inflight and ground calibration techniques have their own relative merits and should be used in conjunction with each other to give test results the highest level of confidence possible.

207. NON-VISUAL PRECISION APPROACH & LANDING GUIDANCE SYSTEMS (PALS)
ICAO AWOP MEMO #82 March 16, 1971.

208. NOTES ON THE APPLICATION OF REDUNDANT SERVO SYSTEMS FOR AEROSPACE VEHICLES
Tourtellotte, F. Vickers Inc.

209. A NOVEL DIGITALLY ADDRESSED ELECTRON BEAM SCANNER FOR ADVANCE SENSOR AND DISPLAY APPLICATIONS
Landrum, B.L.; Jeffries, L. A. Symposium Image Display and Recording, April 8, 1969.

210. OPTIMAL CONTROL
Athans, M.; Falb, P.L.; McGraw-Hill, New York, New York, 1966.

211. OPTIMAL CONTROL OF THE F-8C IN A FULLY AUTOMATIC POWER APPROACH PHASE I - POSITIONING AIRFRAME POLES
Bannett, Roger J. N.A.D.C. Aero Mech. Dept. AD-847 171L Dept. NADC-AM-6871 Jan., 1969.

Modern Control Theory Techniques have been used in the design of a fully automatic carrier approach controller. In particular, the use of optimal control theory has led to the automatic multiloop optimal approach controller (AMOAC). This concept affords a high degree of flexibility in specifying the phugold-and short period airplane dynamics. Specifically, the phugold mode is made compatible with the carrier approach environment. Resulting in good altitude response for both deterministic and stochastic command inputs and stochastic disturbances.

212. AN OPTIMAL CONTROL METHOD FOR PREDICTING CONTROL CHARACTERISTICS AND DISPLAY REQUIREMENTS OF MANNED-VEHICLE SYSTEMS
Elkind, Jerome I; Falb, Peter L.; Kleinman, David; Levison, William H., Bolt Beranek & Newman Inc., AD-672 272 BN-1559, June, 1968.

An analytic procedure for determining information display requirements and human control and instrument monitoring characteristics for complex multivariable vehicular control systems is developed. The method is based upon the assumpption that the human controller will act in a near optimal manner. Optimal control theory and its associated statespace representation is used as the basis for the analytic procedure. A model for the human controller is developed in which the controller's inherent limitations are approximated by a time delay the model includes a predictor for compensating for this time delay. A controller for producing the control inputs to the vehicle and a cost functional that is to be miniminized. The controller is assumed to be optimal. Several suboptimal predictors are investigated. Only quadratic cost functionals are considered. The analytic procedure assumes that the human operator's control characteristics can be represented by a set of gains operating on the delayed state variables of the system.

213. OPTIMAL PATHS FOR MINIMIZING LANDING TRANSITION DISTANCE FOR JET-LIFT VTOL AIRCRAFT
Huntley, E. RAE TR 70134 1970.

214. OPTIMAL 3-DIMENSIONAL MINIMUM TIME TURNS FOR AN AIRCRAFT,
Humphreys, R.P.; Hennig, G.R. Bolding, W.A. and Helgesson L.A. Journal of Astronautical Sciences Vol. 20, Sept-Oct., 1972, A73-18377.

Using a three-dimensional formulation for an aircraft's dynamics, the required controls for minimum time-to-turn are calculated. Three controls are used: (1) angle of attack, (2) bank angle, and (3) thrust. The minimum time-to-turn solutions are subject to varying terminal conditions on both flight path angle and heading angle. In general, the time for the turns are not greatly changed by varying thrust/weight ratios or the final flight path angle. Significant effects on the change in total energy, final altitude, firnal velocity, and control histories are noted for variations of the above parameters. Solutions to the above problem are accomplished through the use of Miele's sequential gradient-restoration algorithm.

215. PAPERS & DISCUSSION BY A GROUP OF PANELISTS ON: STEEP LANDINGS SYSTEMS FOR VTOL AIRCRAFT.
Suggs, R.L.; Kesselring, G.B.; Gallagher, J. E.; Litchford, G.B.; Reeder, J. P. J. of AHS, 14, 1969.

216. PARALLEL PROCESSOR STUDY WESTINGHOUSE ELECTRIC CORP. BALTIMORE, MD. AEROSPACE AND ELECTRONIC SYSTEMS DIVISION
September 70 AD-886 361L.
The overall objectives of this study effort were to: Select typical parallel organized problems and derive the processing requirements inclucing equations. Algorithms, rates and other pertinent parameters, these typically will include the fast fourier transform. Target signature analysis and kalman filtering: Describe in detail critical elements of the parallel organized problems on a baseline processor: Compare the requirements with baseline processor characteristics: Evaluate the processor characteristics as an element in the advanced avionic digital computer (AADC) Concept.

217. PAYOFFS AND PROBLEMS OF FLY-BY-WIRE CONTROL SYSTEMS
Bumby, Edward, A. (Grumman Aerospace Corp., Bethpage, N.Y.). American Institute of Aeronautics and Astronautics, Hofstra University, Hempstead, N.Y., Aug. 16-18, 1971, Paper 71-959.
Discussion of the weight reduction possible for high-performance aircraft by using an electronic or fly-by-wire (FBW) flight control system, together with the control configured vehicle concept. The weight reduction due to incorporation of a FBW system and the control configured vehicle desigr leads to the fuel-structure weight reduction cycle. An FBW system requires quadruple-redundant mechanization in order to achieve two-failure survivability. However, before FBW is applied to an aircraft, there are several problems which require extensive investigation. Mechanization of a quadruple-redundant system and its interface with a single control surface presents the major problem. The various techniques developed to deal with this problem are discussed, and a preferred configuration is indicated. Examples of signal selection and failure monitoring circuits are discussed. It is pointed out that FBW enhances the neutral vehicle stability design due to the inherent SAS (stability augmentation system) function of the FBW flight control system.

218. PENNSYLVANIA-PRINCETON ARMY AVIONICS RESEARCH PROGRAM. COMPUTER ACTIVATER INSTRUMENTATION DISPLAY
Fegley, Kenneth A. Moore School of Electrical Engineering, Phila., Pa.
Report No. 71-02 Dec. 70 AD-881 309.
The report is a description of the results of a feasibility study on the use of digital computer activated displays as navigation aids for helicopter pilots. The purpose of such aids is to enable the pilots to fly with increased ease and improved performance. The study was carried out using a simulation system consisting of several digital computers. A simulated helicopter cockpit with controls, and other elements. The UH-1 helicopter and the AN/ASW-12 autopilot were simulated. The report describes the said simulation system. The simulation of helicopter dynamics and autopilot, and the trade-off between the autopilot and the display during the simulated flights.

219. PERFORMANCE ADVANTAGES OFFERED BY ADVANCED FLIGHT CONTROL TECHNOLOGY
Johannes, Robert P. Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio CASI/ AIAA Meeting on the Prospects for Improvement in Efficiency of Flight, AIAA Paper No. 70-874, Toronto, Canada/July 9-10, 1970.

Inclusion of flight control technology early in the configuration development phase of new aircraft can result in significant reduction in structural weight and improved aerodynamic efficiency. The extension of control system functions to include inherent aircraft stability augmentation, active flutter control, maneuver load control, and active ride control, in addition to normal maneuvering control and handling qualities augmentation, can provide these advantages. In order to validate these potential benefits a series of analytical studies have been conducted applying advanced control functions to various existing and projected aircraft. The results of these efforts will be discussed in terms of weight savings which can be achieved.

220. THE PERFORMANCE BENEFITS DERIVED FOR THE SST THROUGH A NEW APPROACH TO STABILITY AUGMENTATION
Kehrer, W.T. July 1971, AIAA Paper No. 71-785

The U.S. SST has derived substantial benefits in performance and operational safety as a result of development of a stability augmentation system (SAS) that achieves the reliability of basic structure. This system, termed 'hard SAS' (HSAS), is used to back up the normal SAS. It has permitted a further aft placement of the operational center-of-gravity (cg) range than could otherwise be considered. The resulting savings in aircraft weight and drag have netted 225 mi of range improvement plus reduced takeoff and landing speeds and reduced community noise. Improved operational safety also results from the integration of the HSAS concept into the flight control system. HSAS makes it also possible to decelerate descend, and land, with the cg remaining at the supersonic cruise location, in the event of failure to transfer aft tank fuel forward. Also, HSAS provides saft handling qualities throughout the flight envelope, and a safe control in the event of shutdown of all SAS channels.

221. PILOT/AUTOMATIC-RELATIONS, CONFIDENCE, DISPLAYS
Wilckens, V., Society of Experimental Test Pilots, Technical Review, Vol. 11, No. 3, 1973.

The main problem of manual landing control is that the residual problems are primarily caused by the type of information offered to the pilot. Some comments are made on the fully automatic landing concept, the abilities and limitations of man, and the primary requirements to be fulfilled by displays. Many pilots are uncomfortable when delegating blind landing control to a 'full authority' autopilot. The lack of a self-optimizing tendency in man-controlled evolution is discussed, and a display concept is derived.

222. A PILOT's LOOK AT AIRCRAFT INSTRUMENTATION
Foxworth Thomas, G. and Newman, Richard L. American Institute of Aeronautics and Astronautics, Aircraft Design and Operations Meeting, 3rd, Seattle, Wash., July 12-14, 1971, Paper 71-787

Deficiencies in current aircraft instrumentation are discussed from pilots point of view. The performance of typical aircraft instruments is analyzed and it is shown that in many cases they do not properly convey the information needed by the pilot to enable him to do his job. It is suggested that the information content should be improved, and the displays should not mislead the pilot; they should yield correct information, any malfunction or spurious reading should be indicated by clear warning, and they should be simple. What is important should be displayed, and what is temporarily unimportant should be suppressed. A pilot-designed display is proposed and its use is suggested.

223. A PILOTED SIMULATOR STUDY OF THE CONTROLLED DECELERATION TRANSITION OF A VTOL AIRCRAFT IN A STEEP DESCENT
Hornby, R. C., Paper ARC 31415, 1969.

224. PILOT PERFORMANCE WITH A SIMULATED ILS INDEPENDENCE PICTORIAL DISPLAY.
Palmer, Everett, and Wempe, Thomas, National Aeronautics and Space Administration, Ames Research Center Moffett Field, Calif., 1972, N73-10104 01-05

As part of a general investigation of the effectiveness of pictorial displays for manual control and monitoring of aircraft approaches and landings, a simulator study was conducted in which pilot performance with three pictorial displays was evaluated. These displays differed in the type of guidance symbology added to the basic perspective runway display. The effect of decreased resolution and update rate of the runway image on pilot performance was also determined. The results indicate that for pictorial displays with added guidance symbology, there was a marked improvement in pilot performance compared to results of a previous study in which the display consisted of only a runway image and aircraft attitude.

225. PITCH ATTITUDE, FLIGHT PATH, AND AIRSPEED CONTROL DURING APPROACH AND LANDING OF A POWERED LIFT STOL AIRCRAFT
Franklin, James A., and Innis, Robert, C., National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif. Dec. 1972 NASA-TM-X-62203.

Analytical investigations and piloted moving base simulator evaluations were conducted for manual control of pitch attitude, flight path, and airspeed for the approach and landing of a powered lift jet STOL aircraft. Flight path and speed response characteristics were described analytically and were evaluated for the simulation experiments which were carried out on a large motion simulator. The response characteristics were selected and evaluated for a specified path and speed control technique. These characteristics were: (1) the initial pitch response and steady pitch rate sensitivity for control of

attitude with a pitch rate command/attitude hold system. (2) the initial flight path response, flight path overshoot, and flight path-airspeed coupling in response to a change in thrust, and (3) the sensitivity of airspeed to pitch attitude changes. Results are presented in the form of pilot opinion ratings and commentary, substantiated where appropriate by response time histories and aircraft states at the point of touchdown.

226. A PRACTICAL OPTIMIZATION DESIGN PROCEDURE FOR STABILITY AUGMENTATION SYSTEMS
Stapleford, R. L., McRuer, D. T., Hofmann. L. G., Teper, G. L., Systems Technology Inc. AD-717 168 AFFDL-TR-70-11 Oct. 1970.

A systematic procedure for the design of aircraft stability augmentation systems is presented. The key features of this procedure are the selection of essential feedbacks from an examination of several handling quality metrics and the use of parameter optimization techniques to determine the numerical values of the SAS parameters. The optimization problem is structured to include both manual and SAS feedbacks. The cost function includes pilot tracking errors and SAS control deflections. A method of selecting the relative weighting is presented. The feasibility of this procedure is demonstrated by applying it to the longitudinal axis of the F-4 aircraft. Three widely different flight conditions are selected. For all three, the same SAS form (pitch rate and normal acceleration feedbacks to the elevator). The identical problem formulation, and the same method of selecting the cost function weights are used. The resulting systems are judged quite satisfactory and well within the short-period requirements of the current military handling qualities specification.

227. PREDICTION OF HUMAN OPERATOR PERFORMANCE IN THE DESIGN OF COMMAND AND CONTROL SYSTEMS
Ware, C. T. and White, R. T. Douglas Paper 5539 Western Psych. Assoc., June 1969

228. THE PRESENTATION OF NAVIGATIONAL INFORMATION
Treadgold, M.G. and Walters, D. J. Royal Aircraft Establishment, The Journal of the Institute of Navigation, Volume 22, 1969.

Reviewing briefly the operator/machine interactions, we find that these consist of three main areas. First there is the display of present position for the purpose of checking the accuracy of the system. This involves cross comparison with inputs from alternative systems. Secondly, there is the setting of destination possibly more than one, and finally, there is the feedback of instruction to the pilot of what he should be doing about it.

229. PRIMARY FLIGHT CONTROL CIRCUIT DEVELOPMENT FROM MECHANICAL SYSTEMS TO AN ALL-ELECTRIC DIGITAL SIGNALLING SYSTEM
Doetsch, K. H., and Metzdorf, W., Sep., 1968, AGARD, Oslo, Norway, Sept. 1968, C-153-12.

Design principles, development, and problems of mechanical flight control and stability augmentation systems are reviewed and compared with electric signalling systems (fly-by-wire) as a possible alternative for primary flight control of aircraft. Reliability, maintenance, and inflight repair of the electronic part of a fly-by-wire system and of a failure detection subsystem are briefly examined. The feasibility of digital fly-by-wire systems is discussed, including location of the analog-to-digital and digital-to-analog conversion functions, the digital-to-analog converter in the electrohydraulic servo system, and the electrohydraulic servo system with mechanical feedback.

230. THE PRINCETON PENNSYLVANIA ARMY AVIONICS RESEARCH PROGRAM
Born, Gerard J., Dukes, Theodore A., Durbin, Enoch,J. Schmitz, Fredrick, Princeton University, N. J., September 70 AD-884 786L.

The integrated cathode ray tube display developed earlier in the program was tested in a fixed base simulator the objective of the test series was to determine the best scaling factors for the display of vertical error. Error rate and pitch attitude in the station keeping task during straight and level flight as well as climb/descent and turn maneuvers. In the task dealing with instrumentation to enhance VTOL-STOL pilot flight control. Optimal control theory was applied to the take-off of STOL aircraft and heavily loaded helicopters, concerning static electricity in helicopters, the tribo-electric charging process and corona discharges were investigated. In the newly initiated task on precision hovering under IFR conditions, the initial effort concentrated on the display problem, the integrated multicolor CRT display developed earlier in the program was adapted to enhance the information needed for accurate hovering performance.

231. PROBLEMS OF THE COCKPIT ENVIRONMENT
AGARD AD-685 268 AGARD-Extended Summaries-4 November 1968.

Papers are presented on the following topics: The problems of determining crew capability under stress: problems in analysis and measurement of information transfer requirements and effectiveness for various missions: the problems of correlating crew training. Crew size and composition structure and automated assistance: The problems of cockpit design including instrumentation computer/display/control systems and components: the problems of cockpit information generation: The problems of deriving in-cockpit and head-up information display configurations.

232. PROBLEMS OF THE INTEGRATION OF AIRCRAFT AND FLIGHT CONTROL SYSTEM IN THE CASE OF NEW APPROACH PROCEDURES
G. Schanzer (Bodenseewerk Geratetechnik GmbH Oberlingen, West Germany). Deutsche Gesellscaft fur Luft-und Raumfahrt, Jahrestagung, 5th, Berlin, West Germany, Oct. 4-6, 1972, Paper 72-096, in German.

233. PROCEEDINGS OF THE FLY-BY-WIRE FLIGHT CONTROL SYSTEM CONFERENCE
Final Report Sutherland, J. P., Air Force System Command, Wright-Patterson AFB, Ohio. Flight Dynamics Lab., June 1969, Dec. 16-17, 1968, AFFDL-TR-69-58.
The results of fly by wire programs are outlined and a description of the B-47 fly by wire flight tests is given. Papers presented discuss the potential application of fly by wire for advanced fighters, large strategic bombers, and helicopters and outline the philosophy of redundancy, digital computation, handling qualities criterion, and pilot acceptance as related to fly-by-wire flight control systems.

234. PROJECT PLAN FOR THE DIGITAL FLY-BY-WIRE EXPERIMENTAL PROGRAM
Flight Research Center Feb. 16, 1973
The overall objective of this program is to provide the technology required for implementation of advance reliable digital fly-by-wire (DFBW) flight control systems which will permit greater operational capability and increased performance of future aircraft.

235. A PROTOTYPE FLY-BY-WIRE FLIGHT CONTROL SYSTEM
Sperry Phoenix Co., Ariz. Flight Systems Div. Final Report, 15 Apr. 1967 - 15 Aug. 1968, Emfinger, Jack E., Wright-Patterson AFB; Ohio AFFDL, Aug. 1969 AFFDL-TR-69-9, AD-860587.
NOTICE: Available to U.S. Government Agencies and their Contractors Only.
A discussion is presented of fly-by-wire flight control systems in which vehicle motion is the controlled parameter. Electrical signal transmission is employed from the pilots station to the electrohydraulic servomechanism. An experimental laboratory model fly-by-wire control system is designed, constructed, tested, and evaluated for performance to demonstrate the feasibility and capability of the fly-by-wire system. Aircraft analysis of the B-47 is made to determine the artificial feel requirements for this application. Reliability calculations and failure mode analysis are discussed. Peripheral equipment required (such as a side arm controller, preflight automatic self-test equipment, and the pilots control panel) is designed constructed, and described.

236. A PROTOTYPE FLY-BY-WIRE FLIGHT CONTROL SYSTEM
Emfinger, Jack E., Sperry Rand Corp., Phoenix Arizona, Sperry Flight Systems Division Report No. LJ-1273-1020; AD-860 587 August 69.
A discussion is presented of fly-by-wire flight control systems in which vehicle motion is the controlled parameter. Electrical signal transmission is employed from the pilot's station to the electrohydraulic servomechanism. An experimental laboratory model fly-by-wire control system is designed. Contructed, tested, and evaluated for performance to demonstrate the feasibility and capability of the fly-by-wire system.
Aircraft analysis of the B-47 is made to determine the artificial feel requirements for this application, reliability calculations and failure mode analysis are discussed. Peripheral, equipment required (such as a side arm controller, preflight automatic self-test equipment. And the Pilot's control panel) is designed, constructed, and described.

237. QUASI-OPTIMUM DESIGN OF AN AIRCRAFT LANDING CONTROL SYSTEM,
Ling, Chong K., Singer-General Precision, Inc., Little Falls, New Jersey, January-February 1970, Aircraft Vol. 7 No. 1

An explicit quasi-optimum control law for longitudinal aircraft motion with particular application to the landing phase is obtained by use of Friedland's quasi-optimum control technique. A worst-case simulation study (in which the initial errors in altitude, pitch, and angle of attack are -100 ft, -5.4°, and -2.2°, respectively) was performed for a typical jet transport. The resulting trajectory indicated that the aircraft is returned to the desired nominal trajectory in about 20 sec and does not deviate from the nominal trajectory by more than -130 ft. Simulated performance in the presence of steady wind disturbances was also determined to be satisfactory.

238. RADAR INDEPENDENT LANDING MONITORS
Bechtel, B. (Texas Instruments, Inc., Dallas, Tex.), American Institute of Aeronautics and Astronautics, Annual Meeting and Technical Display, 7th, Houston, Tex., Oct. 19-22, 1970, Paper 70-1336.

A radar system operating independently of ground-based electronic equipment has been developed which provides the pilot an on-board sensor to monitor runway alignment during approach, touchdown, and roll-outphases of Category II and III landings. The system features a real-world display providing a true-to-life perspective presentation of the runway. The system and preliminary flight-test results in the form of perspective display photographs are presented. Stimulated by a Lockheed-California request for proposal in late 1968, Texas Instruments, on internal funds, designed and carried out development and preliminary flight test during 1969.

239. RECENT DEVELOPMENTS INLOW-COST HEAD-UP DISPLAYS
Stormo, Milo E., (Singer-General Precision, Inc., Librascope Div., Glendale, Calif.). Flight Safety Foundation, 14th, Washington, D. C., May 13, 14, 1969, A70-33813 16-02

Review of the basic features of 4 flyable head-up display models designed to reduce the incidence of pilots' errors during the take-off, approach and landing phases of flight. Essential in these display designs are a collimating unit used with an opaque reticle to form a head-up display image in the focal plane, and a bar which gives the pilot his actual flight path through the air mass.

240. REDUNDANCY MANAGEMENT FOR FLY-BY-WIRE SYSTEMS
Bumby, E. A. (Grumman Aerospace Corp., Bethpage, N.Y.). American Institute of Aeronautics and Astronautics, Guidance and Control Conference, Stanford, Calif., Aug. 14-16, 1972, Paper 72-884.

Various analog circuit techniques employed in the redundancy management of a quadruple-redundant system are discussed. The redundancy management is separated into two categories, signal selection (voting), and failure detection and isolation (monitoring). The circuits employed in several types of voter/monitor techniques are discussed with respect to their failure response

characteristics and their mode of voting. The voters are separated into averaging and discrete signal selection categories. The monitoring function is discussed with respect to failure detection of redundancy management program for triple-redundant digital computer systems employing voter/monitor techniques similar to the analog circuits is presented.

241. THE RELIABILITY OF FLIGHT CONTROLS
Baumeister, Flugwelt, vol. 17, Oct. 1965, in German.

Discussion of the factors which define the concept of reliability as applied to flight controls, such as automatic landing systems and systems for controlling the flight of VTOL aircraft when in a transitional regime. In general, reliability requirements specify that the chances of failure be less than one in a million. The statistical approach to defining reliability is discussed in comparison with the approach based on "absolute reliability" which is attainable by proper design considerations. The analytical procedure based upon statistical analysis is reviewed. The serviceability of a system is an important criterion in reliability determination inasmuch as the design must make it impossible for the service personnel to affect the functioning of a system through faulty servicing.

242. RELIABILITY AND REDUNDANCY STUDY FOR ELECTRONIC FLIGHT CONTROL SYSTEMS
Helfinstine, Robert F., Niontague, Lyle L. Seller, Gordon L., Honeywell Inc., Minneapolis Minn., Government and Aeronautical Products Div., Report No. 21718-Fr, July 72, AD-902 44SL.

This report contains the results of a three-part study relating to development of electronic (fly-by-wire) flight control systems. Flight safety and mission reliability goals for fly-by-wire flight control systems were derived based on a survey of navy-supplied data on operational aircraft. Electronics augmentation equipment was surveyed to determine achieved reliability on this equipment correlation factors were derived for reliability predictions to achieve better accuracy in prediction techniques for electronic systems. Three basic fly-by-wire system mechanizations were studied. Relative merits of each were determined. Particularly with respect to monitoring and build-in test functions. Design criteria were developed for a selected configuration.

243. GENERAL DYNAMICS/FORT WORTH, TEX., RESEARCH INTO THE DEFINITION AND DEMONSTRATION OF AN OPTIMUM SOLID STATE SWITCHING AND MULTIPLEXING SYSTEM FOR USE IN A FLY-BY-WIRE FLIGHT CONTROL SYSTEM
Final Report, 1 Apr. 1969, 30 Apr. 1970 Mrazek, Jerry G., Roberts, Richard O., and Daggett, Dan H., Wright-Patterson AFB, Ohio, AFFDL June 1970 AFFDL-TR-70-80.

The report describes the trade studies employed in the selection of a preferred multiplexing concept for application in a fly-by-wire flight control system. In addition, a breadboard demonstrator which was designed and fabricated during the subject program is described and the test results are presented. The results of this program indicate that multiplexing is desirable in a fly-by-wire flight control system. The preferred system is one in which all data paths are multiplexed and use is made of pulse coded digital signals for data transmission.

244. RESEARCH AND DEVELOPMENT PROGRAMS OF THE FLIGHT CONTROL DIVISION , AF FLIGHT DYNAMICS LABORATORY
McElReath, Kenneth W., Air Force Flight Dynamics Lab Wright-Patterson AFB, Ohio January 71 AD-888 162.
The summary of research and development programs of the AF flight dynamics laboratory. Wright-Patterson AFB, Ohio, has been prepared as a medium for briefing the industry and government agencies of current Air Force activities in flight control systems R and D.

245. RESEARCH AND DEVELOPMENT PROGRAMS OF THE FLIGHT CONTROL DIVISION AF FLIGHT DYNAMICS LABORATORY
McElreath, Kenneth W., Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio. January 72 AD-900 461L.
This summary of research and development programs of the flight control division has been prepared for presentation to the society of automotive engineers aerospace control and guidance system committee as a medium for briefing the industry and government agencies of current Air Force activities in flight control systems.

246. RESEARCH ON FLIGHT CONTROL SYSTEMS VOL II. FLY-BY-WIRE B-47, PHASES II AND III
Jenney, Gavin D. Hydraulic Research and Mfg. Co., Valencia Calif., August 70, AD-875 136
In order to evaluate the operational characteristics of Fly-By-Wire in a large U.S. Military aircraft. A Fly-By-Wire system was designed and flight tested in a B-47 E aircraft. The Fly-By-Wire system was applied to the pitch axis of the test aircraft, three different phases of evaluation were conducted. Each phase corresponding to a different pitch axis mechanization.

247. RESEARCH ON FLIGHT CONTROL SYSTEMS
Vol. 3, Fly-By-Wire Techniques, Bazill, Dale G., Jenney, Gavin D. AFFDL-TR-69-119 Vol. III Oct. 1970.
This report presents the results of an evaluation of the operational characteristics of the flight control systems and mechanizations that are permanently located in the AFFDL Hydraulic Lab.

248. RESULTS OF THE INVESTIGATION OF DIFFERENT EXTRAPOLATION DISPLAYS
Dey, D., (Berlin, Technische Universitat, Berlin, West Germany). Proceedings of the Advanced Study Institute, Berchtesgaden, West Germany, March 15-26, 1971. Amsterdam, Swets en Zeitlinger, 1972, A72-41402 21-05.
Experiments on 5 subjects show that the steering reliability can be increased and the "lapse time" can be reduced when a prediction display is used in manual aircraft control. It is concluded that a prediction display gives the pilot more exact and faster information about the action of his stick signals and thereby assists in generating an optimal-time steering operation.

249. THE ROLE OF THE TEST PILOT IN EVALUATING AUTO LANDING SYSTEMS (PARTS I AND II)

Norton, Paul S., Engineering Test Pilot, S-3A Program, Lockheed Aircraft Company, The Society of Experimental Test Pilots, Sixteenth Symposium Proceedings, September 28-30, 1972.

The pilot's most significant contribution during the ACLS evaluation, is his ability to interpret the observed automatic control and the flight test data with operational judgement and criteria. Therefore, he can provide significant direction and assistance to the engineer in determining the most effective software/hardware variations to obtain optimum closed loop control. After interpreting the aircraft/ACLS development program from the test pilot's evaluation tasks can be summarized:

1. He should also be aware of the total environment in which the aircraft is being controlled and he should analyze the effects of this environment on automatic control.
2. He should deliberately test the aircraft in the worst operating weather conditions, in a build-up program, ashore and at sea.
3. He should strive to consistently think in terms of the relatively inexperienced pilot in order to effectively evaluate the automatic approach characteristics.
4. The evaluation pilot should have an appreciation for the operation of the entire system and become familiar with the operating characteristics and limitations of each component in this system.
5. He is evaluating the aircraft's response and control, however, he can only observe it, not affect it.
6. The most valuable contribution the pilot can make is to offfer his judgment and criteria, from a pilot's viewpoint, to the engineer.

250. A SIMPLE HEAD-UP DISPLAY FOR CIVIL AIRCRAFT

Greenland, B.J.L., Sperry Rand Limited

This paper describes a simple form of Head-Up Display which has been designed to assist the pilot during the approach and landing and, where necessary, during the overshoot. It is not an all-weather aid and is only for use under good visibility conditions as it has to be referenced to the ground.

251. A SIMPLIFIED KALMAN ESTIMATOR FOR AN AIRCRAFT LANDING DISPLAY

Merrick, Robert B., (NASA, Ames Research Center, Theoretical Guidance and Control Branch, Moffett Field, Calif.). American Institute of Aeronautics and Astronautics, Aerospace Computer Systems Conference, Los Angeles, Calif., Sept. 8-10, 1969, Paper 69-944.

Description of the application of Kalman filter simulation for estimating the position and velocity of an aircraft from data given by an airborne digital computer in a zero-zero landing system. The on-board estimator must operate within very limited allowances of computation time (70 milliseconds) and computer storage (600 words). The pertinent observation equations are linearized around the current estimated trajectory. The first mechanization of the Kalman filter approach drastically exceeded the on-board computer constraints. Several substantial simplifications were made to meet these constraints, and the results show that equivalent performance is obtainable with a much simpler system.

252. SIMULATED FLIGHT TESTS OF A DIGITALLY AUTOPILOTED STOL-CRAFT ON A CURVED APPROACH WITH SCANNING MICROWAVE GUIDANCE.
Farrington, F. D. (Ohio Northern University, Ada, Ohio) and Goodson, R. E. (Purdue University, Lafayette, Ind.). (American Society of Mechanical Engineers, Paper 73-Aut-L, 1973.) ASME, Transactions, Series G - Journal of Dynamic Systems, Measurement and Control, vol. 95, Mar. 1973.

A work is described which studied the capabilities of a STOL aircraft equipped with digital minicomputer serving as an autopilot making a curved approach to a runway. The work involved the development of an ATC scheme for effectively generating a flyable curved approach path and specifying such a path to the aircraft being served. The paths produced are made up of alternating straight and circular segments along which the plane is to maintain prescribed constant airspeeds. The digital autopilot functions include navigation, control trimming, anticipatory calculations, generation of control commands based on utilization of linear optimal state-feedback control theory, filtering (including Kalman techniques) of state measurements, and estimation of prevailing winds. A complete simulation of such a system aboard a McDonnell-Douglas 188/Berquet 941 STOL transport, with realistic winds, turbulence, and measurement noise, was created and exercised on the Purdue University CDC 6500 computer system, and showed the capability of excellent adhesion of the aircraft to the commanded flight path.

253. SIMULATION EVALUATION OF FLIGHT COMMAND FUNCTIONS
Stephan, P.W.: Chandler, W., Hughes Aircraft Co. Culver City, California Aeronautical Systems Division, Report No. ASD-05077R, March 70 AD-869 164.

The primary purpose of this study was to program and simulate advanced flight command computations for flight command functions common to many missions. A systems approach is taken in making use of available aircraft sensors and/or radio information to accomplish mission objectives. The functions simulated were horizontal (area) navigation. Horizontal steering, vertical navigation, pitch control, energy maneuverability (optimum climb), and automatic throttle. Both completely automatic flight and manual (display) steering were simulated. The simulation was conducted at the hybrid computation facilities of the Air Force flight dynamics laboratory, Wright-Patterson air force base, Ohio. The aircraft characteristics used were those of the F-4C.

254. A SIMULATOR COMPARISON BETWEEN TWO METHODS OF COMPUTING AND DISPLAYING THE VELOCITY IN A HEAD-UP DISPLAY FOR LOW SPEED FLIGHT PATH CONTROL
Nordstrom, Lennary and Arne, Hakan (Svenska Aeroplan AB, Linkoping, Sweden). Royal Aeronautical Society, Centenary Congress; International Council of the Aeronautical Sciences, Congress, 5th, London, England, Sept. 12-16, 1966,

Description of a new head-up display which indicates the desired flight path by a perspective pole-track, and the actual flight path by a velocity vector symbol. The display shows collimated flight data information in front of the pilot at eye level and superimposed on the outside environment when this is visible. It is noted that with proper information displayed in an accurate manner, the head-up display is potentially capable of improving handling qualities and accuracy of flight path control, and of reducing pilot work-load during instrument flight, visual flight, and the transition between them.

255. SOME ASPECTS OF THE DISPLAY CONFIGURATION OF MODERN AIRCRAFT
Schweizer, G., Bollinger, W., AGARD Conference Proceedings No. 55, Paper No. 18, 1968.

256. SOME EFFECTS OF BIAS ERRORS IN REDUNDANT FLIGHT CONTROL SYSTEMS
Stengel, Robert F., Massachusetts Inst. of Tech., Cambridge, Charles Stark Drapper Lab., Jun. 1972, NASA-CR-130354; E-2688
The controllability and steady-state response of parallel-redundant flight control systems are examined. It is found that state components which appear in the parallel signal paths, or individual actuator commands, are not controllable, although the sum of the command signals is well-behaved. If the response modes associated with these components are not stable, bias errors can cause the components to diverge, leading to the possibility of nuisance trips in failure detection/isolation logic and eventual control system lock-up (at saturation). Combining the inputs to the control computers assures that sensor bias will not cause divergence, while cross-strapping control strings bounds divergent response to all bias error inputs. Results of numerical solutions confirm the problem and its solutions.

257. SOME PROBLEMS IN THE DEVELOPMENT OF AN ADVANCED INTEGRATED FLIGHT CONTROL SYSTEM FOR STOL-APPROACH
Schanzer, G., Newnav Symposium, Frankfurt am Main, West Germany, Oct. 5-7, 1971, Report. Volume ?, Frankfurt am Main, Vereinigung Cockpit, 1972, A72-40276 21-21.
Review of the design, development, operation, and testing of an integrated STOL flight control system that includes automatic angle-of-attack and throttle control and results in significant approach-accuracy and passenger-comfort improvements. The requirements that must be met by a STOL flight control system are discussed, along with the design criteria for optimal flight control systems as contrasted with conventional STOL flight control systems. The superior performance characteristics of an integrated STOL control system of advanced design, demonstrated in more than 200 automatic landings, are shown to make possible effective noise abatement and safe avoidance of obstacles on steep landing approaches.

258. SOME THOUGHTS ON ALL-WEATHER OPERATION OF JET V/STOL AIRCRAFT INCLUDING THE USE OF RESTRICTED SITES
Farley, J.F. RAS Paper to Test Pilots' Group, 1968

259. SOME THOUGHTS ON V/STOL DISPLAYS AND APPROACH TECHNIQUES.
Millward, R.W., AGARD Conference Proceedings No. 55, Paper No. 7, 1968.

260. SST TECHNOLOGY FOLLOW-ON PROGRAM-PHASE I. TEST AND ANALYSIS OF A QUADRUPLE REDUNDANT HORIZONTAL STABILIZER ACTUATION SYSTEM.
Appleford, L.R. Beattie, M.L., King, C.W., Maylor, E.L., Ryder, E. L., Boeing Co. Seattle Wash. Commercial Airplane, Group. Report No. D6-60270 April 72 AD-901 616L.

An SST flight control system has been analyzed and tested as a technical follow-on to the cancelled U.S.A. Supersonic transport program. The quadruple-redundant horizontal stabilizer actuation system was evaluated to determine static performance, dynamic stability, force synchronization dynamic (flutter), stiffness, electronically compensated stiffness, static stiffness, bottoming loads, failure detection and effects, and high hydraulic flow rate effects. Conclusions are that the actuation system concept was feasible and that linear analysis methods accurately predict the linear characteristics of the system.

261. STABILITY AND CONTROL FOR INSTRUMENT FLIGHT
Barnes, A.G., Advisory Group for Aeronautical Research and Development, Paris (France) Report No. 490 AD-466 836 Oct. 64.

The complex relationships between pilot opinion of handling qualities and aircraft stability and control are greatly influence by task. Implicit with task is the manner in which relevant data is transmitted to the pilot. Present-day instrument flight systems are not designed for, and are quite unsuitable for the control of marginally stable aircraft, so that a considerable gap exists between the levels of stability acceptable for visual and instrument flight, and attempt is made to rationalize the causes of this gap. Many modern aircraft have poor stability without artificial devices: Design penalties are incurred either because fail-safe stabilising devices are required or because stability requirements for instrument flight dictate the basic aerodynamic configuration. Full use is never made of the pilot's inherent capability to stabilize and control an aircraft - the modern trend is to reduce the pilot's role to that of monitor, this trend could be reversed by porviding display elements compatible with the requirement to use the pilot as a stabilising device, an essential feature of such displays is the elimination of lags due either to data transmission or interpretation.

262. STEEP DESCENT LANDING SYSTEMS FOR VTOL AIRCRAFT
Kesselring C.B., (Los Angeles Airways, Inc., Los Angeles, Calif.). American Helicopter Society, Annual National Forum, 24th, Washington, D.C., May 8-10, 1968.

Description of an approach to a steep-descent landing system for VTOL aircraft. A brief background on instrument-flight experience to date is given, and the following three phases are covered: (1) present helicopter and flight techniques; (2) present helicopters manually operated by flight crews with approach equipment and procedures tailored to the performance of these helicopters; and (3) the next generation of VTOL aircraft and automatic coupling equipment throughout the flight regime, with the exception of flare and touchdown. All three phases discussed give definite consideration to passenger comfort, since no pressurized equipment is foreseen in the next generation of VTOL equipment.

263. STOL RIDE CONTROL FEASIBILITY STUDY
Thompson, G.O., Eslinger, D.L., Gordon, C.K., Dodson, R.O., Boeing Co., Presented at AIAA Guidance and Control Conference August, 1973.

A study to determine the feasibility of developing a ride smoothing control system for a passenger STOL aircraft has been performed for NASA Langley Research Center by Boeing-Wichita, with de Havilland Aircraft of Canada, Limited, as the principal subcontractor. The de Havilland DHC-6 Twin Otter was selected for the feasibility study, since it is the only STOL aircraft presently certificated and in use by a number of United States air carriers. The study indicated that a ride control system that significantly reduces vertical and lateral accelerations can be practically implemented on the Twin Otter with minimum airplane performance degradation. The system uses symmetrical ailerons, elevator, rudder and spoiler control surfaces with accelerometers and rate gyros for motions sensors.

264. STUDY OF PILOT-VEHICLE-CONTROLLER INTEGRATION FOR A MINIMUM COMPLEXITY AFCS
Johnston, D.E. Weird, D.H. Systems Technology Inc. Inglewood, Calif., Report No. TR 127 1; AD-451 500L July 64 AD-451 500L.

A brief analysis demonstrates the technique of, and potential payoffs accruing through, a preliminary design approach which views pilot. Vehicle, and automatic flight control system as an integrated system, the technique facilitates the establishment and assessment of successive stability augmentation systems and automatic flight control systems functional complexity levels and the selection of a final configuration. Justifiable by operational and handling quality information, which results in maximum benefit per unit cost. Cost is measured in terms of unreliability, maintenance, downtime, and dollar expenditures.

265. STUDY AND SIMULATION PROGRAM TO INVESTIGATE THE MECHANIZATION OF AN AIRCRAFT FLIGHT CONTROL SYSTEM THAT EMPLOYS DIRECT LIFT CONTROLS.
Chase, Thomas W., Falkner, Victor L.; Helfinstine, Robert , F., Honeywell Inc.; Aerospace Div. AD-335 101 TR-68-69-Vol.-1, June 1968.

This volume and volume II report the first phase of a one-year study and simulation program to investigate the benefits of direct lift control (DLC) in fixed-wing aircraft, a direct lift control produces lift without significant pitching moment. Study emphasis was on systems blending DLC with the elevator. To respond to a single manual control input. Blended DLC systems were designed for the C-5A. F-104, and XB-70 aircraft. Providing both improved short-period handling characteristics and gust alleviation. The DLC-Modified short-period performance violates some criteria developed for elevator-controlled aircraft. But not the C criterion. Optimal control theory was used to design automatic glide slope controllers for the C-5A.

266. SURVIVABLE FLIGHT CONTROL SYSTEM
Garrison, Charles P. Chief, Experimental Test Pilot, McDonnell Douglas Corporation, The Society of Experimental Test Pilots, 1972 Report to the Aerospace Profession, Sixteenth Symposium Proceedings, Sept. 28-30, 1972.

The concept of a fighter flight control system which will produce the "Best of All Worlds" has long been a design goal in the aerospace industry. The reliability/survivability of flight controls has been and will continue to be of prime concern; however, the additional capability to shape aircraft response, irrespective of inherent vehicle stability, looms as a significant contribution when the total task is examined from the Fly-By-Wire viewpoint. This paper is a Synopsis of:

- The initial SFCS design and flight test philosophy.
- A description of the test vehicle.
- Results of the flight test program to date.
- Concluding observations regarding the possible future of redundant, full authority, motion feedback control systems.

267. SURVIVABLE FLIGHT CONTROL SYSTEM COMPATIBILITY TEST PROGRAM.
Jeffrie, H.L. and Rolston, D. R. (McDonnell Aircraft Co., St. Louis, Mo.) American Institute of Aeronautics and Astronautics, Los Angeles, Calif., Aug. 7-9, 1972, Paper 72-761.

A test program was conducted to determine compatibility and operating characteristics of surviviable flight control system (SFCS) components which were developed for flight testing a three-axis, fly-by-wire flight control system in an F-4 aircraft. This paper presents a description of the SFCS hardware, test bed, and the digital computer program used to provide a high fidelity simulation of the aircraft. Pilots used the SFCS simulator to evaluate handling qualities over the entire F-4 flight regime. Results obtained from this program are compared with available flight data obtained during the SFCS flight test program.

268. SURVIVABLE FLIGHT CONTROL SYSTEM DEVELOPMENT PROGRAM.
Lorenzetti, Robert C. Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio Report No. FDC/ ADPO-TM-70-1 Jan. 70 AD-872 286.

The combination of redundant integrated servo actuator packages and a redundant dispersed fly-by-wire flight control system will provide the survivable flight control system, that is the goal of the advanced development program. Not only will aircraft survivability be improved in the face of a given quantity and quality of enemy fire. The improved handling qualities, precision control capability, and reduced pilot workload will combine to destroy a given target with given weapons with fewer passes through improved accuracy. Thus, exposure to hostile fire in performing a given task will be reduced, improving fleet, as well as individual aircraft survivability.

269. SURVIVABLE FLIGHT CONTROL SYSTEM, STUDIES, ANALYSES AND APPROACH
Hooker, David S., Kisslinger, Robert, L., Smith, George, R., and Sheppard, Smyth, May 1971, AFFDL-TR-20, AD-733582.

The Survivable Flight Control System (SFCS) Program is an advanced development program of which the principal objective is the development and flight test demonstration of an SFCS utilizing Fly-By-Wire and Integrated Actuator Package techniques. The studies and analyses-conducted to date have sufficiently defined the system requirements to provide a definition of an approach to the implementation of the SFCS. The results of these studies and the definition of the approach are presented.

270. SURVIVABLE FLIGHT CONTROL SYSTEM, STUDIES ANALYSES AND APPROACH. SUPPLEMENT FOR CONTROL CRITERIA STUDIES
Interim Report, Jul. 1969 May 1971. Kisslinger, Robert L., and Wendl, Michael J., Wright-Patterson AFB, Ohio. AFFDL, May 1971, AFFDL-TR-20-Suppl-1, AD-727762.

The Survival Flight Control System (SFCS) Program is an advanced development program of which the principal objective is the development and flight test demonstration of an SFCS utilizing fly-by-wire and integrated actuator package techniques. The studies and analyses conducted to date have sufficiently defined the system requirements to provide a definition of an approach to the implementation of the SFCS. The results of these studies and the definition of the approach are presented in the basic report. Details of the Control Law Development and Hydraulic Power Actuation studies are presented in report supplements 2 and 3, respectively. The results of the Control Criteria studies presented in this supplement.

271. SURVIVABLE FLIGHT CONTROL SYSTEM, STUDIES, ANALYSES AND APPROACH: SUPPLEMENT FOR CONTROL LAW DEVELOPMENT STUDIES.
Kisslinger, Robert, L.; Vetsch, George J., McDonnell Aircraft Co., AD-729 207 TR-71-20-Suppl.-2 May 1971.

The survivable flight control system (SFCS) program is an advanced development program of which the principal objective is the development and flight test demonstration of an SFCS utilizing fly-by-wire and integrated actuator package techniques. The studies and analyses conducted to date have sufficiently defined the system requirements to provide a definition of an approach to the implementation of the SFCS. The results of these studies and the definition of the approach are presented in the basic report. The details of the control criteria, and hydraulic power and actuation studies are presented in report supplements 1 and 3, respectively, The results of the control law development studies are presented in this supplement 2.

272. SURVIVALBE FLIGHT CONTROL SYSTEM, STUDIES, ANALYSES AND APPROACH: SUPPLEMENT FOR HYDRAULIC POWER AND ACTUATION STUDIES.
Interim Report, Jul. 1969. May 1971. Armies, Gerald, E., Cecil, Clark, Jones, Charles L., and Sheppard, M. Smyth, Wright-Patterson AFB, Ohio, AFFDL, 29 Oct. 1971, AFFDL-TR-20-20-Suppl-3, AD-727763.

The Survivable Flight Control System (SFCS) Program is an advanced development program of which the principal objective is the development and flight test demonstration of an SFCS utilizing Fly-By-Wire and Integrated Actuator Package techniques. The studies and analyses conducted to date have sufficiently defined the system requirements to provide a definition of an approach to the implementation of the SFCS. The results of these studies and the definition of the approach are presented in the basic report. The details of the Control Criteria and Control Law Development studies are presented in report supplements 1 and 2, respectively. The details of the Hydraulic Power and Actuation studies are reported in the supplement 3.

273. SURVIVABLE FLIGHT CONTROL SYSTEM PROGRAM. SIMPLEX ACTUATOR PACKAGE. Hooker, David S., Kisslinger, Robert L., Sheppard, M., Smyth, McDonnell Aircraft Co., St. Louis, Mo., Nov. 70. AD-877 615

The survivable flight control system (SFCS) program is an advanced development program of which the principal objective is the development and flight test demonstration of an SFCS utilizing fly-by-wire and integrated actuator package techniques. Phase 1, which includes the installation, ground and flight testing of a simplex integrated actuator package (simplex package) powering the stabilator of an F-4 aircraft is described. The simplex package was designed and manufactured by Ling-Temco-Vought, electrosystems, Arlington, Texas, under contract to the Air Force Flight dynamics laboratory, the package was furnished to McDonnell Aircraft Company for laboratory check out, installation in an F-4 aircraft, and flight testing to verify the 'get home-and-land' capability provided by the integral emergency hydraulic system. Several minor package redesigns were required prior to flight testing, due to problems uncovered by MCAIR laboratory testing. Results of the flight testing verify the simplex package concept as a feasible design technology for increasing the probability of aircraft survival following loss of central hydraulic system power.

274. SYMPOSIUM ON TEST AND EVALUATION OF AUTOMATIC CONTROL SYSTEMS, SAINT MARY'S COLLEGE OF MARYLAND, SAINT MARY'S CITY, MD. August 31-September 2, 1971, Technical Papers. Symposium sponsored by the Society of Flight Test Engineers., California, Md., 1971.

The papers deal with an automatic approach and hover coupler for a helicopter the flight testing of an automatic carrier landing system, the status of the "Omega" system and its applications to airborne navigation, the use of photogrammetrics in flight testing a navigation system, and simplified criteria for optimization and evaluation of control augmented aircraft aiming performance. Also treated are flight test evaluation of terrain-following concepts for helicopters, wind tunnel investigations of a closed-loop fludic bidirectional jet flap control system for airfoil lift modulation, a variable stability program, a versatile flight control system for a V/STOL flight test program, test and field MTBF of a flight control system, test and evaluation of an automatic drone flight control system, flight test evaluations of a back-up flight control system, and open-loop control systems for external compression engine air inlets. Individual items are abstracted in this issue.

275. SYNTHESIS AND ANALYSIS OF A FLY-BY-WIRE CONTROL SYSTEM FOR AN F-4 AIRCRAFT
Kisslinger, R.L., Vetch, G.J., McDonnell Aircraft Company, 72-022,
August 1972.

276. A SYSTEMS ANALYSIS OF MANUAL CONTROL TECHNIQUES AND DISPLAY ARRANGEMENTS FOR INSTRUMENT LANDING APPROACHES IN HELICOPTERS,Vol. I, Speed and Height Regulation.
Clement, Warren F., Hofmann, Lee G., TR-183-1 July 1969.
A comprehensive theory for displays used in manual control systems is applied to the instrument-landing approach problem for helicopters. A single-articulated-rotor transport and a compound rigid-rotor attack helicopter serve as examples. A comparative analysis of manual control techniques for speed and height regulation in the approach is given. Suitable display arrangements and task performance are predicted for the better control techniques. The applications of the theory incorporate recent revisions for predicting eye scanning patterns, workload measures and preferred arrangements for combined displays as well as separated instruments. Results show how display combinations which enhance the usefulness of parafoveal perception can reduce scanning workload. Other immediate applications of the theory and areas for future research are suggested.

277. TACTICAL AIRCRAFT GUIDANCE SYSTEM ADVANCED DEVELOPMENT PROGRAM.
CAE Electronics LTD Montreal (Quebec) February 72 AD-894 99L.
This report discusses work accomplished during the system definition phase of the tactical aircraft guidance system (TACS) advanced development program. The report contains a detailed description of an advanced flight control concept design to be implemented in a tags-equipped CH-47B helicopter. The analytical design process. Including the use of various forms of simulation as design and evaluation tools is discussed. A description of analytical work and engineering evaluation leading to the definition of system and subsystem requirements is included, rationales are presented for significant engineering decisions made during the process of system definition, the report concludes that sufficient system and subsystem definition activity has been accomplished to permit detailed subsystem.

278. TACTICAL AIRCRAFT GUIDANCE SYSTEM ADVANCED DEVELOPMENT PROGRAM.
CAE Electronics LTD Montreal (Quebec) AD-906 617L October 72.
This report discusses work accomplished during the system development phase of the tactical aircraft guidance system (tags) advanced development program. The report contains a description of the changes to the flight control concept design which have occurred during this phase and which are to be implemented in a tags-equipped CH-47B helicopter, a description of changes to hardware design since the release of subsystem specifications and the impact of these changes on the system performance is given. The tests which have been performed at various levels of integration are described, and the outcome of these tests is discussed. Aircraft modifications to accommodate the tags system are described and discussed. The report concludes that sufficient system development activity has been accomplised to permit flight test to proceed.

279. TELEVISED GRAPHIC DISPLAYS FOR STEEP APPROACH-TO-LANDING RESEARCH.
Elkins, H.C. Hatfield, J.J., Soc. for Info. Dis. Paper to 11th National Symposium 1970

280. TEST AND DEVELOPMENT OF FLIGHT CONTROL ACTUATION SYSTEM COMPONENTS FOR MILITARY AIRCRAFT.
Jenney, Gavin, D. Hydraulic Research and MFG Co., Valencia, Calif., July 71, AD-893 662L.
NAK integrated package laboratory tests; B-47 FBW pumping module evaluation: actuator gunfire vulnerability evaluation: Flow difference sensor continued evaluation life testing: Flow difference sensor continued evaluation gunfire testing: Flow difference sensor continued evaluation contamination sensitivity: Flow difference sensor continued evaluation detection level improvement: Active load system actuator test rig: Evaluation of simplex integrated actuator package: Duplex package evaluation; hydraulic fluid contamination research: input-output reundancy investigation.

281. TEST AND EVALUATION OF AUTOMATIC CONTROL SYSTEMS
Russell, R.A., Paper presented at SFTE Symp., Aug. 31-Sept.2, 1971.

282. THE THEORETICAL PERFORMANCE OF OPTIMISED GLIDE-PATH CONTROLLERS FOR THE COMET IIIB.
Robinson, P. Fry, D.E. Royal Aircraft Establishment, Farnborough (England) Report No. RAE-TR-71095 May 71 AD-901 435.
Two experimental glide-path controllers have been designed for the comet IIIB aircraft. Using a parametric optimisation procedure. Their theoretical performance in the presence of all known disturbance is discussed in detail and compared with that of a controller currently in use with this aircraft. Both controllers show considerable theoretical improvements in beam holding. Particularly with respect to turbulence, in which an improvement of 5:1 in the RMS height error and 2:1 in the RMS velocity error is attained at the end of the approach. Further improvement in performance is known to be restricted by the limitations of the comet power control equipment.

283. THE TOTAL SYSTEMS CONCEPT FOR CATEGORY III OPERATIONS
Stout, Clifford L., Engineering Test Pilot and All-Weather Project Pilot, and Naish, Michael Ph.D., Advanced Visual Displays, Douglas Aircraft Division, McDonnell Douglas Corporation, The Society of Experimental Test Pilots, 1967 Report to the Aerospace Profession, Eleventh Symposium Proceedings, Sept. 28-30, 1967.
In the next few years airlines and aircraft manufactures will, by necessity, increase their indivual capabilities in developing all-weather landing systems. The benefits derived from a fully optimized autoland and associated systems package may, besides improving scheduled reliability, enhance the overall safety of day-to-day operations. Accordingly, guide lines for establishing design concepts for meeting performance criteria with the required redundancy are needed to properly advance the technology at a pace equal to the

demand and importance of the task. The majority of the all-weather landing systems evaluated to date are conceptually defined as fail passive, fail steady or fail operational. Fault survival capability is generally established primarily by the amount and type of "in line" monitoring and in the final analysis by the degree of equipment redundancy. This paper is intended to provide information derived from CAT III all-weather flight tests. A further purpose is to illustrate the importance of providing additional intelligence to the pilot to assure a secondary source of redundancy and to promote crew acceptability of fully automatic landing and roll out guidance systems.

284. TRENDS IN HELICOPTER GUIDANCE AND CONTROL SYSTEMS WITH BAD WEATHER CAPABILITY

Metzdorff, W., Dornier Post (English Edition), No. 3. A73-13921, 1972.

As the helicopter displays unfavorable natural flight characteristics in hover flight and the low transition range, and as these characteristics are subject to change over the entire flight envelope, the control performance by the pilot no longer meets the increasing difficulties of the missions. Also, the human control performance available is reduced by bad weather, since data acquisition from instruments places a heavier workload on the pilot than direct visibility. The control performance necessary for an operational military helicopter guidance and control system must be made good by technical control systems. Attention is given to dynamic response to disturbances, handling response, guidance, and technical design of integrated mechanical and electronic control systems.

285. THE TRUE PERSPECTIVE PATH IN THE SKY, AT APPROACH TO AIRCRAFT NAVIGATION.

Russa, J. L. and Baurr, M. C. (Farrand Opitical Co., Inc., Valhalla, N.Y.). Electro-Optical Systems Design Conference, New York, N.Y., September 14-16, 1971 Proceedings Chicago, Industrial and Scientific Conference Managements, Inc., 1971, A72-32026-15-16.

Description of a head-up display system that provides a true three-dimensional sky path extending from the aircraft to any desired location such as a touchdown point on a runway. This display literally enables the pilot to 'drive' the aircraft down to a landing. Actual airspeed, desired airspeed, steering errors, crab angle, roll attitude, pitch attitude, angle of attack, runway outline, and an artificial horizon are all provided as picture analogs thereby reducing interpretation time. Computer units, the CRT display system, and image generating subsystems are outlines.

286. AN ULTRA-LOW POWER RADAR DISPLAY USING A DIGITALLY-ADDRESSED ELECTRON BEAM SWITCHING TECHNIQUE

Goede, W.F. presented at 1971 Soc. for Info. Display Int'l Symp., May 1971

287. A UNIVERSAL DIGITAL AUTOPILOT AND INTEGRATED AVIONICS SYSTEM
Rouse, William E., Sperry Rand Corp.

The paper describes a system that was developed to perform navigation, guidance, control and pilot-interface flight experiments in a variety of flight research vehicles. Emphasis placed on versatility and growth potential induced selection of an integrated digital system using modern avionics components. The system performs all computation for time-constrained navigation, guidance, control and display in a general-purpose computer. Methods for conserving computation time while maintaining easy performance modification are described. Cockpit display flexibility was achieved by using cathode-ray-tube units; one is used to present a complex moving map. Description of, and some results from, the inertially smoothed navigation technique are given. The system architecture was chosen such that the system is transferable to any new mission by changing only the computer software, and to any new flight vehicle by changing computer software and flight control interface.

288. THE USE OF ELECTRIC SIGNAL TRANSMISSION IN AIRCRAFT FLIGHT CONTROL SYSTEMS
Harle, T.F., et al Joint conference on the Importance of Electricity in the Control of Aircraft.

289. UTILITY OF THE VERTICAL CONTACT-ANALOG DISPLAY FOR CARRIER LANDINGS-A DIAGNOSTIC EVALUATION.
Cross, K.D.; Cavallero, F.R., AGARD, Paper to Conference on Guidance and Control Display Oct. 1971.

290. THE VALUE OF A HEAD-UP DISPLAY WHEN LANDING A LARGE AIRCRAFT
Armstrong, B.D., M. of A. RAA TR o9236 Oct. 1969.

This Report undertakes a critical review of the situations in which a collimated head-up display of cockpit information might be useful to the pilot of a large aircraft during the approach and landing manoeuvre. The analysis was attempted because of a need to streamline the BLEU work on head-up display, and it has been used as a basis for the setting of priorities in research; but the arguments developed seem to be of general interest to the civil airline and military transport pilot community.

291. THE "VARSITY" G-ARFP - A FLYING TEST BENCH FOR THE DEVELOPMENT OF AUTOMATIC LANDING
K. Fearnside (S. Smiths and Sons/England/, Ltd., Smiths Aviation A, Wembley, Middx., England). Jan.-Feb. 1965, In French.

Description of the modified Varsity aircraft and of the equipment carried for the purpose of developing a "second generation" system of flight control for automatic landing. The aircraft was chosen for the work because, although it has low approach and landing speeds, it is easily controllable and docile.

thus allowing the crew to devot most of their attention to monitoring the automatic control system. Various modifications were made in the interior layout, the brading system, and the autopilot. The radio installation comprises three vhf transceivers, two marker beacon receivers, three radio altimeters, three leader cable receivers, a TACAN receiver, a Doppler transceiver, and an intercom system. The automatic flight control system, its current supply, its subsystems, and the recording systems are described.

292. VERY MUCH IN THE FUTURE-BOEING 2707 FLIGHT-DECK PROPOSALS
Gannett, J.R. (Boeing Co., Supersonic Transport Div., Seattle, Wash.). Flight International, vol. 92, Dec. 21, 1967.
Discussion of the various requirements for improved instrumentation with respect to the total flight profile of the Boeing 2707. Proposals for instrumentation needed for safe taxiing, for high-resolution pitch-attitude information, and for information concerning en route climb, en route cruise, descent, approach, and landing operations are considered.

293. A VISUAL FLIGHT LANDING APPROACH AIR
Boeing Co., Seattle, Wash. Glover, J.H. 29 Oct. 1968, (AD-858191L; IDEP-428.04.40.70-C6-01: D6-23712-TN) CSCL 1/5
It is recognized that large transport aircraft such as the 747 may possibly, because of their large dimensions and inertia, require pilots to pay closer attention to flight path control during manual landing approaches in visual flight conditions than current aircraft. The feasibility of reducing pilot work-load by providing displayed flight path information was examined, and practicable techniques and display hardware were evaluated. Three possible techniques for implementing the computational hardware necessary to provide signals to the display are described and an experimental computer was constructed which incorporates all three of these techniques. This computer, together with a prototype optical display unit was installed in a 727 airplane.

294. V/STOL CONTROLS AND DISPLAYS
Howard, R. W., Elliot Flight Automation Ltd., Interavia, February 1971.
The multi-fan lift engine VTOL aircraft will require a complex flight control system, to augment the aircraft's inherently poor handling qualities during the ascent, hover and descent operating regimes. However, the automatic flight control system requirements for both STOL and VTOL are not expected to present any severe difficulties and are seen to be well encompassed by the present state of the art. In the case of VTOL, the complexity of the aircraft and its systems will result in a great increase in the volume of data required to be presented to the crew. The flexibility of the new rastergraphic displays makes them very suitable for this task. It is also possible that the recent advent of both head-up and head-down displays combined with the flexibility in approach speeds and approach angles possible with STOL and VTOL aircraft may allow "pilot-in-the-loop" directed take-off and landings to be acceptable for all weather operations.

295. V/STOL CONTROL-DISPLAY SYSTEM REQUIREMENTS AND SIMULATION STUDY
Hainesworth, T.E. Lukuso, R., Fellinger, J., Hardwick, F.R., Lensing,L., Lear Siegler Inc. Grand Rapids, Mich. Instrument Division, AD-470 958 July 65

A preliminary control-display investigation of the hover and transition flight phases of a tactical, high speed V/STOL aircraft was conducted using a fixed-base dynamic simulator. A lift-cruise engine configuration with thrust deflection was studied. Analysis included hover/landing displays: Translation control systems: altitude control systems; automatic flight control systems; and individual flight data parameters including-mach number. Angle of attack, indicated airspeed, attitude, side-slip angle, absolute and barometric altitude, altitude rate, and engine thrust. The ability to make IFR touchdowns at a specific point was emphasized and glide path angles from 3 to 15 degrees were investigated.

296. V/STOL DISPLAYS FOR APPROACH AND LANDING
AGARD, AD-746 744 AGARD-R-594 July 1972.

The report documents the findings and opinions of a working group tasked with considering how V/STOL aircraft displays should be designed to ensure effective approach and landing manoeuvres in all types of weather, general requirements are argued for both aircraft operations and display content. Current display techniques are considered and some specific display formats are compared. Finally, a key selection of research and development topics is made.

297. V/STOL DISPLAYS FOR APPROACH AND LANDING, A PRESENTATION OF THE JANAIR PROGRAM
Lyon, H.B., AFFDL May 1970

298. V/STOL FLIGHT CONTROL-TREND AND REQUIREMENTS.
Brammer, K. and Metzdorff W. (Dornier AG, Friedrichshafer, West Germany). Airport Forum, June 1972.

Discussion of some of the design problems of all-weather flight control and guidance systems for V/STOL aircraft. Discussed topics include mission and flight path profiles, VTOL and STOL flight characteristics, weather minima, flight safety, pilot's capacity limits, and control information display. Special attention is given to VTOL landing and touchdown navigation systems, and speed measurement and guidance computer subsystems. VTOL control laws and the reliability problem are also discussed.

299. V/STOL HEAD UP DISPLAY WORK
At Royal Aircraft Establishment, Martin, F.P., Office of Naval Research, London AD-849-115, Rept. ONRL-M-4-69 March 1969

300. V/STOL VERTICAL SITUATION DISPLAY
Bondurant, R.A. III; Kearns, J.H. III, Paper presented at SAE NASE Meeting #690694, Oct. 1969.

The capability of V/STOL aircraft to fly an assortment of approach and landing flight profiles dictated the need for a display that presents pilot situation information in the vertical plane. This work describes the development of a display system known as the Flight Profile Indicator (FPI) designed to provide this information in a manner analogous to that of the USAF Horizontal Situation Indicator (HSL). The FPL is a CRT device that displays the geometrical relationship between the parameters necessary to determine the aircraft situation in the vertical plane. The significant advantage of the FPR is that minimizes the pilot's need to interpret various kinds of vertical situation information presently available on aircraft instrument panels and provides a more rapid, accurate, and easier assessment of the aircraft status and flight progress in the vertical plane. It is not intended to replace existing guidance and control information, but will complement current and projected navigational aids and displays.

301. VTOL DISPLAYS AND CONTROLS FOR ALL-WEATHER FLIGHT
Cundari, F. L., Nicholson, R. M., Gurman, B.S., Baker, C.A., AGARD, Conference Proceedings No. 55, Paper No. 19 1968

302. VTOL FLIGHT CONTROL IN 1980
Tribken, E.R. (Sperry Rand Corp., Sperry Flight Systems Div., Phoenix, Ariz.) and Dendy, John, C. (Sperry Rand Corp., Sperry Flight Systems Div., Engineering Section, Phoenix, Ariz.). American Institute of Aeronautics and Astronautics, Washington, D.C., Feb. 12-14, 1968, Paper 68-192.

The paper forecasts the type of flight control system which will be used for VTOL aircraft in 1980. It arrives at this forecast by first treating in some detail the VTOL flight control system of the early 1970s. From this a projection of the 1980 system is made. Treatment of the 1970 system separates commercial from military usages. The application, design, and impact of fly-by-wire systems are discussed, as is flight control system integration. Projections for the 1980 era include auto navigation in high-density areas and multipath automatic approach control. Advanced implementation concepts are described, and tradeoffs are provided. The 1980 system is forecasted both by extending the concepts of the 1970 system as well as by forecasting extensions in related technolies such as path sensors.

303. VTOL FLIGHT INVESTIGATION TO DEVELOP A DECELERATING INSTRUMENT APPROACH CAPABILITY
Garren, John, F., Jr., Kelly, James, R., and Sommer, Robert W., (NASA), Washington, D.C.). Society of Automotive Engineers, National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angles, Calif., Oct. 6-10, 1969, Paper 690693.

The inability of available situation displays to provide an instrument approach capability decelerating to a hover led to a flight research program in which control command information was displayed for three degrees of freedom. The test aircraft was stablized with a high gain attitude command system. Using this system, the pilot was able to decelerate the aircraft to a hover while simultaneously following a 6 deg glidepath. Although these tests demonstrate the potential of this concept, several factors, including adequate integration of command and situation information, were identified as affecting pilot acceptance of the system.

304. VTOL IFR TECHNOLOGY PROGRAM
Kearns, J.H., Bondurant, R.A., AGARD Committee Paper 58, N69-20381, Sept. 1968.

The program is concerned with achieving an instrument flight rule (IFR) operational capability for VTOL weapon systems in a manner which macimizes flight safety for the pilot. The stress is on design requirements and criteria associated with the transition and hover regions of flight. Development of the necessary control-display-guidance technology is outlined; the principle of the control-display concept is that the pilot is an active element of the control loop at all times. This is achieved through the use of the force steering concept. A computer provides command information to both the pilot and the autopilot. The CH-3C helicopter used for inflight research two ground-based helicopter simulators, the Pilot Factors Program (PIFAX) for defining pilot control-display requirements and instrumentation used in the program are briefly described.

305. YAW SAS YAW AUTOPILOT, AND AUTO-THROTTLE ANALYSIS DIAGRAMS
Carlso , D.N. Honeywell, August 13, 1971.

## APPENDIX B

## SUBJECT INDEX

### I ELECTRONIC FLIGHT CONTROL DISPLAYS

| Index No. | Title |
|---|---|
| 2 | ADVANCED CONTROL SYSTEM CONCEPTS |
| 6 | ADVANCED MANNED STRATEGIC AIRCRAFT (AMSA). TASK 5-7. CONTROL DISPLAY REPORT |
| 9 | ADVANCES IN V/STOL COCKPIT INFORMATION |
| 10 | AIRCRAFT DISPLAYS FOR STEEP ANGLE APPROACHES |
| 15 | AIRCRAFT LANDING SYSTEMS CONFERENCE PROCEEDINGS |
| 31 | ANALYSIS AND PRELIMINARY DESIGN OF AN ADVANCED TECHNOLOGY TRANSPORT AIRCRAFT FLIGHT CONTROL SYSTEM, VOL. I |
| 34 | APPLICATION OF THE HEAD-UP DISPLAY/HUD/TO A COMMERCIAL JET TRANSPORT |
| 43 | BIBLIOGRAPHY OF THE JOINT ARMY-NAVY AIRCRAFT INSTRUMENTATION RESEARCH PROGRAM |
| 50 | COLOR CATHODE RAY INSTRUMENTS ENHANCE DISPLAY SYSTEMS |
| 59 | CONTROL TECHNIQUE AND FLIGHT QUALITY OF NEW GENERATION AIRCRAFT |
| 76 | DEVELOPMENT AND EVALUATION OF A TWO-COLOR ELECTROLUMINESCENT V/STOL HOVER DISPLAY |
| 85 | A DIGITALLY-ADDRESSED FLAT PANEL CART |
| 87 | DISPLAYS FOR APPROACH AND LANDING OF V/STOL AIRCRAFT |
| 88 | DISPLAY INSTRUMENTATION FOR V/STOL AIRCRAFT IN LANDING |
| 89 | DISPLAYS FOR APPROACH AND LANDING OF V/STOL AIRCRAFT, AGARD |
| 90 | DISPLAY SYSTEMS FOR VERTICAL TAKEOFF TRANSPORT AIRCRAFT |
| 91 | EADI/MFD ID PROGRAM |

| Index No. | Title |
|---|---|
| 95 | ELECTRONIC ATTITUDE DIRECTOR DEVELOPMENT FOR THE SST |
| 96 | ELECTRONIC ATTITUDE DISPLAY INDICATORS |
| 99 | EVALUATION OF A CLOSED-CIRCUIT TELEVISION DISPLAY IN LANDING OPERATIONS WITH A HELICOPTER |
| 100 | EVALUATION OF A CONTACT-ANALOG DISPLAY IN LANDING APPROACHES WITH A HELICOPTER |
| 103 | EVALUATION OF A MOVING-GRAPH INSTRUMENT DISPLAY FOR LANDING APPROACHES WITH A HELICOPTER |
| 104 | EVALUATION OF A VTOL FLIGHT-DIRECTOR CONCEPT DURING CONSTANT-SPEED INSTRUMENT APPROACHES |
| 105 | EVOLUTION OF THE ELECTRONIC HEAD-UP DISPLAY |
| 108 | AN EXPERIMENTAL EVALUATION OF AIRCRAFT DISPLAYS FOR IFR STEEP ANGLE APPROACHES |
| 109 | EXPERIMENTAL TESTING OF FLIGHT-CONTROL HEAD-UP DISPLAYS |
| 114 | FLIGHT CONTROLS |
| 115 | FLIGHT-CONTROL HEAD-UP DISPLAY |
| 120 | FLIGHT CONTROL TECHNIQUES FOR ADVANCED COMMERCIAL TRANSPORTS |
| 121 | FLIGHT DIRECTOR DESIGN FOR STOL AIRCRAFT |
| 123 | FLIGHT EVALUATIONS OF THE EFFECT OF ADVANCED CONTROL SYSTEMS AND DISPLAYS ON THE HANDLING QUALITIES OF A GENERAL AVIATION AIRPLANE |
| 126 | FLIGHT INVESTIGATION OF VTOL CONTROL AND DISPLAY CONCEPT FOR PERFORMING DECELERATING APPROACHES TO AN INSTRUMENT HOVER |
| 127 | FLIGHT MANAGEMENT CONCEPTS |
| 130 | FLIGHT SYSTEMS, FLIGHT DECK DISPLAY AND AUTOMATIC FLIGHT CONTROL |
| 142 | THE FUTURE OF ELECTRONIC DISPLAYS |
| 145 | HEAD-UP DISPLAY FOR AIRLINES |
| 146 | HEAD-UP DISPLAY STUDY |

| Index No. | Title |
|---|---|
| 148 | HELICOPTER COCKPIT INSTRUMENTATION SYSTEM (HCIS) |
| 149 | HELICOPTER IFR FLIGHT PATH CONTROL SYSTEM |
| 150 | HIGHLY RELIABLE VERTICAL DISPLAY SYSTEM |
| 152 | HOLOGRAPHY IN AN AIRBORNE DISPLAY SYSTEM |
| 156 | IFR STEEP ANGLE APPROACH: EFFECTS OF SYSTEM NOISE AIRCRAFT CONTROL AUGMENTATION VARIABLES |
| 157 | THE IMPACT OF ELECTRONIC DISPLAYS ON AIRCRAFT CONTROL |
| 163 | INFORMATION TRANSFER IN ALL-WEATHER OPERATION |
| 165 | INSTRUMENT CAPABILITIES SURVEY HELICOPTER PIFAX PROGRAM CDG-PF-8 |
| 166 | INSTRUMENT-PANEL ELECTRONIC DISPLAY SYSTEM |
| 167 | AN INTEGRATED APPROACH TO THE STEEP DESCENT PROBLEM |
| 168 | AN INTEGRATED DISPLAY CONCEPT FOR HELICOPTERS AND VTOL AIRCRAFT |
| 169 | INTEGRATED DISPLAY PRINCIPLES AND SOME APPLICATIONS TO V/STOL AIRCRAFT |
| 170 | INTEGRATED INFORMATION PRESENTATION AND CONTROL SYSTEM STUDY, VOL. 1, SYSTEM DEVELOPMENT CONCEPTS |
| 171 | AN INTERIM NOTE ON THE DEVELOPMENT OF A BLIND GROUND ROLL SYSTEM IN A COMET 3B AIRCRAFT |
| 172 | INTERPRETABILITY OF SYMBOLS IN A HEAD-UP DISPLAY |
| 177 | AN INVESTIGATION OF THE NEED FOR IMPROVED DISPLAYS IN HEAVY-LIFT HELICOPTERS |
| 198 | NATIONAL SUPERSONIC TRANSPORT PROGRAM CONTROL DISPLAY PILOT FACTORS PROGRAM, INSTRUMENT PILOT INSTRUCTOR SCHOOL RANDOLPH AFB, TEX. |
| 209 | A NOVEL DIGITALLY ADDRESSED ELECTRON BEAM SCANNER FOR ADVANCE SENSOR AND DISPLAY APPLICATIONS |
| 212 | AN OPTIMAL CONTROL METHOD FOR PREDICTING CONTROL CHARACTERISTICS AND DISPLAY REQUIREMENT OF MANNED-VEHICLE SYSTEMS |

| Index No. | Title |
|---|---|
| 224 | PILOT PERFORMANCE WITH A SIMULATED ILS INDEPENDENCE PICTORIAL DISPLAY |
| 230 | THE PRINCETON PENNSYLVANIA ARMY AVIONICS RESEARCH PROGRAM |
| 231 | PROBLEMS OF THE COCKPIT ENVIRONMENT |
| 239 | RECENT DEVELOPMENTS IN LOW-COST HEAD-UP |
| 251 | A SIMPLIFIED KALMAN ESTIMATOR FOR AN AIRCRAFT LANDING DISPLAY |
| 252 | SIMULATED FLIGHT TESTS OF A DIGITALLY AUTOPILOTED STOL-CRAFT ON A CURVED APPROACH WITH SCANNING MICROWAVE GUIDANCE |
| 254 | A SIMULATOR COMPARISON BETWEEN TWO METHODS OF COMPUTING AND DISPLAYING THE VELOCITY IN A HEAD-UP DISPLAY FOR LOW SPEED FLIGHTPATH CONTROL |
| 255 | SOME ASPECTS OF THE DISPLAY CONFIGURAITON OF MODERN AIRCRAFT |
| 259 | SOME THOUGHTS ON V/STOL DISPLAYS AND APPROACH TECHNIQUES |
| 261 | STABILITY AND CONTROL FOR INSTRUMENT FLIGHT |
| 262 | STEEP DESCENT LANDING SYSTEMS FOR VTOL AIRCRAFT |
| 276 | A SYSTEMS ANALYSIS OF MANUAL CONTROL TECHNIQUES AND DISPLAY ARRANGEMENTS FOR INSTRUMENT LANDING APPROACHES IN HELICOPTERS |
| 279 | TELEVISED GRAPHIC DISPLAYS FOR STEEP APPROACH-TO-LANDING RESEARCH |
| 290 | THE VALUE OF A HEAD-UP DISPLAY WHEN LANDING A LARGE AIRCRAFT |
| 292 | VERY MUCH IN THE FUTURE-BOEING 2707 FLIGHT-DECK PROPOSALS |
| 293 | A VISUAL FLIGHT LANDING APPROACH AIR |
| 294 | V/STOL CONTROLS AND DISPLAYS |
| 295 | V/STOL CONTROL-DISPLAY SYSTEM REQUIREMENTS AND SIMULATION STUDY |
| 296 | V/STOL DISPLAYS FOR APPROACH AND LANDING |
| 297 | V/STOL DISPLAYS FOR APPROACH AND LANDING A PRESENTATION OF THE JANAIR PROGRAM |
| 299 | V/STOL HEAD-UP DISPLAY WORK |
| 300 | V/STOL VERTICAL SITUATION DISPLAY |

## II ELECTRONIC NAVIGATIONAL GUIDANCE DISPLAYS

| Index NO. | Title |
|---|---|
| 6 | ADVANCED MANNED STRATEGIC AIRCRAFT (AMSA), TASK 5-7, CONTROL DISPLAY REPORT |
| 8 | ADVANCES IN HELICOPTER AVIONICS |
| 9 | ADVANCES IN V/STOL COCKPIT INFORMATION |
| 15 | AIRCRAFT LANDING SYSTEMS CONFERENCE PROCEEDINGS |
| 22 | AIR TRAFFIC NAVIGATION DISPLAY CONSIDERATIONS FOR THE DESIGN OF AN ONBOARD AIR TRAFFIC SITUATION DISPLAY |
| 31 | ANALYSIS AND PRELIMINARY DESIGN OF AN ADVANCED TECHNOLOGY TRANSPORT AIRCRAFT FLIGHT CONTROL SYSTEM |
| 36 | AREA NAVIGATION SYSTEMS AND DISPLAYS |
| 43 | BIBLIOGRAPHY OF THE JOINT ARMY-NAVY AIRCRAFT INSTRUMENTATION RESEARCH PROGRAM |
| 44 | A "BUILDING BLOCK" APPROACH TO INTEGRATED NAVIGATION DISPLAYS |
| 46 | CATHODE RAY-TUBE CENTERED HSI |
| 50 | COLOR CATHODE-RAY INSTRUMENTS ENHANCE DISPLAY SYSTEMS |
| 54 | CONCEPT PAPER FOR AN INTEGRATED FLIGHT CONTROL AND NAVIGATION SYSTEM FOR THE EUROPLANE PROGRAM |
| 61 | CONTROL WHEEL CONSOLES FOR CONTROL-DISPLAY MODE SELECTION SWITCHING |
| 80 | DEVELOPMENT OF STOL AND A VERSATILE NAVIGATION, GUIDANCE AND CONTROL SYSTEM |
| 83 | DIGITAL FLIGHT CONTROL TECHNOLOGY ROADMAP |
| 85 | A DIGITALLY-ADDRESSED FLAT PANEL CART |
| 91 | EADI/MFD ID PROGRAM |
| 92 | EFFICIENT FLIGHT MANAGEMENT - A STEP FORWARD IN FLIGHT SAFETY |
| 114 | FLIGHT CONTROLS |
| 120 | FLIGHT CONTROL TECHNIQUES FOR ADVANCE COMMERCIAL TRANSPORTS |

| Index No. | Title |
|---|---|
| 127 | FLIGHT MANAGEMENT CONCEPTS |
| 142 | THE FUTURE OF ELECTRONIC DISPLAYS |
| 148 | HELICOPTER COCKPIT INSTRUMENTATION SYSTEM (HCIS) |
| 149 | HELICOPTER IFR FLIGHT PATH CONTROL SYSTEM |
| 157 | THE IMPACT OF ELECTRONIC DISPLAYS ON AIRCRAFT CONTROL |
| 166 | INSTRUMENT-PANEL ELECTRONIC DISPLAY SYSTEM |
| 168 | AN INTEGRATED DISPLAY CONCEPT FOR HELICOPTERS AND VTOL AIRCRAFT |
| 169 | INTEGRATED DISPLAY PRINCIPLES AND SOME APPLICATIONS TO V/STOL AIRCRAFT |
| 170 | INTEGRATED INFORMATION PRESENTATION AND CONTROL SYSTEM STUDY, VOL. 1, SYSTEM DEVELOPMENT CONCEPTS |
| 185 | LANDING GUIDANCE FOR VTOL AIRCRAFT |
| 198 | NATIONAL SUPERSONIC TRANSPORT PROGRAM CONTROL DISPLAY PILOT FACTORS PROGRAM, INSTRUMENT PILOT INSTRUCTOR SCHOOL, RANDOLPH AFB, TEX. |
| 199 | NAVIGATION GUIDANCE, AND CONTROL SYSTEMS FOR V/STOL AIRCRAFT ORDER |
| 203 | NEW DEVELOPMENTS IN SCANNING BEAM LANDING GUIDANCE SYSTEMS |
| 204 | A NEW GUIDANCE SYSTEM FOR APPROACH AND LANDING |
| 207 | NON-VISUAL PRECISION APPROACH AND LANDING |
| 212 | AN OPTIMAL CONTROL METHOD FOR PREDICTING CONTROL CHARACTERISTICS AND DISPLAY REQUIREMENTS OF MANNED-VEHICLE SYSTEMS |
| 214 | OPTIMAL 3-DIMENSIONAL MINIMUM TIME TURNS FOR AN AIRCRAFT |
| 215 | PAPERS AND DISCUSSION BY A GROUP OF PANELISTS ON: STEEP LANDINGS SYSTEMS FOR VTOL AIRCRAFT |
| 218 | PENNSYLVANIA-PRINCETON ARMY AVIONICS RESEARCH PROGRAM. COMPUTER ACTIVATOR INSTRUMENTATION DISPLAY |
| 228 | THE PRESENTATION OF NAVIGATIONAL INFORMATION |
| 231 | PROBLEMS OF THE COCKPIT ENVIRONMENT |

| Index No. | Title |
|---|---|
| 238 | RADAR INDEPENDENT LANDING MONITORS |
| 248 | RESULTS OF THE INVESTIGATION OF DIFFERENT EXTRAPOLATION DISPLAYS |
| 253 | SIMULATION EVALUATION OF FLIGHT COMMAND FUNCTIONS |
| 254 | A SIMULATOR COMPARISON BETWEEN TWO METHODS OF COMPUTING AND DISPLAYING THE VELOCITY IN A HEAD-UP DISPLAY FOR LOW SPEED FLIGHT PATH CONTROL |
| 255 | SOME ASPECTS OF THE DISPLAY CONFIGURATION OF MODERN AIRCRAFT |
| 264 | STUDY OF PILOT-VEHICLE-CONTROLLER INTEGRATION FOR A MINIMUM COMPLEXITY AFCS |
| 277 | TACTICAL AIRCRAFT GUIDANCE SYSTEM ADVANCED DEVELOPMENT PROGRAM |
| 278 | TACTICAL AIRCRAFT GUIDANCE SYSTEM ADVANCED DEVELOPMENT PROGRAM |
| 284 | TRENDS IN HELICOPTER GUIDANCE AND CONTROL SYSTEMS WITH BAD WEATHER CAPABILITY |
| 285 | THE TRUE PERSPECTIVE PATH IN THE SKY, AT APPROACH TO AIRCRAFT NAVIGATION |
| 286 | AN ULTRA-LOW POWER RADAR DISPLAY USING A DIGITALLY-ADDRESSED ELECTRON BEAM SWITCHING TECHNIQUE |
| 287 | A UNIVERSAL DIGITAL AUTOPILOT AND INTEGRATED AVIONICS SYSTEM |
| 294 | V/STOL CONTROLS AND DISPLAYS |
| 295 | V/STOL CONTROL-DISPLAY SYSTEM REQUIREMENTS AND SIMULATION STUDY |
| 299 | V/STOL HEAD-UP DISPLAY WORK |
| 301 | VTOL DISPLAYS AND CONTROLS FOR ALL-WEATHER FLIGHT |

## III HUMAN FACTORS

| Index No. | Title |
|---|---|
| 25 | ALL-WEATHER LANDING FLIGHT DIRECTOR AND FAULT WARNING DISPLAY SIMULATOR STUDIES |
| 28 | ANALYSIS OF HUMAN FACTORS DATA FOR ELECTRONIC FLIGHT DISPLAY SYSTEMS |
| 30 | ANALYSIS OF PILOT SURVEY ON V/STOL APPROACHES AND LANDING |
| 48 | COCKPIT EQUIPMENT |
| 49 | COCKPIT WARNING SYSTEM COMPARATIVE STUDY |
| 53 | A COMPUTER-GENERATED DISPLAY TO ISOLATE ESSENTIAL VISUAL CUES IN LANDING |
| 56 | CONTROL PROBLEMS IN THE CASE OF VTOL AIRCRAFT WITH SPECIAL ALLOWANCE FOR MAN AS PART OF THE CONTROL SYSTEM |
| 57 | CONTROL PROBLEMS IN VTOL AIRCRAFT TAKING PARTICULAR ACCOUNT OF MAN AS A LINK IN THE CONTROL LOOP |
| 98 | ENHANCEMENT OF HUMAN EFFECTIVENESS IN SYSTEM DESIGN, TRAINING, AND OPERATION |
| 106 | EXPERIMENTAL DISPLAY REFERENCED FLIGHT CONTROL SYSTEM WITH AUTOMATIC TAKEOFF ROTATION AND CLIMBOUT |
| 121 | FLIGHT DIRECTOR DESIGN FOR STOL AIRCRAFT |
| 125 | A FLIGHT INVESTIGATION OF SYSTEMS DEVELOPED FOR REDUCING PILOT WORKLOAD AND IMPROVING TRACKING ACCURACY DURING NOISE-ABATEMENT LANDING APPROACHES |
| 127 | FLIGHT MANAGEMENT CONCEPTS |
| 153 | HUMAN ENGINEERING FOR THE AIR FORCE CONTROL DISPLAY PROGRAM |
| 154 | HUMAN ENGINEERING PILOT FACTORS PROGRAM |
| 156 | IFR STEEP ANGLE APPROACH: EFFECTS OF SYSTEM NOISE AIRCRAFT CONTROL AUGMENTATION VARIABLES |
| 162 | THE INFLUENCE OF A PREDICTION DISPLAY ON THE HUMAN TRANSFER CHARACTERISTICS |

| Index No. | Title |
|---|---|
| 174 | AN INVESTIGATION OF ADVANCED PILOTS VERTICAL DISPLAY TECHNIQUES |
| 190 | MANUAL AND AUTOMATIC LANDING SYSTEM TERMINAL CONTROL THEORY, SYSTEM INTEGRATION CONCEPTS. FLIGHT TEST RESULTS, AND FUTURE DEVELOPMENTS |
| 191 | MANUAL DIGITAL POSITIONING IN 2 AXES - A COMPARISON OF JOYSTICK AND TRACK BALL CONTROLS |
| 221 | PILOT/AUTOMATIC-RELATIONS, CONFIDENCE, DISPLAYS |
| 222 | A PILOT's LOOK AT AIRCRAFT INSTRUMENTATION |
| 224 | PILOT PERFORMANCE WITH A SIMULATED ILS INDEPENDENCE PICTORIAL DISPLAY |
| 227 | PREDICTION OF HUMAN OPERATOR PERFORMANCE IN THE DESIGN OF COMMAND AND CONTROL SYSTEMS |
| 228 | THE PRESENTATION OF NAVIGATIONAL INFORMATION |
| 231 | PROBLEMS OF THE COCKPIT ENVIRONMENT |
| 233 | PROCEEDINGS OF THE FLY-BY-WIRE FLIGHT CONTROL SYSTEM CONFERENCE |
| 248 | RESULTS OF THE INVESTIGATION OF DIFFERENT EXTRAPOLATION DISPLAYS |
| 249 | THE ROLE OF THE TEST PILOT IN EVALUATING AUTO LANDING SYSTEMS (PARTS I AND II) |
| 261 | STABILITY AND CONTROL FOR INSTRUMENT FLIGHT |
| 276 | A SYSTEMS ANALYSIS OF MANUAL CONTROL TECHNIQUES AND DISPLAY ARRANGEMENTS FOR INSTRUMENT LANDING APPROACHES IN HELICOPTERS |
| 292 | VERY MUCH IN THE FUTURE-BOEING 2707 FLIGHT-DECK PROPOSALS |

## IV ADVANCED FLIGHT CONTROLS

| Index No. | Title |
|---|---|
| 1 | ADVANCED ACTIVE CONTROLS TECHNOLOGY |
| 2 | ADVANCED CONTROL SYSTEM CONCEPTS |
| 3 | ADVANCED CONTROLS TECHNOLOGY |
| 4 | ADVANCED FLIGHT CONTROL SYSTEM CONCEPTS FOR VTOL AIRCRAFT |
| 5 | ADVANCED FLIGHT CONTROL SYSTEMS POWER-BY-WIRE AND FLY-BY-WIRE |
| 6 | ADVANCED MANNED STRATEGIC AIRCRAFT (AMSA). TSSK 5-7, CONTROL DISPLAY REPORT |
| 7 | ADVANCED TECHNOLOGY TRANSPORT CONFIGURATION |
| 11 | AIRCRAFT DYNAMICS AND AUTOMATIC CONTROL |
| 12 | AIRCRAFT FLIGHT CONTROL SYSTEMS FIELD SAFETY EXPERIENCE |
| 15 | AIRCRAFT LANDING SYSTEMS CONFERENCE PROCEEDINGS |
| 16 | AIRCRAFT PERFORMANCE BENEFITS FROM MODERN CONTROL SYSTEMS TECHNOLOGY |
| 17 | AIRCRAFT PERFORMANCE BENEFITS FROM MODERN CONTROL SYSTEMS TECHNOLOGY |
| 18 | AIRCRAFT PERFORMANCE ENHANCEMENT THROUGH AUTOMATIC CONTROL |
| 19 | AIRCRAFT SIMULATION APPLICATION TO THE DEVELOPMENT OF THE CONCORDE PROJECT |
| 20 | AIR FORCE EVALUATION OF THE B-52G AND H PROTOTYPE STABILITY AUGMENTATION AND FLIGHT CONTROL SYSTEM |
| 27 | ANALOG SIMULATION OF AUTOMATIC GLIDE SLOPE CONTROL USING WING LIFT SPOILERS AS DIRECT LIFT CONTROL |
| 31 | ANALYSIS AND PRELIMINARY DESIGN OF AN ADVANCED TECHNOLOGY TRANSPORT AIRCRAFT FLIGHT CONTROL SYSTEM |
| 32 | ANALYSIS OF V/STOL FLIGHT CONTROL SYSTEM CONCEPTS AS RELATED TO OPERATIONAL EFFECTIVENESS |
| 37 | ATC AND LANDING AIDS FOR VTOL AIRCRAFT |

| Index No. | Title |
|---|---|
| 40 | AUTOMATIC LANDING SYSTEMS FOR ALL-WEATHER OPERATION BY CIVIL TRANSPORT AIRCRAFT |
| 41 | AUTOMATIC LANDING SYSTEMS MECHANIZATION - SERIES OR PARALLEL SERVOS? |
| 42 | BELL COMMERCIAL AUTOMATIC FLIGHT CONTROL SYSTEM DESIGN AND TEST |
| 51 | COMBAT CAPABILITIES AND VERSATILITY THROUGH CCV |
| 52 | COMMAND AUGMENTATION - DIGITAL FLIGHT CONTROL EVALUATION |
| 54 | CONCEPT PAPER FOR AN INTEGRATED FLIGHT CONTROL AND NAVIGATION SYSTEM FOR THE EUROPLANE PROGRAM |
| 56 | CONTROL PROBLEMS IN THE CASE OF VTOL AIRCRAFT WITH SPECIAL ALLOWANCE FOR MAN AS PART OF THE CONTROL SYSTEM |
| 57 | CONTROL PROBLEMS IN VTOL AIRCRAFT TAKING PARTICULAR ACCOUNT OF MAN AS A LINK IN THE CONTROL LOOP |
| 58 | CONTROL STUDY FOR ADVANCED SUPERSONIC TRANSPORT |
| 60 | CONTROL THEORY RESEARCH (FINAL SCIENTIFIC REPORT) |
| 62 | CRITICAL ANALYSIS OF B-52 STABILITY AUGMENTATION AND FLIGHT CONTROL SYSTEMS FOR IMPROVED STRUCTURAL LIFE. PART I. INITIAL FEASIBILITY STUDY |
| 63 | DESIGN AND DEVELOPMENT OF THE PRIMARY FLY-BY-WIRE FLIGHT CONTROL SYSTEM FOR THE XV-4B V/STOL RESEARCH AIRCRAFT |
| 64 | DESIGN CRITERIA FOR HIGH-AUTHORITY CLOSED-LOOP PRIMARY FLIGHT CONTROL SYSTEMS |
| 65 | DESIGN CRITERIA FOR HIGH-AUTHORITY CLOSED-LOOP PRIMARY FLIGHT CONTROL SYSTEMS |
| 66 | DESIGN OF ELASTIC MODE SUPPRESSION SYSTEMS FOR RIDE QUALITY IMPROVEMENT AND APPLICATION TO AN SST |
| 67 | DESIGN AND EVALUATION OF MINIATRURE CONTROL SURFACE ACTUATION SYSTEMS FOR AEROELASTIC MODELS |
| 68 | DESIGN OF FIXED GAIN COMPENSATOR SYSTEM FOR THE LONGITUDINAL AXIS OF THE C-141 FLY-BY-WIRE AIRCRAFT |

| Index No. | Title |
|---|---|
| 69 | DESIGN AND FLIGHT EXPERIENCE WITH A DIGITAL FLY-BY-WIRE CONTROL SYSTEM IN AN F-8 AIRPLANE |
| 70 | DESIGN AND FLIGHT EXPERIENCE WITH A DIGITAL FLY-BY-WIRE CONTROL SYSTEM USING APOLLO GUIDANCE SYSTEM HARDWARE ON AN F-8 AIRCRAFT |
| 71 | A DESIGN PROCEDURE AND HANDLING QUALITY CRITERIA FOR LATERAL-DIRECTIONAL FLIGHT CONTROL SYSTEMS |
| 72 | DESIGNS TO REDUCE AIRCRAFT FLIGHT CONTROL VULNERABILITY |
| 77 | DEVELOPMENT AND FLIGHT TEST OF A DIGITAL FLY-BY-WIRE F-8 AIRPLANE |
| 78 | DEVELOPMENT OF A GYROLESS DIGITAL FLIGHT DIRECTOR |
| 79 | THE DEVELOPMENT OF AN INTEGRATED FLIGHT GUIDANCE AND CONTROL SYSTEM FOR MODERN HIGH-PERFORMANCE AIRCRAFT |
| 80 | DEVELOPMENT OF STOL AND, A VERSATILE NAVIGATION, GUIDANCE AND CONTROL SYSTEM |
| 81 | DFCS DESIGN REPORT III |
| 8[illegible] | DIGITAL FLIGHT CONTROL SYSTEM (DFCS) INTERFACE DEFINITIONS |
| 83 | DIGITAL FLIGHT CONTROL TECHNOLOGY ROADMAP |
| 84 | DIGITAL FLY-BY-WIRE NEARS LAUNCH |
| 86 | DIRECT LIFT CONTROL FOR THE LAMS B-52 |
| 93 | ELECTRICAL INTERCONNECTIONS FOR FLY-BY-WIRE FLIGHT CONTROL SYSTEMS |
| 97 | ELECTRONIC FLIGHT CONTROL GETTING SET TO TAKEOFF |
| 107 | EXPERIMENTAL ELECTRONIC CIRCUITS FOR AN INTEGRATED MANOEUVRE DEMAND FLIGHT CONTROL SYSTEM |
| 110 | AN EXPLORATORY STUDY OF FLYING QUALITIES OF VERY LARGE SUBSONIC TRANSPORT AIRCRAFT IN LANDING APPROACH |
| 111 | FACTORS IN STOL FLIGHT CONTROL CONFIGURATION |
| 112 | FIGHTER FLIGHT CONTROL SYSTEM DESIGN CONSIDERATIONS |
| 113 | FLIGHT CONTROL |

| Index No. | Title |
|---|---|
| 114 | FLIGHT CONTROLS |
| 116 | FLIGHT CONTROLS DAMP BIG AIRCRAFT BENDING |
| 117 | FLIGHT CONTROL SYSTEM MECHANIZATION |
| 118 | A FLIGHT CONTROL SYSTEM PROVIDING A SIMPLE-TO-FLY, CONSTANT ATTITUDE AIRCRAFT |
| 119 | A FLIGHT CONTROL SYSTEM FOR STOL AIRCRAFT |
| 120 | FLIGHT CONTROL TECHNIQUES FOR ADVANCED COMMERCIAL TRANSPORTS |
| 123 | FLIGHT EVALUATIONS OF THE EFFECT OF ADVANCED CONTROL SYSTEMS AND DISPLAYS ON THE HANDLING QUALITIES OF A GENERAL AVIATION AIRPLANE |
| 128 | FLIGHT PATH CONTROL SYSTEM CONCEPT, EVALUATION AND APPLICATION |
| 129 | FLIGHT RESEARCH CENTER FLY-BY-WIRE FLIGHT-TEST PROGRAM |
| 130 | FLIGHT SYSTEMS, FLIGHT DECK DISPLAY AND AUTOMATIC FLIGHT CONTROL |
| 131 | FLIGHT TEST RESULTS OF A TRAILING EDGE FLAP DESIGNED FOR DIRECT LIFT CONTROL |
| 132 | FLIGHT TESTING STRUCTURAL PERFORMANCE OF THE LAMS FLIGHT CONTROL SYSTEM |
| 134 | FLY-BY-WIRE |
| 135 | FLY-BY-WIRE FOR COMBAT AIRCRAFT FLIGHT INTERNATIONAL |
| 136 | FLY-BY-WIRE CONTROL SYSTEM |
| 137 | FLY-BY-WIRE FLIGHT CONTROL SYSTEMS |
| 138 | THE FLY-BY-WIRE SYSTEMS APPROACH TO AIRCRAFT FLYING QUALITIES |
| 139 | FLY-BY-WIRE TECHNOLOGY |
| 140 | FLY-BY-WIRE TECHNIQUES |
| 141 | FUTURE NAVAL AIRCRAFT SUBSYSTEM/AADC INTERFACE DEFINITION FOR OPERATIONAL AND OBC REQUIREMENTS (VOL. 1) |
| 143 | GUIDANCE AND CONTROL PHILOSOPHY FOR ALL-WEATHER LANDING |

| Index No. | Title |
|---|---|
| 144 | A G AND C REDUNDANCY MANAGEMENT CONCEPT FOR SPACE SHUTTLE VEHICLES |
| 151 | HLF PRIMARY FLIGHT CONTROL SYSTEM DESIGN |
| 155 | IDENTIFICATION AND OPTIMIZATION OF AIRCRAFT DYNAMICS |
| 173 | INTRODUCTION AND SUMMARY (LAMS) |
| 176 | AN INVESTIGATION OF DIRECT SIDEFORCE CONTROL FOR IMPROVING MANEUVER CAPABILITY OF ATTACK AIRCRAFT |
| 178 | JB-47F FLY-BY-WIRE FLIGHT TEST PROGRAM |
| 180 | LAMS B-52 FLIGHT EXPERIMENTS IN DIRECT LIFT CONTROL |
| 181 | LAMS FLIGHT CONTROL SYSTEM ANALYSIS AND DESIGN |
| 182 | LAMS FLIGHT DEMONSTRATION |
| 183 | LAMS - A TECHNOLOGY TO CONTROL AIRCRAFT STRUCTURAL MODES |
| 184 | LAMS TEST VEHICLE MODIFICATION AND SYSTEM TESTS |
| 188 | LINEAR OPTIMAL THEORY APPLIED TO ACTIVE STRUCTURAL BENDING CONTROL |
| 189 | LONGITUDINAL ANALYSIS OF TWO CCV DESIGN CONCEPTS |
| 190 | MANUAL AND AUTOMATIC LANDING SYSTEM TERMINAL CONTROL THEORY, SYSTEM INTEGRATION CONCEPTS, FLIGHT TEST RESULTS, AND FUTURE DEVELOPMENTS |
| 191 | MANUAL DIGITAL POSITIONING IN 2 AXES - A COMPARISON OF JOYSTICK AND TRACK BALL CONTROL |
| 192 | A METHOD FOR ESTABLISHING INSTRUMENT APPROACH LIMITATIONS FOR HELICOPTERS |
| 193 | MORE NOTES ON THE ESTABLISHMENT OF AIRCRAFT APPROACH LIMITATIONS FOR HELICOPTERS |
| 194 | MULTIPLE LOOP CONTROL OF THE F-8C DURING A POWER APPROACH, PHASE II-ANALOG SIMULATION WITH PILOT MODEL |
| 195 | MULTIPLEX ELECTROHYDRAULIC SYSTEM FOR FLY-BY-WIRE ACTUATORS, WITH MAJORITY VOTING AND PRESSURE LOGIC |
| 196 | NASA FLIGHT RESEARCH CENTER FLY-BY-WIRE FLIGHT TEST PROGRAM |

| Index No. | Title |
|---|---|
| 197 | NASA GETS SHUTTLE 'LANDING' DATA |
| 198 | NATIONAL SUPERSONIC TRANSPORT PROGRAM CONTROL DISPLAY PILOT FACTORS PROGRAM, INSTRUMENT PILOT INSTRUCTOR SCHOOL, RANDOLPH AFB, TEX. |
| 199 | NAVIGATION GUIDANCE, AND CONTROL SYSTEMS FOR V/STOL AIRCRAFT ORDER |
| 200 | NAVY DIGITAL FLIGHT CONTROL SYSTEM DEVELOPMENT |
| 201 | A NEW CONCEPT IN AUTOMATIC FLIGHT CONTROL |
| 202 | NEW CONTROLS TO SHAPE FUTURE AIRCRAFT |
| 205 | NEW METHODS IN ADAPTIVE FLIGHT CONTROL |
| 208 | NOTES ON THE APPLICATION OF REDUNDANT SERVO SYSTEMS FOR AEROSPACE VEHICLES |
| 209 | A NOVEL DIGITALLY ADDRESSED ELECTRON BEAM SCANNER FOR ADVANCE SENSOR AND DISPLAY APPLICATIONS |
| 210 | OPTIMAL CONTROL |
| 211 | OPTIMAL CONTROL OF THE F-8C IN A FULLY AUTOMATIC POWER APPROACH, PHASE I - POSITIONING AIRFRAME POLES |
| 212 | AN OPTIMAL CONTROL METHOD FOR PREDICTING CONTROL CHARACTERISTICS AND DISPLAY REQUIREMENTS OF MANNED-VEHICLE SYSTEMS |
| 213 | OPTIMAL PATHS FOR MINIMIZING LANDING TRANSITION DISTANCE FOR JET-LIFT VTOL AIRCRAFT |
| 216 | PARALLEL PROCESSOR STUDY, WESTINGHOUSE ELECTRIC CORP., BALTIMORE, MD., AEROSPACE AND ELECTRONIC SYSTEMS DIVISION |
| 217 | PAYOFFS AND PROBLEMS OF FLY-BY-WIRE CONTROL SYSTEMS |
| 218 | PENNSYLVANIA-PRINCETON ARMY AVIONICS RESEARCH PROGRAM. COMPUTER ACTIVATOR INSTRUMENTATION DISPLAY |
| 219 | PERFORMANCE ADVANTAGES OFFERED BY ADVANCED FLIGHT CONTROL TECHNOLOGY |
| 220 | THE PERFORMANCE BENEFITS DERIVED FOR THE SST THROUGH A NEW APPROACH TO STABILITY AUGMENTATION |

| Index No. | Title |
|---|---|
| 226 | A PRACTICAL OPTIMIZATION DESIGN PROCEDURE FOR STABILITY AUGMENTATION SYSTEMS |
| 229 | PRIMARY FLIGHT CONTROL CIRCUIT DEVELOPMENT FROM MECHANICAL SYSTEMS TO AN ALL-ELECTRIC DIGITAL SIGNALLING SYSTEM |
| 233 | PROCEEDINGS OF THE FLY-BY-WIRE FLIGHT CONTROL SYSTEM CONFERENCE |
| 234 | PROJECT PLAN FOR THE DIGITAL FLY-BY-WIRE EXPERIMENTAL PROGRAM |
| 235 | A PROTOTYPE FLY-BY-WIRE FLIGHT CONTROL SYSTEM |
| 236 | A PROTOTYPE FLY-BY-WIRE FLIGHT CONTROL SYSTEM |
| 240 | REDUNDANCE MANAGEMENT FOR FLY-BY-WIRE SYSTEMS |
| 241 | THE RELIABILITY OF FLIGHT CONTROLS |
| 242 | RELIABILITY AND REDUNDANCE STUDY FOR ELECTRONIC FLIGHT CONTROL SYSTEMS |
| 243 | GENERAL DYNAMICS/FORT WORTH, TEX., RESEARCH INTO THE DEFINITION AND DEMONSTRATION OF AN OPTIMUM SOLID STATE SWITCHING AND MULTIPLEXING SYSTEM FOR USE IN A FLY-BY-WIRE FLIGHT CONTROL SYSTEM |
| 244 | RESEARCH AND DEVELOPMENT PROGRAMS OF THE FLIGHT CONTROL DIVISION, AF FLIGHT DYNAMICS LABORATORY |
| 245 | RESEARCH AND DEVELOPMENT PROGRAMS OF THE FLIGHT CONTROL DIVISION, AF FLIGHT DYNAMICS LABORATORY |
| 246 | RESEARCH ON FLIGHT CONTROL SYSTEMS, VOL. II, FLY-BY-WIRE B-47, PHASES II AND III |
| 247 | RESEARCH ON FLIGHT CONTROL SYSTEMS, VOL. 3 |
| 252 | SIMULATED FLIGHT TESTS OF A DIGITALLY AUTOPILOTED STOL-CRAFT ON A CURVED APPROACH WITH SCANNING MICROWAVE GUIDANCE |
| 256 | SOME EFFECTS OF BIAS ERRORS IN REDUNDANT FLIGHT CONTROL SYSTEMS |
| 257 | SOME PROBLEMS IN THE DEVELOPMENT OF AN ADVANCED INTEGRATED FLIGHT CONTROL SYSTEM FOR STOL-APPROACH |
| 260 | SST TECHNOLOGY FOLLOW-ON PROGRAM, PHASE I. TEST AND ANALYSIS OF A QUADRUPLE REDUNDANT HORIZONTAL STABILIZER ACTUATION SYSTEM |

| Index No. | Title |
|---|---|
| 261 | STABILITY AND CONTROL FOR INSTRUMENT FLIGHT |
| 263 | STOL RIDE CONTROL FEASIBILITY STUDY |
| 265 | STUDY AND SIMULATION PROGRAM TO INVESTIGATE THE MECHANIZATION OF AN AIRCRAFT FLIGHT CONTROL SYSTEM THAT EMPLOYS DIRECT LIFT CONTROLS |
| 266 | SURVIVABLE FLIGHT CONTROL SYSTEM |
| 267 | SURVIVABLE FLIGHT CONTROL SYSTEM COMPATIBILITY TEST PROGRAM |
| 268 | SURVIVABLE FLIGHT CONTROL SYSTEM DEVELOPMENT PROGRAM |
| 269 | SURVIVABLE FLIGHT CONTROL SYSTEM, STUDIES, ANALYSES, AND APPROACH |
| 270 | SURVIVABLE FLIGHT CONTROL SYSTEM, STUDIES ANALYSES AND APPROACH, SUPPLEMENT FOR CONTROL CRITERIA STUDIES |
| 271 | SURVIVABLE FLIGHT CONTROL SYSTEM, STUDIES, ANALYSES AND APPROACH, SUPPLEMENT FOR CONTROL LAW DEVELOPMENT |
| 272 | SURVIVABLE FLIGHT CONTROL SYSTEM, STUDIES, ANALYSES AND APPROACH, SUPPLEMENT FOR HYDRAULIC POWER AND ACTUATION STUDIES |
| 273 | SURVIVABLE FLIGHT CONTROL SYSTEM PROGRAM, SIMPLEX ACTUATOR PACKAGE |
| 274 | SYMPOSIUM ON TEST AND EVALUATION OF AUTOMATIC CONTROL SYSTEMS, SAINT MARY'S COLLEGE OF MARYLAND, SAINT MARY'S CITY, MD |
| 275 | ANALYSIS OF A FLY-BY-WIRE FLIGHT CONTROL SYSTEM FOR AN F-4 AIRCRAFT |
| 277 | TACTICAL AIRCRAFT GUIDANCE SYSTEM ADVANCED DEVELOPMENT PROGRAM |
| 278 | TACTICAL AIRCRAFT GUIDANCE SYSTEM ADVANCED DEVELOPMENT PORGRAM |
| 280 | TEST AND DEVELOPMENT OF FLIGHT CONTROL ACTUATION SYSTEM COMPONENTS FOR MILITARY AIRCRAFT |
| 281 | TEST AND EVALUATION OF AUTOMATIC CONTROL SYSTEMS |
| 288 | THE USE OF ELECTRIC SIGNAL TRANSMISSION IN AIRCRAFT FLIGHT CONTROL SYSTEMS |
| 298 | V/STOL FLIGHT CONTROL-TREND AND REQUIREMENT |
| 302 | VTOL FLIGHT CONTROL IN 1980 |
| 304 | VTOL IFR TECHNOLOGY PROGRAM |

## V APPROACH AND LANDING

| Index No. | Title |
|---|---|
| 10 | AIRCRAFT DISPLAYS FOR STEEP ANGLE APPROACHES |
| 11 | AIRCRAFT DYNAMICS AND AUTOMATIC CONTROL |
| 13 | AIRCRAFT LANDING CONTROL AUTOMATION |
| 14 | AIRCRAFT LANDINGS, DDC, AD-523 400, DDC-TAS-72-49 |
| 15 | AIRCRAFT LANDING SYSTEMS CONFERENCE PROCEEDINGS |
| 21 | AIRPLANE AND SYSTEMS CONFIGURATIONS DEVELOPED FOR THE NOISE ABATEMENT LANDING APPROACH TASK |
| 23 | AIR TRANSPORT 1969 (VOZDUSHNYI TRANSPORT 1969) |
| 24 | ALL-WEATHER CARRIER LANDING SYSTEM AIRBORNE SUBSYSTEM, GENERAL REQUIREMENTS FOR |
| 25 | ALL-WEATHER LANDING FLIGHT DIRECTOR AND FAULT WARNING DISPLAY SIMULATOR STUDIES |
| 26 | ALL-WEATHER LANDING SYSTEM, VOL. 1, RESULTS OF FLIGHT |
| 27 | ANALOG SIMULATION OF AUTOMATIC GLIDE SLOPE CONTROL USING WING LIFT SPOILERS AS DIRECT LIFT CONTROL |
| 29 | AN ANALYSIS OF LONGITUDINAL CONTROL DURING LANDING APPROACH |
| 30 | ANALYSIS OF PILOT SURVEY ON V/STOL APPROACHES AND LANDING |
| 31 | ANALYSIS AND PRELIMINARY DESIGN OF AN ADVANCED TECHNOLOGY TRANSPORT AIRCRAFT FLIGHT CONTROL SYSTEM |
| 33 | THE APPLICATION OF CORRELATION ILS TECHNIQUES TO TERMINAL AREA TRAFFIC CONTROL |
| 35 | APPROACH GUIDANCE TO CIRCULAR FLIGHT PATHS |
| 38 | AUTOMATED LANDING SYSTEM |
| 39 | AUTOMATIC LANDING SYSTEM 727 AIRPLANE |

| Index No. | Title |
|---|---|
| 40 | AUTOMATIC LANDING SYSTEMS FOR ALL-WEATHER OPERATION BY CIVIL TRANSPORT AIRCRAFT |
| 41 | AUTOMATIC LANDING SYSTEMS MECHANIZATION - SERIES OR PARALLEL SERVOS? |
| 45 | C-5A CATEGORY I ENGINEERING FLIGHT TEST AUTOMATIC FLIGHT CONTROL SYSTEM TEST RESULTS |
| 52 | COMMAND AUGMENTATION - DIGITAL FLIGHT CONTROL EVALUATION |
| 53 | A COMPUTER-GENERATED DISPLAY TO ISOLATE ESSENTIAL VISUAL CUES IN LANDING |
| 55 | CONTROL EQUIPMENT OF AIRCRAFT |
| 56 | CONTROL PROBLEMS IN THE CASE OF VTOL AIRCRAFT WITH SPECIAL ALLOWANCE FOR MAN AS PART OF THE CONTROL SYSTEM |
| 57 | CONTROL PROBLEMS IN VTOL AIRCRAFT TAKING PARTICULAR ACCOUNT OF MAN AS A LINK IN THE CONTROL LOOP |
| 59 | CONTROL TECHNIQUE AND FLIGHT QUALITY OF NEW GENERATION AIRCRAFT |
| 73 | THE DESIGN OF STABILITY AUGMENTATION SYSTEMS FOR DECOUPLING AIRCRAFT RESPONSES |
| 74 | DEVELOPMENT OF DC-10 AUTOMATIC LANDING MONITOR |
| 75 | DEVELOPMENT AND EVALUATION OF A FLIGHT DIRECTOR SYSTEM FOR INSTRUMENT LANDINGS |
| 76 | DEVELOPMENT AND EVALUATION OF A TWO-COLOR ELECTROLUMINESCENT V/STOL HOVER DISPLAY |
| 87 | DISPLAYS FOR APPROACH AND LANDING OF V/STOL AIRCRAFT |
| 88 | DISPLAY INSTRUMENTATION FOR V/STOL AIRCRAFT IN LANDING |
| 89 | DISPLAYS FOR APPROACH AND LANDING OF V/STOL AIRCRAFT |
| 90 | DISPLAY SYSTEMS FOR VERTICAL TAKEOFF TRANSPORT AIRCRAFT |
| 94 | ELECTRONICS IN ALL-WEATHER OPERATIONS |
| 99 | EVALUATION OF A CLOSED-CIRCUIT TELEVISION DISPLAY IN LANDING OPERATIONS WITH A HELICOPTER |

| Index No. | Title |
|---|---|
| 100 | EVALUATION OF A CONTACT-ANALOG DISPLAY IN LANDING APPROACHES WITH A HELICOPTER |
| 101 | EVALUATION OF FLIGHT DIRECTOR ELEMENTS-RISING RUNWAY, EXPANDED LOCALIZER, AND ROLLOUT STEERING DURING SIMULATED CATEGORY 3-C MANUAL AND SPLIT-AXIS LANDINGS |
| 102 | EVALUATION OF AN INTEGRATED FLIGHT DISPLAY FOR THE MANUAL IFR-LANDING OF VTOL AIRCRAFT |
| 103 | EVALUATION OF A MOVING-GRAPH INSTRUMENT DISPLAY FOR LANDING APPROACHES WITH A HELICOPTER |
| 104 | EVALUATION OF A VTOL FLIGHT-DIRECTOR CONCEPT DURING CONSTANT-SPEED INSTRUMENT APPROACHES |
| 108 | AN EXPERIMENTAL EVALUATION OF AIRCRAFT DISPLAYS FOR IFR STEEP ANGLE APPROACHES |
| 110 | AN EXPLORATORY STUDY OF FLYING QUALITIES OF VERY LARGE SUBSONIC TRANSPORT AIRCRAFT IN LANDING APPROACH |
| 113 | FLIGHT CONTROL |
| 114 | FLIGHT CONTROLS |
| 119 | A FLIGHT CONTROL SYSTEM FOR STOL AIRCRAFT |
| 120 | FLIGHT CONTROL TECHNIQUES FOR ADVANCED COMMERCIAL TRANSPORTS |
| 121 | FLIGHT DIRECTOR DESIGN FOR STOL AIRCRAFT |
| 122 | A FLIGHT EVALUATION OF CURVED LANDING APPROACHES |
| 123 | FLIGHT EVALUATIONS OF THE EFFECT OF ADVANCED CONTROL SYSTEMS AND DISPLAYS ON THE HANDLING QUALITIES OF A GENERAL AVIATION AIRPLANE |
| 125 | A FLIGHT INVESTIGATION OF SYSTEMS DEVELOPED FOR REDUCING PILOT WORKLOAD AND IMPROVING TRACKING ACCURACY DURING NOISE-ABATEMENT LANDING APPROACHES |
| 126 | FLIGHT INVESTIGATION OF VTOL CONTROL AND DISPLAY CONCEPT FOR PERFORMING DECELERATING APPROACHES TO AN INSTRUMENT HOVER |
| 133 | FLIGHT TESTS UNDER IFR WITH A STOL TRANSPORT AIRCRAFT |
| 143 | GUIDANCE AND CONTROL PHILOSOPHY FOR ALL-WEATHER LANDING |

| Index No. | Title |
|---|---|
| 145 | HEAD-UP DISPLAY FOR AIRLINES |
| 147 | HELICOPTER ALL-WEATHER OPERATION - EQUIPMENT FOR THE TRANSPORT ROLE |
| 156 | IFR STEEP ANGLE APPROACH: EFFECTS OF SYSTEM NOISE AIRCRAFT CONTROL AUGMENTATION VARIABLES |
| 158 | INERTIAL SYSTEMS AS SENSORS FOR FLIGHT CONTROL |
| 159 | IN-FLIGHT INVESTIGATION OF AN UNAUGMENTED CLASS III AIRCRAFT IN THE LANDING APPROACH TASK, PHASE I - LATERAL-DIRECTIONAL |
| 160 | AN IN-FLIGHT INVESTIGATION OF LATERAL-DIRECTIONAL DYNAMICS FOR THE LANDING APPROACH |
| 161 | IN-FLIGHT INVESTIGATION FOR AN UNAUGMENTED CLASS III AIRPLANE IN THE LANDING APPROACH TASK. PHASE II - LONGITUDINAL STUDY |
| 163 | INFORMATION TRANSFER IN ALL-WEATHER OPERATION |
| 164 | INITIAL ASSESSMENT OF THE AUTOLAND PERFORMANCE |
| 165 | INSTRUMENT CAPABILITIES SURVEY HELICOPTER PIFAX PROGRAM CDG-PF-8 |
| 167 | AN INTEGRATED APPROACH TO THE STEEP DESCENT PROBLEM |
| 171 | AN INTERIM NOTE ON THE DEVELOPMENT OF A BLIND GROUND ROLL SYSTEM IN A COMET 3B AIRCRAFT |
| 175 | INVESTIGATION OF DATA RATE REQUIREMENTS FOR LOW VISIBILITY APPROACH WITH A SCANNING BEAM LANDING GUIDANCE SYSTEM |
| 179 | LABORATORY LANDING |
| 185 | LANDING GUIDANCE FOR VTOL AIRCRAFT |
| 186 | LANDING VTOL AIRCRAFT IN ADVERSE CONDITIONS AND SOME POSSIBLE SOLUTIONS |
| 187 | LANDING VTOL AIRCRAFT IN ALL WEATHER |
| 190 | MANUAL AND AUTOMATIC LANDING SYSTEM TERMINAL CONTROL THEORY, SYSTEM INTEGRATION CONCEPTS. FLIGHT TEST RESULTS, AND FUTURE DEVELOPMENTS |

| Index No. | Title |
|---|---|
| 192 | A METHOD FOR ESTABLISHING INSTRUMENT APPROACH LIMITATIONS FOR HELICOPTERS |
| 193 | MORE NOTES ON THE ESTABLISHMENT OF AIRCRAFT APPROACH LIMITATIONS FOR HELICOPTERS |
| 194 | MULTIPLE LOOP CONTROL OF THE F-8C DURING A POWER APPROACH, PHASE II - ANALOG SIMULATION WITH PILOT MODEL |
| 197 | NASA GETS SHUTTLE 'LANDING' DATA |
| 203 | NEW DEVELOPMENTS IN SCANNING BEAM LANDING GUIDANCE SYSTEMS |
| 204 | A NEW GUIDANCE SYSTEM FOR APPROACH AND LANDING |
| 207 | NON-VISUAL PRECISION APPROACH AND LANDING GUIDANCE SYSTEMS |
| 213 | OPTIMAL PATHS FOR MINIMIZING LANDING TRANSITION DISTANCE FOR JET-LIFT VTOL AIRCRAFT |
| 215 | PAPERS AND DISCUSSION BY A GROUP OF PANELISTS ON: STEEP LANDINGS SYSTEMS FOR VTOL AIRCRAFT |
| 221 | PILOT/AUTOMATIC-RELATIONS, CONFIDENCE, DISPLAYS |
| 223 | A PILOTED SIMULATOR STUDY OF THE CONTROLLED DECELERATION TRANSITION OF A VTOL AIRCRAFT IN A STEEP DESCENT |
| 224 | PILOT PERFORMANCE WITH A SIMULATED ILS INDEPENDENCE PICTORIAL DISPLAY |
| 225 | PITCH ATTITUDE, FLIGHT PATH, AND AIRSPEED CONTROL DURING APPROACH AND LANDING OF A POWERED LIFT STOL AIRCRAFT |
| 237 | QUASI-OPTIMUM DESIGN OF AN AIRCRAFT LANDING CONTROL SYSTEM |
| 238 | RADAR INDEPENDENT LANDING MONITORS |
| 241 | THE RELIABILITY OF FLIGHT CONTROLS |
| 250 | A SIMPLE HEAD-UP DISPLAY FOR CIVIL AIRCRAFT |
| 251 | A SIMPLIFIED KALMAN ESTIMATOR FOR AN AIRCRAFT LANDING DISPLAY |
| 252 | SIMULATED FLIGHT TESTS OF A DIGITALLY AUTOPILOTED STOL-CRAFT ON A CURVED APPROACH WITH SCANNING MICROWAVE GUIDANCE |

| Index No. | Title |
|---|---|
| 257 | SOME PROBLEMS IN THE DEVELOPMENT OF AN ADVANCED INTEGRATED FLIGHT CONTROL SYSTEM FOR STOL-APPROACH |
| 258 | SOME THOUGHTS ON ALL-WEATHER OPERATION OF JET V/STOL AIRCRAFT INCLUDING THE USE OF RESTRICTED SITES |
| 259 | SOME THOUGHTS ON V/STOL DISPLAYS AND APPROACH TECHNIQUES |
| 260 | SST TECHNOLOGY FOLLOW-ON PROGRAM - PHASE I. TEST AND ANALYSIS OF A QUADRUPLE REDUNDANT HORIZONTAL STABILIZER ACTUATION SYSTEM |
| 261 | STABILITY AND CONTROL FOR INSTRUMENT FLIGHT |
| 262 | STEEP DESCENT LANDING SYSTEMS FOR VTOL AIRCRAFT |
| 263 | STOL RIDE CONTROL FEASIBILITY STUDY |
| 264 | STUDY OF PILOT-VEHICLE-CONTROLLER INTEGRATION FOR A MINIMUM COMPLEXITY AFCS |
| 274 | SYMPOSIUM ON TEST AND EVALUATION OF AUTOMATIC CONTROL SYSTEMS, SAINT MARY'S COLLEGE OF MARYLAND, SAINT MARY'S CITY, MD. |
| 276 | A SYSTEMS ANALYSIS OF MANUAL CONTROL TECHNIQUES AND DISPLAY ARRANGEMENTS FOR INSTRUMENT LANDING APPROACHES IN HELICOPTERS |
| 279 | TELEVISED GRAPHIC DISPLAYS FOR STEEP APPROACH-TO-LANDING RESEARCH |
| 282 | THE THEORETICAL PERFORMANCE OF OPTIMIZED GLIDE-PATH CONTROLLERS FOR THE COMET IIIB |
| 283 | THE TOTAL SYSTEMS CONCEPT FOR CATEGORY III OPERATIONS |
| 289 | UTILITY OF THE VERTICAL CONTACT-ANALOG DISPLAY FOR CARRIER LANDINGS - A DIAGNOSTIC EVALUATION |
| 290 | THE VALUE OF A HEAD-UP DISPLAY WHEN LANDING A LARGE AIRCRAFT |
| 291 | THE "VARSITY" G-ARFP - A FLYING TEST BENCH FOR THE DEVELOPMENT OF AUTOMATIC LANDING |
| 293 | A VISUAL FLIGHT LANDING APPROACH AIR |
| 296 | V/STOL DISPLAYS FOR APPROACH AND LANDING |
| 297 | V/STOL DISPLAYS FOR APPROACH AND LANDING, A PRESENTATION OF THE JANAIR PROGRAM |

| Index No. | Title |
|---|---|
| 301 | VTOL DISPLAYS AND CONTROLS FOR ALL-WEATHER FLIGHT |
| 303 | VTOL FLIGHT INVESTIGATION TO DEVELOP A DECELERATING INSTRUMENT APPROACH CAPABILITY |

## VI TERMINAL ENVIRONMENT

| Index No. | Title |
|---|---|
| 14 | AIRCRAFT LANDINGS, DDC, AD-523 400, DDC-TAS-72-49 |
| 15 | AIRCRAFT LANDING SYSTEMS CONFERENCE PROCEEDINGS |
| 37 | ATC AND LANDING AIDS FOR VTOL AIRCRAFT |
| 119 | A FLIGHT CONTROL SYSTEM FOR STOL AIRCRAFT |
| 258 | SOME THOUGHTS ON ALL-WEATHER OPERATION OF JET V/STOL AIRCRAFT INCLUDING THE USE OF RESTRICTED SITES |

## VII PILOT AND FLIGHT OPERATIONAL PROCEDURES

| Index No. | Title |
|---|---|
| 2 | ADVANCED CONTROL SYSTEM CONCEPTS |
| 12 | AIRCRAFT FLIGHT CONTROL SYSTEMS FIELD SAFETY EXPERIENCE |
| 13 | AIRCRAFT LANDING CONTROL AUTOMATION |
| 14 | AIRCRAFT LANDINGS, DDC, AD-523 400, DDC-TAS-72-49 |
| 15 | AIRCRAFT LANDING SYSTEMS CONFERENCE PROCEEDINGS |
| 29 | AN ANALYSIS OF LONGITUDINAL CONTROL DURING LANDING APPROACH |
| 33 | THE APPLICATION OF CORRELATION ILS TECHNIQUES TO TERMINAL AREA TRAFFIC CONTROL |
| 47 | THE CHANGING WORLD OF THE PILOT IN THE NEXT DECADE - V/STOL AIRCRAFT OPERATIONS |
| 52 | COMMAND AUGMENTATION - DIGITAL FLIGHT CONTROL EVALUATION |
| 88 | DISPLAY INSTRUMENTATION FOR V/STOL AIRCRAFT IN LANDING |
| 89 | DISPLAYS FOR APPROACH AND LANDING OF V/STOL AIRCRAFT |
| 90 | DISPLAY SYSTEMS FOR VERTICAL TAKEOFF TRANSPORT AIRCRAFT |
| 104 | EVALUATION OF A VTOL FLIGHT-DIRECTOR CONCEPT DURING CONSTANT-SPEED INSTRUMENT APPROACHES |
| 108 | AN EXPERIMENTAL EVALUATION OF AIRCRAFT DISPLAYS FOR IFR STEEP ANGLE APPROACHES |
| 125 | A FLIGHT INVESTIGATION OF SYSTEMS DEVELOPED FOR REDUCING PILOT WORKLOAD AND IMPROVING TRACKING ACCURACY DURING NOISE-ABATEMENT LANDING APPROACHES |
| 156 | IFR STEEP ANGLE APPROACH: EFFECTS OF SYSTEM NOISE AIRCRAFT CONTROL AUGMENTATION VARIABLES |
| 179 | LABORATORY LANDING |
| 190 | MANUAL AND AUTOMATIC LANDING SYSTEM TERMINAL CONTROL THEORY, SYSTEM INTEGRATION CONCEPTS. FLIGHTTEST RESULTS, AND FUTURE DEVELOPMENTS |

| Index No. | Title |
|---|---|
| 191 | MANUAL DIGITAL POSITIONING IN 2 AXES - A COMPARISON OF JOYSTICK AND TRACK BALL CONTROLS |
| 196 | NASA FLIGHT RESEARCH CENTER BLY-BY-WIRE FLIGHT TEST PROGRAM |
| 206 | NF-8D VARIABLE STABILITY PROGRAM |
| 221 | PILOT/AUTOMATIC-RELATIONS, CONFIDENCE, DISPLAYS |
| 225 | PITCH ATTITUDE, FLIGHT PATH, AND AIRSPEED CONTROL DURING APPROACH AND LANDING OF A POWERED LIFT STOL AIRCRAFT |
| 232 | PROBLEMS OF THE INTEGRATION OF AIRCRAFT AND FLIGHT CONTROL SYSTEM IN THE CASE OF NEW APPROACH PROCEDURES |
| 261 | STABILITY AND CONTROL FOR INSTRUMENT FLIGHT |

APPENDIX C

AUTHORS