AFFDL-TR-72-109

# HUMAN ENGINEERING FOR THE AIR FORCE CONTROL-DISPLAY PROGRAM

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# FOREWORD

This final report summarizes the human engineering activities of the Bunker Ramo Corporation during the three contract years of AF33615-69-C-1716. The period of performance covered in this report is from 25 June 1969 to 24 June 1972.

The contract was initiated under AF Project 6190, "Control-Display for Air Force Aircraft and Aerospace Vehicles", which is managed by Mr. J. H. Kearns, III, as project engineer and principal scientist for the Flight Deck Development Branch (AFFDL/FGR), Flight Control Division, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. The work was performed as a part of Task number 6190 07 under the guidance of Mr. Eldon Bobbett (AFFDL/FGR) as task engineer.

Human engineering support to the program was provided within the facilities of the Flight Deck Development Branch located at Wright Field, Wright-Patterson Air Force Base, Ohio, and the Research and Development Division, Instrument Flight Center, Randolph Air Force Base, Texas. The on-site groups were an element of the Electronic Systems Division, Bunker Ramo Corporation (with headquarters located in Westlake, California).

Bunker Ramo personnel associated with the contract activities during the three year contract were Gerald Armstrong, Mary Baisden, Carol Berryhill, Robert Burgin, John Carroll, Hazel Carter, Ronald Dalton, Donald Eldredge, Michail Fogarty, John Howley, Bobbiee Logan, Dr. A. C. McTee, James Marshall, Robert Mengelkoch, Richard Moss, Dr. John Reising, Ellen Seylar, Leola Schultze, Thomas Snyder, William Swartz, Richard Walchli, Wayne Ward, Don Watkinson, Kenneth Woodruff, and Bertha Weigold.

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This technical report has been reviewed and is approved.

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## ABSTRACT

A research program is being conducted in support of Project 6190 which addresses each of two interface problems to be considered in the conduct of advanced control-display research within the systems context, namely, the manager/information systems interface and the pilot/aircraft interface. The Research Control Process Program is involved in the problem of designing an interface between the technical manager of control-display research and the system to be directed and controlled. 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. The Mode and Function Program activities centered around the specification and development of the pilot performance measurement system to be used in the Multi-Crew Mockup for the study of cockpit management problems. Other related activities included the establishment of the criteria to be used in the determination of aircraft subsystem simulation requirements and the selection of the controls and displays to be made operational in the implementation of those requirements. The Display Elements Research Program continued to assure that the appropriate engineering and human engineering considerations and skills were applied throughout the development cycle of cockpit display systems. This was accomplished through the application of analytical and empirical techniques in the conduct of research using dynamic flight simulators and test aircraft as research tools. The Facility Integration Program was involved primarily in the planning and execution of the Multi-Crew Simulator Facility Sample Study which was designed to exercise selected combinations of the hardware, software, data gathering routines, and experimental procedures as well as provide basic vehicle performance data.

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# SECTION I

# INTRODUCTION

Mission effectiveness of Air Force aircraft is dependent in some measure upon the design of the interface between the pilot and his aircraft. The Air Force formally acknowledged the importance of the man-machine interface to operational capability with the creation in 1958 of Project 6190, The Air Force Integrated Flight Control-Display Program. Project 6190 is charged with "the responsibility of providing the Air Force with adequate skills, capabilities, and techniques for assuring control-display capability in future aerospace systems." By the nature of its subject, Project 6190 has been involved as much in the development of methods and techniques for improving the science of control-display. The project requires diverse skills to bring inter-disciplinary thought to the problem. The integration of the human engineer into the project team is a notable example, and the project has pioneered in the use of the pilot as a systematic evaluator. The formulation of an integrated test facility, consisting of the mockup, the ground-based simulator, and the inflight testbed has led to the development of an extremely refined filtering system for the answering of relevant questions at the appropriate level of development.

Through this integrated approach, a workable research philosophy was developed which centers upon the human pilot as the fundamental element of the weapons system. The implementation of this philosophy is extremely demanding. It requires a thorough understanding of the problem, considering the pilot as an element in the system, as well as an understanding of the approach necessary to develop the alternative solutions. The pilot must be considered as the key element in the system because effective operation in the Air Force environment demands the flexibility and decision-making characteristics that can only be provided by the human pilot. Project 6190 has made significant contributions to understanding the conduct of research for technology that exploits the human pilot through flight control-display.

## 1. BRIEF CONTRACT HISTORY

Employment of human engineering specialists for the purpose of consultation, analysis, and research as an integral part of control-display research and development engineering activities was originally launched by the Flight Control Laboratory in 1955. Early contract support was provided by the Aviation Psychology Laboratory, University of Illinois. The activity provided the opportunity to demonstrate the type of contributions that the psychological discipline could make as a member of an interdisciplinary team formed to undertake the advancement of control-display technology. When Project 6190 was formed, a need for on-site human engineering assistance was defined to assist in the conduct of analytical and empirical research on the "whole panel concept." The Electronic Systems and Products Division of The Martin Company was awarded the contract in 1958 and it has been held since then by The Martin Company, Martin-Marietta Corporation, and Bunker Ramo Corporation.

## 2. PROGRAM APPROACH

Bunker Ramo recognized that the character of the participating disciplines involved in Project 6190 must be adapted to meet the changing requirements, and human engineering is not an exception. In fact, the impact may affect the human engineering role more than any other. Human engineering has historically been involved in the interface between the pilot and his aircraft. More specifically, particular attention has been devoted to identifying the pilot's control-display requirements and evaluating alternative solutions to determine performance expectations in an operational context. Experiments have been composed and conducted to define this problem; techniques research has been accomplished to improve the effectiveness of the experimentation; evaluations have been conducted using the improved methodology to ascertain if the concept was worth pursuing.

The capability that would provide an information system for control-display research under Project 6190 imposes similar responsibilities upon the human engineering discipline. Today, the problem is one of definition of the interface between the personnel engaged in the technical direction of Project 6190 and their store of information. The role of the human engineer is not radically different from that used in the pilot/aircraft interface. What are the problems? What are the relative priorities? What are the means for solving the problems within the present state-of-the-art? Will the solution be generated in time for introduction into the fleet? How is the information to be formatted? All of these are relevant questions for which data are needed to specify the manager's requirements. Experiments must be set up and conducted to establish the data requirements. Advances in the means of gathering, processing, and retrieving information related to the problem area of control-display must be made through empirical verification.

The role of human engineering as participant in Project 6190, then, must necessarily be expanded to consider both the pilot/aircraft interface and the technical management/information system interface. There is nothing dramatically different, but the role has been forced to expand to meet the challenge of the impact of today's advanced technology upon the relevancy of the exploratory research program being conducted under Project 6190. Bunker Ramo developed a research program which addressed each of these two interface problems. Specifically, the following efforts were established: (1) Cockpit Analysis, (2) Control-Display Testing, (3) Control Display Information Center, (4) Research Control Process, and (5) Facility Integration.

## SECTION II

## COCKPIT ANALYSIS

### 1. THE PROBLEM

Paramount to the dissecting of the control-display process is the task of identifying the cockpit problem and establishing a hierarchy of importance. Bunker Ramo made a concerted effort in the cockpit problem research area. Clarification, identification, and classification of cockpit problems is required to increase the effectiveness and validity of all cockpit environmental research, whether it is human engineering or instrument engineering. Previously, work in this area was intermittent, incomplete, and on an as-needed basis. A few military, commercial, and private concerns have sustained some minimal effort but the work has supplied neither precise direction nor reliable and adequate results.

Few pilots would deny that there is something wrong or that something could be better in most of our military aircraft. Strangely enough, defining the basic problem is not easy and too often "solutions" are proposed and even incorporated before the problems are defined; time, dollars, and manpower availability require the establishment of a problem priority. For example, where does one begin with the following broad categories of problems which contributed to the loss of Air Force lives and property during the past several years:

(1) Landing short of the runway

(2) Misreading of instruments

(3) Actuating the wrong control

(4) Exceeding aircraft structural limitations

(5) Flying on the back side of the power curve

(6) Fuel mismanagement

(7) Faulty navigation

(8) Mid-air collisions

(9) Foreign object damage.

The problems are numerous and each is important and costly to the Air Force.

## 2. THE APPROACH

The need to look at the overall cockpit environment is mandatory. Once a particular display or subsystem is developed, it must be evaluated in terms of the total crew station. Likewise, to adequately study the problems in existing aircraft, the total cockpit environment must be considered and scrutinized. Basic to the solution of any problem is a thorough understanding of the problem itself.

Several approaches were used to identify operator problems in the aircraft cockpit: (1) personal experiences of an analysis staff; (2) interviews of experienced military personnel; and (3) reviews of aircraft accident data.

## 3. PERSONAL EXPERIENCE OF AN ANALYSIS STAFF

The education and work experience background that a group of engineers applies to design of an new product contributes significantly to the success of that product. Likewise, in the study of any problem area, education and experience play a large role in assuring that all possible facets of the problem are investigated. Therefore, it is important, when dealing with cockpit problems, that the analysis staff is properly trained in the scientific approach to problem investigation and that it has personal experience in the operation and control of military aircraft. Education and experience prove extremely valuable in sorting through the numerous avenues involved in cockpit problem investigation.

## 4. INTERVIEWS OF EXPERIENCED MILITARY PERSONNEL

The potential utility of expert opinion that may be elicited from flight-qualified personnel with respect to control-display problems is almost unlimited. This potential source of data has been disregarded, misused, or completely avoided at times (particularly by some behavioral scientists who exhibit greater affinity for objective performance data).

Problems involved in making suitable use of pilot opinion concern both the modes whereby opinion is elicited and the treatment of the data. Bunker Ramo's experience suggests that:

(1) Pilot "bias," or the effect of earlier established opinions, changes slowly when the pilot is exposed to conditions that logically should call for the formulation of a "true," and probably revised, opinion

(2) Pilot responses sometimes reflect another bias to satisfy the investigator's expectations

(3) Pilots sometimes withhold reporting of difficulties experienced because of pride in personal proficiency.

Recognition of these limitations allows the scientific investigator to make maximum use of much valuable information through the soliciting of expert opinion, while at the same time being cautious in screening out "biased" portions.

## 5. REVIEW OF AIRCRAFT ACCIDENT DATA

Air Force aircraft accident records provide a massive source of data related to the shortcomings of military aircraft and the pilots who fly them. The factors involved include aircraft design, training instructions and procedures, flight manual information, control-display components and arrangements, operating conditions, and pilot behavior. Although previous Bunker Ramo research has indicated that a large percentage of aircraft accidents are related to flight manual information and the following of instructions (which are not directly related to control-display research programs), it is felt that sufficient information can be gleaned from the accident records pertaining to actual control-display problems to warrant investigation of this information source.

Within this context, the following analyses were conducted

### a. Crew Systems

#### (1) Overview of Problems in the Fighter Cockpit

A report was prepared as an introductory description of the missions that the fighter must fly, a detailed definition of how each is flown—complete with a description of problems facing the pilot—and the training curriculum in which each pilot must participate to maintain currency. One completes the report with some appreciation for the dynamics of the problems facing the fighter pilot, particularly when he refers to "high workload" during certain critical times, i.e., run-in to the target when there are an incredible number of things to do and little time to accomplish the tasks, accompanied by a great deal of psychological stress because of the hazards involved.

#### (2) Crew Station Management

Crew Station Management is a critical problem issue relating to pilot workload in the fighter cockpit. The analysis shows the rapid growth in terms of annunciator displays, switches, and procedures over a 60 year time frame. The rate of increase appears to rise exponentially. The analysis clearly shows why the management of avionics subsystems has become a major problem to the pilot: a large amount of switching has to be done in situations where there is a limited amount of time to accomplish it. Reduction of workload in the single seat fighter is dependent to a very large degree upon finding solutions to the crew station management problem. The report validates the work that FGR is doing in Crew Station Management.

(3) STOL Cockpit

The analysis identified the control-display problem issues that would impact on the design and development of the Air Force's future STOL transport. These issues were grouped into five functional areas: (I) Operational Factors, (II) STOL Aircraft Factors, (III) Flight Deck Issues, (IV) Primary Flight and Engine Instruments, and (V) Controllers.

The report discussed the problems that pilots encounter while flying the C-7, C-123, and C-130 aircraft as well as the Breguet 914 S. The Breguet is an immersed wing STOL vehicle and problems encountered while flying it were included in this report because it is a candidate design for the Air Force's STOL transport.

The issues identified indicate that much needs to be done in the cockpit if the future STOL transport is to realize its full potential. The pilots interviewed pointed out that the control-display problems encountered during the STOL profile are different from those found during conventional resupply missions, since steep angle approaches, long fatiguing missions, large communications and navigation workloads and specialized airborne delivery equipment all generate unique control-display requirements complete with their own set of problems. These are not necessarily vulnerable to the solutions generated for conventional aircraft.

This report makes no attempt to evaluate the relative importance of any one particular problem. Instead, it points out how this problem is likely to impact on the mission effectiveness of any future STOL transport and offers an assessment of how the issue may be attacked.

(4) Helicopters

Bunker Ramo supported IFC in a survey of operational capabilities being realized by the Air Force in helicopters. Assistance was provided in the construction of a questionnaire distributed to USAF helicopter pilots throughout the major user commands. The objective was to determine present operational capabilities and to identify deficiencies affecting the ability to fly in the vertical portion of the profile under conditions of weather and low visibility. The results are to be used by IFC and AFFDL in determining requirements for, and direction of, future control-display developments for helicopters. The survey has been completed and a report published.

A sampling of the survey indicates that helicopter pilots fly 50% 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 could well increase mission effectiveness by as much as 75%. The conclusion was that existing helicopter instrument flight displays, controls, and navigation systems are inadequate for the USAF pilot to perform the demanding mission profile in a weather environment. The present helicopters are restricted to a fixed wing flight profile under instrument flight conditions. The recommendation was made that users of helicopters re-evaluate and re-state their requirements so that an effective development program can be approved and undertaken.

(5) HH-53

An assessment of control-display problems being experienced by Air Force pilots in the HH-53 was undertaken to develop a thorough understanding of the present capabilities and limitations in accomplishing the Air Force SAR mission. This task is directed to enhancing the Flight Deck Development Branch's capability to evaluate the suitability of an advanced SAR control-display system being developed by a joint service working group for use in the 1972-1975 time frame. Understanding present difficulties in the cockpit is instrumental in evaluating the proposed system in meeting Air Force needs. Data generated by surveys and reports were searched for relevant problem issues. In addition, pilots from Aeronautical Systems Division of Wright-Patterson Air Force Base, Ohio, and the Aerospace Rescue and Recovery Training Center, Eglin Air Force Base, Florida, were interviewed. Taken as a whole, the data generated by the surveys, reports, and interviews provide an extremely comprehensive collection of SAR cockpit problems. Twenty-seven critical problems were identified and their impact upon mission performance assessed. The results clearly indicate that cockpit and control-display improvements in the HH-53 will lead directly to an improved SAR operational capability.

The report was put into audio-visual format for facilitating the dissemination of information. A working paper was forwarded to FGR describing Bunker Ramo's experiences and observations obtained in preparing the audio-visual report. To our knowledge this is the first time that the technique has been employed in control-display work.

To gain an insight into the potential of speech compression, the master tape was compressed 10%, 20%, and 30%. The 20% compression rate was judged to be best in terms of speech recognition.

(6) Voice Command

An analysis was conducted to investigate possible uses of voice command in the cockpit. With pilot workload continually rising due to the number of switches, dials, and knobs that he must contend with, voice command systems may provide an effective means for alleviating problems imposed by exclusive reliance on manually accomplishing the necessary actions with just the hands. The analysis specifically considered the following topics:

(1) How Voice Command works

(2) Possible cockpit applications of Voice Command

(3) Voice Command considerations

(4) Manufacturers and government research

(5) Analysis of the potential of Voice Command

(6) Voice Command system development

(7) Proposed research program for airborne Voice Command

(8) Conclusions

The analysis began by examining speech and automatic speech recognition. Since automatic speech recognizers are the heart of any voice command system, it was necessary to understand something about how they function in order to appreciate the various capabilities and problems associated with voice command. Therefore, a representative automatic speech recognizer is discussed in detail. A block diagram of the system is presented, and each of the system components is discussed in detail. A block diagram of the system is presented, and each of the system components is discussed at some length.

The main payoff of voice command for the Air Force is through its use in the cockpit. However, there are a number of ways in which voice command can be applied in the cockpit. Voice command can be utilized to set up weapon systems, to change radio frequencies and perform other communications tasks, to aid in the performance of checklists and emergency procedures, and to serve as a means of providing the pilot with information on the status of his various systems. These applications certainly do not exhaust the list of uses of voice command within the cockpit, but rather serve as examples of ways of using voice command that have direct payoff to the Air Force.

Voice command is a system and as such requires that a number of system considerations be taken into account before it can be used effectively in the cockpit. The considerations can be broken down into those relating to equipment, human factors, and pilot factors. Equipment considerations takes into account the unique characteristics of the machine we are dealing with. Human factors considerations relate to the fact that a man will be operating the equipment. Therefore man's particular capabilities and limitations must be taken into account if an effective system is to result. The third and most important system consideration is pilot factors. It must constantly be remembered that a pilot will be the ultimate user of the system. Consequently, all the factors unique to the airborne environment must be examined.

Research concerned with automatic speech recognition, the heart of the voice command system, is currently being carried on by both industry and government agencies. As far as industry is concerned at least 10 separate firms are currently engaged in automatic speech recognition research. On the government side, the Air Force, Army, and Navy, as well as the Advanced Research Projects Agency (ARPA) of DoD are conducting research in automatic speech recognition.

The analysis concludes that voice command is on the threshold of having the technology in hand for applying the concept to Air Force cockpits if a vocabulary of 100 words will be adequate using discrete speech. It is proposed that the first step in applying voice command be the determination of the effects of "g" and pressure breathing in an oxygen mask upon word recognition by the voice command system.

b. Instruments

In Bunker Ramo experiences in dealing with pilots, we have come to appreciate the subtle difference between asking pilots: "What are your problems?" and "What are your requirements?" Pilots can certainly tell you what the problems are. Pilots experience the problems every time they take off. We have shown how to organize and analyze the problem statements to make them useful for our purposes. But the caliber of the responses to the question "What are your display requirements?" falls off dramatically in comparison to the question "What are the problems?"

Stating requirements demands a capability to break the problem into its elements, consider what the design deficiencies are and project what is needed to resolve those deficiencies.

Most pilots do not have that capability; they simply are not involved in the R&D end of the operation. However, some USAF pilots do have that capability—notably those at the Instrument Flight Center. Their mission and involvement with AFFDL in programs over the last 15 years has served to make the pilots adept at looking at display requirements. IFC is very capable in advancing problem understanding of display issues to the next step of defining requirements from a piloting point of view.

Two major analyses were undertaken in the instrument area in conjunction with IFC:

(1) Range and Range Rate in the Terminal Area. The provision of a display of range to a station has eliminated much of the pilot's navigational workload. It is suggested that a source of range information located at the runway threshold would offer similar reductions in pilot workload and computation during takeoff, approach, and landing. The addition of a

computational step between the receiver and the display panel promises effective monitors of takeoff and stopping performance based on acceleration, velocity, and present position compared to runway remaining. Similar computations would allow the pilot's displays of parameters like glide slope and localizer to read in linear units, rather than in angular modes as at present. This achievement alone would be expected to significantly increase precision and reduce workload in the landing approach and terminal area maneuvering.

(2) Lateral C-D Requirements. Control and display problems in the lateral axis remain a major deterrent to extremely low visibility landings. Past research on vertical axis control and display has enabled flight into visibility conditions which demonstrate the inadequacies of present capabilities in lateral axis control and display.

The lateral axis tracking task is more complex than the vertical axis task because of the aerodynamics and mechanics of lateral corrections. At the same time, supporting information is less complete in the lateral axis, creating an "information gap" for the pilot. Although the autopilot may be content to simply satisfy a steering command, the pilot needs to know where the command is directing him. The pilot would prefer that the information were complete, directing him to the runway rather than to a beam center; if this direction could be presented in linear (feet, yards) instead of angular (degrees, dots) units, this would be preferred. The displayed information should include at least (1) direction and magnitude of error; (2) deviation rates; and (3) maximum tolerable rate/displacement.

Control in the lateral axis should allow pilot participation as an active element; this integration of pilot and autopilot can be accomplished by a properly tailored Force Wheel Steering System. The goal must be a system which degrades gracefully, if at all, and accommodates pilot inputs at all levels from coupled through manual. For full-mission capability, a sequential displacement/rate force wheel system may be desirable.

To eliminate some near-touchdown lateral maneuvering, a "hold-what-you-got" technique may be feasible; if the aircraft is in a position to touch down safely on the runway, although displaced to one side or another, no correction to centerline would be commanded below a certain altitude or range, and no further deviation would be allowed.

An Independent Landing Monitor (ILM) is a requirement for operations into very low visibility. The role of the Heads-Up-Display (HUD) in the all-weather operation is yet to be adequately defined.

# SECTION III

# CONTROL-DISPLAY TESTING

The on-site human engineering support group was directly involved in many of the programs that Project 6190 sponsored. If the group were not directly involved in the execution of the program, it most likely had a consulting role. As members of the Project 6190 team, human engineering specialists were willing to accept a share of the responsibility on a continuing basis and assist in the formulation of technical programs. Training in experimental design and measurement of human operator performance makes the human engineer an essential element in translating requirements into action. He is of value in communicating the objectives, methods, and goals of the program to organizations that must do the actual work, particularly to human factors groups within those organizations. He serves as an impartial judge in assessing the quality of the program while it is conducted and, moreover, the human engineer has a large responsibility in taking data that are derived from the program and integrating the results into the overall research strategy.

The approach must start necessarily from an awareness of what Project 6190 requires of its human engineering staff in the consulting role. Consulting has always been provided at the program element level under prior contracts, but an appreciation of what is required with respect to the total project has taken time to evolve. With the advent of the past contract, Bunker Ramo assisted Project 6190 in fulfilling the total project consulting role, in addition to providing human engineering inputs at the program element level. Two types of testing were accomplished. Covered under the Display Elements Program section will be such areas as head-up displays and instrument mechanization. In the Crew Systems integration area such tasks as cockpit lighting are covered.

c. Display Elements Program

(1) Spreading Runway Concept, Electromechanical Mechanization: Flight Test Evaluation (4058V)

After preliminary investigation in two simulation studies, the 4058V ADI was installed in a USAF T-39 aircraft at Randolph AFB, Texas, to be flight tested under the direction of the USAF Instrument Flight Center, Research and Development Division. The objective of the flight test was to provide preliminary assessment of pilot acceptance, establish the utility of the display element as supporting information during final approach, establish the optimum altitude for initiation of the spread of the V symbol, and to explore in actual flight the problem associated with interpretation of the lateral information feature that was noted in the simulation studies. Human factors support was provided the IFC R&D project pilots in establishing the experimental designs and in coordinating the findings of the simulation tests with human engineers located at Randolph AFB. Periodic coordination between IFC and FGR has also been provided by the display elements team. Flying has not been completed due to instrument malfunctions.

(2) Spreading Runway Concept: CRT Mechanization

The simulation studies of the spreading runway concept and preliminary findings of the follow-on flight test evaluation demonstrated that the basic concept appeared to have merits in terms of the type of information being displayed to the pilot. However, the electromechanical mechanization technique was found to be limited in its ability to manipulate other significant information parameters. To further explore the information requirements appropriate to this display concept, work was initiated by FGR through other on-site contractor personnel to develop a CRT version of the display to use as a research tool. As a part of the human engineering support to the display elements program, design specifications for the display features of the CRT were provided. Additional detailed planning for management assessment of the scope of the task and for establishing the technical approach and experimental designs for studies using the CRT display tool was also provided. Due to the commitment of contract resources to other priority tasks, the decision was made by FGR to arrange for other on-site contractor personnel to accomplish the planned research studies. Human engineering support to the display elements team for this project has continued in the form of technical consultation to assist in the monitoring of the CRT studies and the formulation of advance planning for further development of the concept.

(3) ME-1 Digital Data Acquisition Capability Development

Early in the planning phase of 4058 V Simulation Program, it became apparent to the display elements team that the development of a digital data acquisition capability for the ME-1 simulator would be necessary to accomplish the planned studies in a timely and cost effective manner. As a result, arrangements were made by FGR through other on-site contractors to design and construct the necessary equipment for interfacing the ME-1 signal outputs to the Mark II digital computer's datamech. Performance requirements for this digital data acquisition capability were provided by Bunker Ramo as a part of the human engineering support to the display elements research program. In addition, follow-up coordination with the equipment contractor was accomplished to initiate the required software programming for the Mark II computer.

(4) Vertical Situation Display Development: Baseline Study

The objective of this task was to determine what information a pilot requires of a vertical situation display to develop criteria leading to specification of the display format and to assess compatibility of a vertical situation display with the basic Air Force panel containing a flight director display. The flight profile indicator (FPI), a CRT vertical situation display developed by FGR, was used as the basic research tool for studying the problem. During the previous contract, a series of simulation studies were planned to systematically examine the problems of information content and display format. Due to manpower commitments to other display elements tasks, no experimental effort was initiated during the term of the previous contract. To prevent the reoccurrence of delays in this project due to resource limitations of the display elements research program, the first of the planned studies was subsequently contracted to an off-site contractor to be accomplished at their facility. As a part of the human engineering support to the display elements research program, Bunker Ramo provided technical consultation to the Air Force program manager in establishing the detailed objectives, experimental designs, and performance measurement requirements for the contracted study of the FPI. Similar support was provided the program manager in the review of the final technical report of this simulation study of the RPI.

(5) VFR HUD

A truly significant VFR HUD program was initiated by FGR. The program has been formulated from two rather seemingly diverse projects going back several years.

In 1967, the Air Training Command requested the Flight Deck Development Branch to develop a solution to the VFR landing-short problem in the T-38. The Command was losing three to four aircraft a year. Mr. Knemeyer designed and introduced a unique computational system for providing a flight director capability on an externally mounted head-up instrument. The Mechanical Path Angle Display (MEPAD) was fabricated and installed, along with the computational system, by Northrup on an Instrument Pilot Instructor School (IPIS) T-38 aircraft for flight test. The indicator malfunctioned. In order to sustain the program, the Branch procured a Visual Landing System and installed it on the T-38. The system was employed as a tool to evaluate the relative goodness of the displacement versus command concept of providing the pilot with control information. A collimated display is mounted on the glare shield so the testing portion of the program will be straightforward. If possible, the results of flying with the computations in the Visual Landing System will be compared with those of Mr. Knemeyer's. Completion of this project early in the next fiscal year will mark the first time that a visual landing aid has been tested in a high performance aircraft under controlled conditions. Numerous airlines are testing it on the Boeing 747.

Two important activities have been conducted as adjuncts under the present contract. The first undertook to document the T-38 VFR profile. There was reason to suspect that the VFR approach was not a straight line, i.e., an ILS, but in fact dual angle. If so, this could possibly have an influence on the computational aspects of the command function; i.e., should the command ask the pilot to fly as he would normally VFR or constrain him to a straight-in? And, secondly, the profile data without display augmentation would be valuable as a baseline comparison for performance obtained with the visual landing aid. Some 300 approaches of T-38s were tracked by means of theodolite. Preliminary indications are that the profile is dual angle. The report is being put into final draft. As such, it will provide the most comprehensive picture of the visual approach profile ever documented in this country for high performance aircraft. The Branch has already been involved in meetings with Air Force training organizations and the FAA flight safety groups concerned with how to better guard against the landing-short problem through procedures.

The second activity documented the "Piloting Techniques" being employed for VFR final approach. Responses from over 100 pilots of various experience levels were obtained in the survey conducted by Bunker Ramo. The results will indicate how the pilots are handling the problem, and perhaps explain why we are seeing what we see in the T-38 VFR baseline profile data. If so, the results will have even more important and far-reaching value. A successful correlation will demonstrate that piloting techniques can be worked into the design of advanced displays.

(6) IFR/VFR HUD

There is considerable controversy about the role of HUD. The issue really comes down to not knowing what information the pilot requires in the HUD to properly execute his responsibilities as command pilot.

In assessing the situation, the Flight Deck Development Branch determined that the see-to-land problem was one of legitimate concern for the Air Force. For example, HUDs have been installed in the A-7 and F-111 with no understanding of what the pilot needs in the way of information to do the job. It was evident that the correct approach lay in the consideration of a head-up display as a tool for defining the problem issues. Accordingly, an externally mounted electromechanical display was mounted on the nose of a T-39. Extensive flights were made down to and including 1200 RVR. The testing was recently completed at IFC. Bunker Ramo designed the test and reduced the data. The results are outstanding in that for the first time, pilot inputs on what information is needed on a HUD for low visibility landing have been generated based on actual experience rather than conjecture or limited simulator experience. In addition to command information, roll and pitch attitude, rate-of-closure, altitude above runway, lateral situation, and speed command information are critical.

Results indicate that the external HUD as configured is limited in what can be accomplished in addition to the basic definition work. However, it has served its purpose well. The question of interval versus external mounting of the HUD is still open. Each has its advantages and disadvantages. The next step is the fabrication of a head-up device incorporating the findings of Phase I. One thing is for certain, HUD research by its very nature is accomplished most productively inflight. The overall problem is just too difficult to simulate in its entirety on the ground.

(7) Silent Incapacitation

A simulator study on effects of silent incapacitation upon approach performance was conducted by Bunker Ramo in conjunction with Lt. Colonel Shaud, who was working on his PhD Dissertation at Ohio State. The XC-142 moving base simulator located in Building 434 was used. Twenty subject pilots were brought in to fly the simulator as copilots. Bunker Ramo developed the questionnaire and provided the "command pilot" as well as the experimenter. None of the pilots knew what to expect. The command pilot became incapacitated unexpectedly and without warning. Reaction time for the copilot to assume control was measured. Admittedly, the simulation was not fully representative of the inflight situation. But the average response time was better than 15 seconds for the copilot to wake up to what was happening and assume control of the simulator. This finding certainly provides grounds for further investigation into what might be done in the way of control-display to alert the copilot to what has happened and direct him to take control. The British are sufficiently concerned about the problem to be looking into the matter in some detail. They are concentrating upon physiological measurements for obtaining an indication that incapacitation has occurred. Simpler means may be possible using the so-called "dead-man switch," or monitoring the pilot control inputs. In any event, this problem area demands some attention. Otherwise, it might come back to undermine the pilot manager concept, long advocated by AFFDL, and generally accepted in the aviation community.

(8) Preliminary Investigation of Primary Flight Control-Display Problems Associated with Steep Angle Approaches

STOL approaches were made in the XC-142 simulator. Approach angles of 3, 6, 7.5, and 9 degrees were accomplished. Objective performance measures were obtained as well as subject-pilot comment. Bunker Ramo designed the test and reduced the data.

The evidence indicated that the type of displayed information was dependent in part upon the steepness of the angle. It is doubtful if steep angle approaches, greater than 9 degrees, can be made without the use of a flight director command, particularly on short final. Flight path angle information has tremendous impact upon STOL approaches, especially when using raw displacement information from glide slope. The flight director concept of using pitch attitude as the basic control parameter for vertical path control breaks down when flying STOL as thrust is used primarily by the pilot to control vertical path in the STOL immersed-wing design. Attitude is used primarily to control speed. There is an acute need for a vertical navigation display such as the Flight Profile Indicator.

In addition to these findings, insight was obtained into the problems brought up by the STOL Cockpit Analysis. Examples are the engine instruments, crew comfort, and lighting.

The preliminary investigation served to provide FGR with first-hand exposure to some of the more critical problems in control and display associated with STOL operations. The knowledge will be of value in participating in the contracted efforts having to do with the development of the STOL cockpit, which are being undertaken by the Branch in support of the ADP.

(8) Landing Displays

Displays fabricated as a part of the T-39 EL cockpit lighting program were used in further studying the matter of display principles on final approach. The Approach Sequence, Speed Director, and Lateral Situation Indicators were designed using electroluminescent techniques. When data collection was finished on the T-39 Lighting Program, Bunker Ramo, in support of ASD and the Flight Deck Development Branch, conducted an investigation of the display problem on short final using the instruments as tools. The program served to provide FGR with first-hand exposure to the control-display issues involved and to augment what has been said by IFC in its report on the problems. A report is being written. The report will recommend that a tightly controlled simulation program be undertaken to resolve the principal issues. The results would have payoff for all classes of aircraft in support of the National Landing Program.

d. Crew Systems Integration

(1) Crew System Management

Work has been in progress now for over three years. The FGR/ Bunker Ramo/SRL project team was given the task of converting the shell of a multi-jet transport into an effective testbed for examining the crew management task in a dynamic situation. All controls, switches, knobs, and levers, and their associated displays were mechanized for a representative transport configuration as a baseline effort. A communications system to Bunker Ramo specifications has been implemented, complete with ground-based radio operator's console for dealing with the communication task in real time. Extensive measurement capability defined by Bunker Ramo has been provided in which reaction time and correctness of response can be measured. The simulation is complete in every way with the exception of imposing the flight control task.

By this experience, the project team has become thoroughly grounded in the problem area. Bunker Ramo worked with the IFC to develop the mission scenario for developing the communications script. The engineers have become skilled ground-based radio operators. The team has studied and learned the Dash One T.O. for operating the avionic subsystem. A survey was given to MAC and the IFC to obtain first-hand experience in specifically defining what the problems are for pilot in multi-crew cockpit. Each of the project members has rotated through each of the crew positions in becoming intimately familiar with the annunciation and switching task. There is no question but that the Project Team has an outstanding grasp of the issues involved from a piloting viewpoint.

The pacing item in the program has been the heart of the capability — the Dynamic Mock-Up. The job there was to convert a wooden shell into a research facility tailored to the specific needs of attacking a very complex problem indeed. Final checkout of the mock-up was completed in conjunction with SRL. Meanwhile, plans are well along for detailing the program to be conducted. Controlled studies will be performed using pilots from user commands to generate both objective and subjective data, first on the baseline configuration — which essentially is that of a multi-jet transport — and then on annunciation and switching solutions proposed to attack the identified problems.

A primer on the subject of workload, its definition and measurement, has been prepared as a consequence of getting into the human operator measurements aspects. The analysis showing what lies ahead in mode annunciation, mode selection, and fault warning, unless drastic changes are made in the way that cockpits are designed and developed was completed and published as an AFFDL-TM.

(2) T-39 EL Program

Cockpit lighting has been a very stubborn problem to solve. It is felt that the disappointing results to date stem from the components approach to the problem. The basic premise has rested upon optimizing the lighting of each individual instrument so that the lighting in the cockpit would be satisfactory when the instruments were combined. However, the fallacy lies in the fact that lighting must be considered in the systems context. In addition, light comes from other sources, and it is most difficult to control the ambient light. The T-39 EL program was formulated to study the lighting problem in the systems context. Electroluminescent lighting is really being used as a tool but a direct result of the program will be the assessment of electroluminescent utility in satisfying the more general problem of lighting.

Bunker Ramo human engineering consulting support to this program under AF33(615)-5225 included the following activities:

(1) Attendance at the roll-out ceremonies for the EL panel at Lear Siegler in Grand Rapids, Michigan

(2) Active participation in the first two monthly program review meetings at FDCR.

Bunker Ramo human engineering consulting support to this program under the current contract included the following activities:

(1) Active participation in all monthly program review meetings at FDCR

(2) Completion of arrangements to forward copies of North American Rockwell's pilot opinion questionnaire to the Instrument Pilot Instructors School at Randolph Air Force Base via Bunker Ramo's San Antonio contract personnel

(3) Review of the results of the cockpit lighting questionnaire survey conducted by North American Rockwell

(4) Discussion of the experimenter's station in the T-39 flight test aircraft

(5) Review of the flight test plan submitted by North American Rockwell

(6) Assisted in the preparation and made the presentation of the paper, "A program in Cockpit Lighting," at the 13th annual meeting of the Human Factors Society, Philadelphia, Pennsylvania, 7 October 1969

(7) Visit to North American Rockwell facilities in Columbus, Ohio, to discuss the experimental design for the EL panel evaluation

(8) Participation in the flight test plan review with Bomber Operations personnel

(9) Preparation of written comments on report by North American Rockwell on "A Survey of U.S. Air Force Pilot Opinion on Cockpit Lighting"

(10) Data collection in the T-39 test aircraft

(11) Review of the Final Report.

(3) SAR

A joint service program on advanced avionic requirements for SAR in the near time frame of 1972-1980 was initiated in 1969. The program is unique in that four services (Air Force, Navy, Army, and Coast Guard) are jointly engaged in the program.

In terms of the technical effort, Honeywell was given a contract in 1969 to define the avionic requirements of an advanced SAR Helicopter. Two basic missions were considered which encompassed the requirements of the four services. Conventional analytical techniques were employed. A report was prepared and submitted for review early last fiscal year.

The Joint-Service Working Group decided that the next step was to evaluate the configuration defined by the analysis. At about the same time, the Working Group learned that a new SAR vehicle would not be forthcoming in the time period being considered in the study. The Air Force has determined that the HH-53 will be the basic SAR helicopter in the 70s.

The problem for FGR then became one of determining if the configuration proposed by Honeywell would be suitable in the HH-53 to the Air Force operational requirements. Certainly it was important that Air Force interests be protected along these lines.

The Flight Deck Development Branch undertook to develop an in-house evaluation capability to be able to look into specific Air Force problems. Additionally the capability would be available to support the Working Group if the need should arise. Bunker Ramo constructed a mock-up of the cockpit, complete with models of the armor shielded HH-53 seats. A sample problem was selected for analysis to demonstrate the capability. In this case it was the Before Engine Start Checklist and had to do with unwieldy procedures—a major complaint of HH-53 pilots. The study used the technique developed in the Crew Station Management Program. The investigation showed why the particular arrangement of switches and sequence of checklist items caused problems for the crew and developed a solution. A film was made documenting the work. Bunker Ramo provided technical inputs to the filming and generated the script.

# SECTION IV

# CONTROL-DISPLAY INFORMATION SYSTEM

The maintenance of the day-to-day operation of satisfying the technical information requirements of control-display researchers is in itself a major task. Engineering inquiries must be processed by the librarian and new data must be placed in the data bank. Future development of the Control-Display Information System requires an iterative design process to ensure that realistic system requirements are specified. The state of the art in scientific and technical data storage and retrieval techniques does not provide an adequate solution to the unique requirements of the control-display community. However, a carefully planned and cautiously executed project to determine and verify user characteristics will provide a substantial basis for the future development of the required system. To systematically design, verify, and implement future generations of the control-display data function requires consideration of the extremely elusive and difficult problems of developing a system that will be responsive to the variety of interests, technical backgrounds, and experience of the potential user population. The current technical data search and retrieval problem is largely a result of hereditary constraints imposed by library systems that were designed to store published documents. A control-display technical report is a different type of document written with a substantially different purpose in mind and useful to a very select, but widely varied, audience. Nevertheless, a characteristic search and retrieval approach suggested that search and retrieval problems could be alleviated by converting an inadequate manual system to a semiautomatic mechanized system. A properly designed search and retrieval system utilizing the computer to its fullest potential will not only save time in retrieving information but could possibly save manpower. To accomplish the technical requirements of this program, Bunker Ramo has utilized the information retrieval skills available within the Corporate organization and has directed effort toward the following tasks.

## 1. DEVELOPMENT OF A STORAGE AND RETRIEVAL SYSTEM

The objective of this task was to develop a semiautomatic information center by developing a software package to use a computer for storage and retrieval of documents.

The design of the software was to have the following four restrictions:

(1) A modular approach was to be utilized in writing the software

(2) All programs were to be written in FORTRAN IV to facilitate conversion to a different hardware system

(3) The system was to be considered as an interim capability and therefore certain short cuts were permissible (for example, the file editing capability could be limited and software documentation could be kept to a minimum)

(4) The software package would be implemented on the IBM 7094 computer at Wright-Patterson Air Force Base. The system developed under this design, which was named the Control Display Information Center (CDIC) Storage and Retrieval Software Package, is described below.

The CDIC S&R system consists of three basic modules which contain a total of five programs. These modules work independently of each other as do the individual programs within the three modules.

a. Update Module

The update module consists of a single program called UPDT. This module adds the new records to the data base. There are four steps to follow in using the update module:

(1) Coding

(2) Keypunching

(3) Mechanical sorting

(4) Program UPDT run

The first three steps deal with the manual preparation of the data to be entered into the system. A more detailed explanation of the coding and keypunching instructions is contained in "Guidelines for Indexing and Coding Information Intended for the CDIC Computerized Data Base," Working Paper No. 10, dated 24 December 1969. The punched cards are then sorted by CDIC accession number and record sequence number and are submitted for a program UPDT run.

b. Query Module

The query module consists of a single program called CDIC. This module provides the search capabilities of the system through two basic types of searches:

(1) <u>Filter Query</u>. This query filters any item equal to the request (i.e., filter author equal to Joe Doe).

(2) Scored Query. This query provides the keyword and phrase search capabilities through any of the fields on the data base (i.e., score 1 for key word computer in text). Figure 1 presents an example of a scored search.

c. Listing Module

This module provides the Control Display Information Center with the various listings that aid in the manual searching of the system. Three programs provide this capability. All of the listings are on standard computer printouts in formats dependent upon the information contained.

(1) ACSKWS: Two listings

(a) Accession Number: This is a listing of the entire data base sorted by CDIC accession number.

(b) KWIC Index: This listing is generated by deleting non-essential terms from the titles and then sorting the remaining terms in alphabetical order and listing these terms with their corresponding file numbers and truncated titles. The KWIC Index is stored on magnetic tape.

(2) BOOK: Nine listings

(a) Author: Lists the authors alphabetically with the associated CDIC numbers.

(b) Sponsor: Lists the sponsoring agency and the CDIC number of the corresponding document.

(c) Report Number: Gives the report number of all documents that fall into this class along with the CDIC number.

(d) Agency: This is a list of the author's organization and the corresponding CDIC number of the record.

(e) Task Number: This lists the Air Force task number and the associated CDIC number of the entry.

(f) Contract Number: This is a listing of Air Force contract number and the record's CDIC accession number.

(g) Project Number: This listing contains the Air Force project number and the CDIC accession number.

```
FILTER*ITEM*EQUAL*TO*REPORT*$
SCORE*40*FOR*PHRASE*TERRAIN FOLLOWING DISPLAY*IN*TITLE*$
SCORE*20*FOR*PHRASE*TERRAIN FOLLOWING DISPLAY*IN*TEXT*$
SCORE*1*FOR*KEYWORD*TERRAIN*IN*TEXT*$
SCORE*3*FOR*KEYWORD*CLEARANCE*IN*TEXT*$
SCORE*3*FOR*KEYWORD*AVOIDANCE*IN*TEXT*$
OUTPUT*ALL*SCORES*GREATER*THAN*4*$
END*$

SCORE.................. 50
CDIC NUMBER ........... 243
TITLE.................. RESEARCH IN NEW TECHNIQUES FOR CONTROL-DISPLAY
                        TERRAIN FOLLOWING DISPLAYS
AUTHOR................. HANES, L. F./WILLIAMS, W. L./SCHUMACHER, J. A./
                        RITCHIE, M. L.
AUTHOR AGENCY ......... RITCHIE INC.
SPONSOR AGENCY ........ A.F. - FDL
ITEM CATEGORY.......... REPORT
PRINTING DATE ......... NOV 1964
REPORT NUMBER.......... FDL TDR 64-000
CONTRACT NUMBER........ AF33(615)-1189
PROJECT NUMBER ........ 6190
TASK NUMBER ........... 619008
DDC ORDER NUMBER ...... NONE
ABSTRACT............... THIS REPORT PRESENTS THE RESULTS OF ANALYTIC AND
                        EXPERIMENTAL WORK PERFORMED BY RITCHIE INC. IN
                        DESIGNING AN ENSEMBLE OF TERRAIN FOLLOWING DIS-
                        PLAYS FOR A HYPOTHETICAL TACTICAL V/STOL AIRCRAFT.
                        THE OPERATIONAL AND INFORMATION REQUIREMENTS FOR
                        LOW ALTITUDE HIGH SPEED (LAHS) FLIGHT WERE DEFINED
                        UNDER AN EARLIER AIR FORCE CONTRACT. THREE ALTI-
                        TITUDE TACTICS - TERRAIN CLEARANCE, TERRAIN FOLLOW-
                        ING, AND TERRAIN AVOIDANCE - WERE ALSO DEFINED.
```

Figure 1. Scored Search

(h) DDC Number: This is a listing of the Defense Documentation Center number and the CDIC number of the document.

(i) Title: This is an alphabetical listing of the titles on the CDIC data base.

(3) PRTC: This program prints a document when requested by its CDIC accession number.

The "Control Display Information Center Storage and Retrieval" software package described above was designed and implemented on the IBM 7094. This package is completely operational and is being maintained by Flight Deck Development Branch personnel. The entire software package was converted to the Control Data Corporation 6600 computer by the Computer Center programmers with the assistance of Bunker Ramo. At the present time, plans call for the software capability to be maintained on both the CDC 6600 and the IBM 7094 until the IBM computer is phased out.

## 2. USER NEEDS STUDY

The objective was to interview prospective users in an effort to determine their information requirements in the control-display area.

Structured interviews were conducted with various users of CDIC. The users were asked to describe how they go about their tasks. Particular attention was given to information inputs and outputs of user tasks, as well as to the information processes and needs involved in these tasks. Subsequent to the user interviews, function flow logic diagrams were drawn describing the information patterns ascertained from the user interviews. The various tasks performed in FGR were grouped according to similarities in the function flow logic diagrams describing these tasks. A list of the information sources, processes, and needs of the users were ascertained from the interviews.

A conclusion drawn from the study was that CDIC should provide this information whenever possible. Toward this end, CDIC should provide or have access to textual material (stored literature, current literature, textbooks, contract files, blueprints, handbooks, proposals, and company brochures). A more detailed explanation of the user survey is contained in Working Paper No. 8, 5 September 1969.

## 3. COORDINATE INDEXING SCHEME

The objective was to explore the possibilities of using a coordinate indexing system to improve the interim CDIC computerized storage and retrieval system.

Concurrent to the user needs survey, consideration was given to "how do we supply information of need to the user." The various techniques for the storage and retrieval of information were reviewed. Based on the following considerations, a coordinate indexing system was chosen as an appropriate technique.

(1) This scheme allowed for variation in concept formation between engineers and psychologists.

(2) It lends itself to automation.

(3) A study by Debons, Scheffler, and Snide (AFFDL-TR-67-119) indicated that a coordinate system would be appropriate for CDIC.

The proposed coordinate indexing system was presented and it was agreed that a modified version (due to personnel considerations) of this system be implemented on an interim basis to determine the feasibility of this system in the FGR environment. The modified system would be a free indexed semiautomatic system.

The general principle behind coordinate indexing is the determination of terms that are descriptive of the concepts in a document. When a search is run on a topic, terms descriptive of the concept in question are matched (by boolean logic) against the terms used to describe the documents. If the terms describing the document meet the logical grouping of terms in the search questions, the documents described by these terms would be listed. The test system was designed and programs written in FORTRAN for the IBM 7094 (102 documents were free indexed to comprise the initial file). A feasibility study was conducted and it was determined that, although the concept was good, the manual indexing of terms for each document was a monumental task. Therefore, this particular trial system has been dropped in favor of exploring a more automated indexing system.

4. GUIDELINES FOR INDEXING AND CODING DOCUMENTS

The objective was to establish a rigid set of rules or guidelines to assist indexers in coding information for the CDIC computerized data base.

The guidelines were established to assist indexers in coding information (documents) for the Control Display Information Center and as an initial step in standardizing the input data to the present computerized system. While every attempt was made to clarify the coding procedures, it was clearly understood that all documents would not fall neatly into one of the categories discussed in Working Paper No. 10, "Guidelines for Indexing." Therefore, the point was stressed that when a question did arise, help should be solicited from the CDIC librarian. Guidelines for coding CDIC report items (technical, documentary, contractor, progress, final and interim reports, brochures, special publications, theses, technical memorandums, technical notes, symposium papers, journal and magazine articles, FTD notices, summaries, bibliographies and proprietary documents) and keypunching instructions for coding these data are completely covered in the Working Paper No. 10. This document is available to all FGR contractors, and all future reports received in CDIC from FGR contractors should comply with these specifications.

## 5. ADDITION OF 1000 DOCUMENTS TO THE SEMI-AUTOMATIC COMPUTERIZED DATA BASE

The objective of this task was to enter a block of 1000 documents into the computerized data base from the manual retrieval system. This exercise was undertaken to determine what problems would be encountered when entering large blocks of documents into the computerized system. The completion of this task brought the total number of CDIC records on the computerized data base to 2250.

Considering the above factors the following are possible courses of action:

(1) Utilize part-time students to code the citation data. This data would be sent to Building 57 for keypunching. Textual data would be pre-edited and sent to an outside firm for keypunching.

(2) Citation and textual data would be coded by part-time students and sent to Building 57 for keypunching.

(3) The author and title would be the only citation data that would be input to the system. Textual data would be pre-edited and sent to an outside firm for keypunching.

A detailed cost break down for all three courses of action is covered in Working Paper No. 9, 10 November 1969.

## 6. FUTURE BACKLOG PROCESSING

The objective was to (1) document the approach taken in processing 1000 CDIC records from the manual system to a semiautomatic system and the problems encountered in this work effort, and (2) suggest methods for processing the remaining 3000 backlog records and possible problems which may influence the rate of input.

The initial effort was to determine the input problems and costs associated with processing a block of CDIC records so that we might be able to better judge future courses of action. Flow charts were utilized to show the technique used in processing the 1000 documents. Complete details of the processing technique and the associated problems encountered are outlined in Working Paper No. 9, 10 November 1969.

There appear to be several possible courses of action which may be utilized in processing the remaining 3000 backlog records in CDIC. In approaching the problem the following factors were established:

(1) A CDIC record is divided into two parts:

(a) Citation data

(b) Textual data (abstract)

(2) The possibility exists that some of the CDIC McBee cards are incomplete

(3) Citation data will be coded manually and sent to Building 57 for keypunching

(4) All textual data must be pre-edited

(5) Three thousand backlog records remain for processing (in addition, there will be approximately 100 new records received per month for processing)

(6) Keypunching costs are approximately $0.05 per card.

During this task, small blocks of hard copy documents were pulled from the CDIC files for processing into the system. The bibliographic (citation) data were edited, coded, and sent to Building 57 for keypunching,and the text (abstract) was edited and sent to Steele Data Processing in Washington C.H., Ohio, for keypunching. Two of the problems encountered with this phase of the operation were: (1) incompatibilities between the IBM 026 keypunch machine used by Steele Data Processing and the IBM 7094 computer and (2) keypunch errors which resulted because of a misunderstanding in coding instructions. After all the information had been coded onto IBM punched cards, the cards then required sorting according to the CDIC accession and sequence numbers before entering the information in the computer data base. The sort procedure was complicated by an inferior quality card used by Steele Data Processing. The cards were difficult to process using the IBM card sorter. This exercise provided CDIC personnel with valuable experience regarding the problems associated with data input as well as some knowledge of procedures to incorporate when planning for the processing of future documents.

## 7. PROCESSING OF THE CDIC BACKLOG (3000 DOCUMENTS)

The objective was to process 3000 backlog documents into the CDIC data bank.

The task of processing the backlog documents was broken out into three separate subtasks: (1) input preparation, (2) coding and keypunching, and (3) updating the data base. Bunker Ramo provided overall guidance throughout the entire operation in all phases and was specifically responsible for input preparation and updating the data base. The Flight Deck Development Branch was able to make a full time clerk available for processing (coding) the documents. Keypunching was handled by the Computer Center personnel. All 3000 documents were processed within one year.

## 8. CONTROL DISPLAY INFORMATION CENTER BROCHURE

The objective was to produce a brochure which would convey to the general aerospace community the capabilities and mission of the Control Display Information Center (CDIC).

An outline of the entire system (CDIC) was prepared explaining the following major items: (1) Misson of CDIC, (2) Range and Type of Information in CDIC, (3) Who Used CDIC, (4) Services Provided by CDIC, (5) Advantages to Users of Utilizing CDIC, (6) CDIC Response to Specific Needs, (7) Procedures for Using CDIC, and (8) Location of the Center. The outline was reviewed by Bunker Ramo and Flight Deck Development Branch personnel several times until a final draft was approved. The outline was then given to a technical writer from Horstman Printing Company. After several review cycles by all parties concerned, the brochure was approved and 2000 copies were printed.

## 9. CONVERSION OF CDIC IBM 7094 SOFTWARE PROGRAMS TO THE CONTROL DATA CORPORATION 6600 COMPUTER

The objective was to convert the CDIC programs written for the IBM 7094 computer to the new Control Data Corporation 6600 computer.

This task was divided into several major areas of responsibility. Computer Center personnel were concerned with the actual conversion of the software and where necessary new programs were written. Bunker Ramo furnished general consulting on all phases of the operation and was specifically responsible for the acceptance testing phase. Although many computer problems were experienced, the software has been converted to the CDC 6600 computer and is now fully operational.

# SECTION V

## RESEARCH CONTROL PROCESS PROGRAM

Avionics state-of-the-art advances have had a significant impact upon the complexity of managing and controlling the progress of flight control-display research. Mechanization constraints have been removed, thereby eliminating size and weight as areas of primary concern. The "what to do," then becomes more important than the "how to do." Degrees of freedom are available today to the control-display research technical manager which were unheard of a decade ago. However, this new degree of freedom is accompanied by a failure risk which, unfortunately, has risen proportionately in terms of dollars. The success of a program depends on properly implementing the program, updating the information on the execution of the program, and critiquing the performance of the program.

As stated earlier, management and control of the technical activity is an integral part of the total research system for conducting flight control-display research. The capability to direct research is as essential to success as the quality of the technical work itself. This may be illustrated by referring to the "productivity equation:"

Execution + Direction = Productivity

The capability to execute has reached an unprecedented level. Attention must now be devoted to maximizing the capability to manage and control that research if maximum productivity is to be realized.

The peculiar and unique demands of control-display research in the exploratory research environment require that the technical manager be provided with a system tailored to his specific requirements. The processes which are available to him today were created largely in the era of "component" design. Consideration of the "system" impact upon the control and management of control-display research must be introduced into the process if the productivity factor is to be maximized.

The problem then is really one of designing an interface between the technical manager and the system which he must direct and control. Generally speaking, it is a man/machine problem, and as such, human engineering can play a vital role in determining the objectives of the system and defining the approach which must be taken to realize these objectives.

## 1. THE APPROACH

### a. Functional Requirements

A basic contention emphasized by Bunker Ramo throughout the development stages of the system has been the importance of the functional requirements; therefore, these functional requirements have remained unchanged throughout the development, implementation, and maintenance of the system. A brief description of each follows.

#### (1) Communication

Effective two-way communication is vital when results are dependent on an exchange of information between managers and engineers. Front line management must be responsive to everyday needs and to the needs of top management.

#### (2) Multi-Project Control

A great need exists for integration of resources, schedules, and performance control for single projects. An even greater need exists for the development of simultaneous multi-project control techniques since today's Project 6190 manager must function in a total system environment, controlling projects of varying value, duration, and technical complexity.

#### (3) Character

Certain research requirements exist which are peculiar to control-display research; therefore, a system for management control must have "character" (i.e., a uniqueness which is tailored to the specific needs of Project 6190).

#### (4) Evaluation

The quality of performance of future control-display research programs can be improved only if management utilizes a system that will establish a set of indicators to judge the degree of success in satisfying the goals and objectives of a program.

#### (5) Compatibility

The system should be designed open-ended to facilitate integration with other systems being employed. It must respond to the real information needs of managers at all levels, achieving objectives without damaging the existing planning and command structures.

b. Major Steps

In considering the problem of developing a control system for management of research, it was necessary to separate the problem into its major elements so that it could be attacked systematically. Bunker Ramo considered the elements as being defined in terms of the sequence of activities that must be accomplished in conducting a research program. The sequence is one of planning the program, executing the program, and evaluating the program.

(1) Planning

The manager must formulate the problem statement and communicate this to those responsible for technical work so that the project engineer may undertake the planning of the detailed program. From the dialog which takes place between the project manager and the project engineer, the engineer derives a firm understanding of what is required and the manager derives confidence that the program can be conducted within the time specified. The culmination of these related activities is approval or disapproval for the pending program.

(2) Maintenance and Update

While the technical program is being conducted, the flow of status information must be continuously updated and presented to the manager so that problems which may threaten the completion of the program may be dealt with. There must be a set of indicators established so that it is possible to gauge the degree of success the project is having in meeting original goals and objectives. This set of indicators will facilitate trade-off studies on resources across all programs.

(3) Evaluation

Evaluation is an important aspect of the program inasmuch as future programs can benefit from experience gained in past research.

Bunker Ramo utilized a modular approach in attacking each of the three problem elements. This "building block" approach permitted immediate implementation of the subsystems without waiting for the entire system to be developed. Each module was designed and developed using the following steps:

(1) Analyze management requirements. Determine pertinent data needed by management to effectively control research projects.

(2) Format management data. Studying the output format through mockup design, selecting most promising from alternative configurations.

(3) Develop software. Determined appropriate data processing techniques in gathering, transmitting, storing, and retrieving information.

(4) Perform operational tests. Test each management tool or subsystem operationally to verify validity of the approach.

(5) Prepare documentation. Documenting each module as it is developed, tested, and verified.

## 2. PROGRESS

The objectives and status of each of the Research Control Process tasks are discussed in the following paragraphs.

### a. Remote Terminal

The objective was to explore the potential of the on-line terminal with a CRT and printer. The need for some type of remote terminal became evident during the design and development of the FGR information system. The following problem areas prompted further investigation into remote terminal capabilities:

(1) Volume of input data to maintain the various management systems caused "peak workload periods."

(2) Turn-around time on management queries became lengthy due to number of active files.

(3) Manpower limitations restricted daily operation of the system and pointed out the need for increased mechanization.

Mechanization of the system was undertaken with the installation of a Bunker Ramo remote terminal with a CRT. The equipment was obtained on a loan basis to explore the benefits possible from utilizing such hardware. The initial phase was strictly a familiarization exercise. The control unit was interfaced with a compact tape recorder for playback and display of reports (data) on the CRT. Because the initial phase was so successful, the decision was made to interface the remote terminal equipment with a computer. A three month demonstration phase was scheduled utilizing a limited financial data base from which management reports were generated on the CRT display screen and/or the printer. Figure 2 represents a section of a management report displayed on the CRT display screen.

This phase of development was more difficult than originally anticipated because of the amount of detailed work required to get the system "on the air."

| | |
|---|---|
| FDCR CONTRACTS | SET 2 OF 5<br>(by official completion date) |
| PROJECT-TASK-WORK UNIT -<br>6190-09-015 | TITLE-GAS DISCHARGE<br>DISPLAY |
| REMARKS | |
| CONTRACT NUMBER - F33615-<br>69-C-1355 | CONTRACTOR - SPERRY |
| RESPONSIBLE ENG - LAWRENCE | |
| ESTIMATED COMPLETE DATE -<br>700309 | OFFICIAL COMPLETE DATE<br>70039 |

(80 characters horizontal, 12 lines vertical)

Figure 2. CRT Display Screen

Because the Bunker Ramo 2200 remote terminal was provided on a loan basis at no cost, efforts were made to locate a computer which was compatible with the equipment (software compatibility: interface routines were already written and debugged and were therefore considered off-the-shelf items). Several possibilities were explored and the decision was made to interface with a Honeywell 1200 located at Technology, Inc., Dayton, Ohio. The deciding factor in favor of the Honeywell 1200 was that the interface software had been developed and was stated to be completely operational. (A statement by a computer firm to the effect that a program is "operational" does not imply that you merely input the program and are automatically "on the air.") Bunker Ramo's experience has been that usually some modifications, either major or minor, are necessary before going "on the air."

The approach employed to interface the remote terminal with the computer and the development of programs to be utilized by the system was grouped in two main activities.

b. System Implementation and Control

The specific approach to this phase of the remote terminal development is outlined in the following paragraphs and illustrated in Figure 3. Five stages or activities were involved.

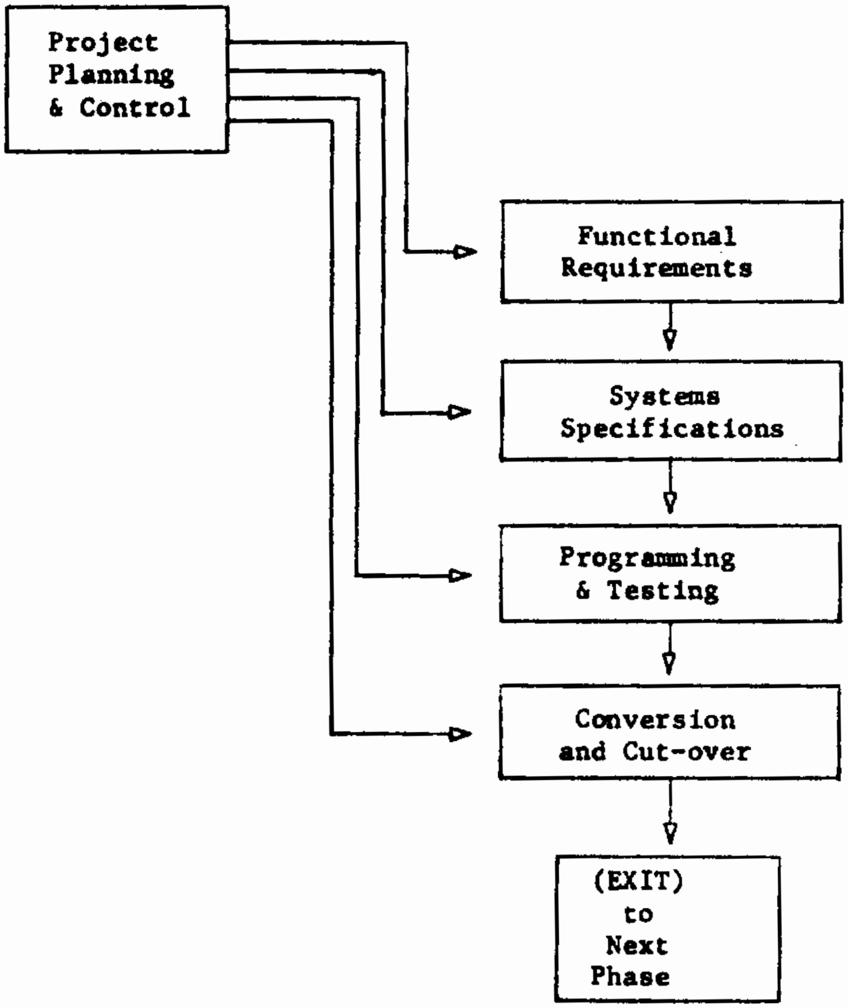


Figure 3. System Implementation and Control

(1) Project Planning and Control

The scope of this activity was general control of all phases and accountability for the success of the entire project. This included scheduling, project budgeting, initiation of phases, and technical review. This responsibility was assigned to one on-site individual, thereby providing a single focus for planning and control of the entire project. It was logical that this person be on-site to provide technical and administrative continuity to the project. Detailed schedules, budgets, and required manpower estimates were established during this phase. Monthly progress reports were initiated and scheduled throughout the entire development phase.

(2) Functional Requirements

The objective was to establish complete and comprehensive specifications of precisely what the system was to do from a functional standpoint and communicate this information to the system designer and to the ultimate user. The user (FGR) reviewed these specifications and when approved the system designer proceeded with detailed design and development. This phase was conducted informally because of the nature of the program and due to time restraints.

(3) Systems Specifications

The objective was to specify precisely how the system was to fulfill the functional requirements and to specify the required data formats (Input and Output/Management Reports/Specifications). A financial data base with management report formats was selected for the initial three month demonstration. Bunker Ramo in-plant programming personnel were utilized to write application programs. Detailed data I/O specifications with desired management report formats were developed on-site by the systems analyst. The computer, peripherals, communications, and terminal hardware requirements were specified by the systems analyst. Programming language to be used, test specifications, conversion plan, record and file designs were assigned to the in-plant programmers.

(4) Programming and Testing

The objective was to write the application programs necessary to conform to the design outlined in the system specification phase. All programs were written by in-plant personnel at Bunker Ramo, California. This effort was limited to compiling the programs in California and final debugging on-site. The formal and complete operating instructions and manual procedures for the system were developed through a combination of efforts by the systems analyst and in-plant programming personnel. The training of the users (FGR) and operating personnel was conducted by the systems analyst.

(5) Conversion and Cut-Over

The objective was to permit the user (FGR) to formally accept the system prior to cut-over. The systems analyst conducted a thorough explanation of system capabilities for the user and demonstrated the operating techniques before officially giving the user full responsibility for operation of the system.

Although this was a six-month exercise, it was desirable to follow some of the more formal steps (System Implementation and Control, etc.), thereby setting the mode of operation for implementation of a more sophisticated system.

Although most of the preceding activities were conducted informally, the importance of these activities in the implementation of a successful system cannot be overemphasized.

c. Hardware Planning, Procurement and Installation

The objective was to use the basic hardware specifications developed during the system design (specification) phase as a starting point for developing detailed hardware configuration specifications. Since it was tentatively planned that Bunker Ramo would provide a remote terminal at no cost to the contract, there remained only the matter of specifying the exact equipment which would satisfy the I/O requirements of the system. A qualified system analyst was consulted prior to considering what buffers, control units, and other essential items would be appropriate for the system. Installation requirements were studied in depth to assure an efficient operation and to prevent any large time delays. Installation requirements considered were:

Size of the room where the equipment was to be installed

Computer location

Peripheral equipment location in relationship to the control unit

Budget coverage for the cost of the installation

The required equipment for the system was:

Remote terminal (includes keyboard, CRT, control unit, two buffer modules, control module, two data sets, and output only printer)

Telephone line

281-R control unit (Honeywell)

Honeywell 1200 computer

Technical Memorandum AFFDL-TM-72-1-FGR, "Remote Terminal Overall System Specification - Design, Installation, and Testing" was written describing the entire program starting with the system specification through the hardware installation phase.

Figure 4 presents the system hardware configuration.

d. Evaluation of Remote Terminal Concept

The objectives of the study (evaluation) were to explore the potential benefits of utilizing the remote terminal data entry concept for providing a more efficient means of managing data, and gain an insight into future software and hardware requirements for an operational remote terminal system.

The study was specifically concerned with answering the following questions: (1) can secretarial personnel effectively use the remote terminal, thereby eliminating the need for skilled operators? (2) and if secretarial personnel can be used for data input utilizing the remote terminal, what is the training time for bringing this type of individual up-to-speed? Results indicate that secretarial personnel can effectively use the remote terminal and training time is certainly within acceptable limits. The study is documented in Technical Memorandum AFFDL-TM-72-2-FGR, "Evaluation of the Remote Terminal Data Entry Concept."

e. Division 1498/1634 Storage and Retrieval System

The objective was to implement the present Flight Deck Development Branch's (FGR) storage and retrieval system to handle the entire divisional 1498/1634 document file.

The various steps followed were: (1) copies of the current 1498/1634s were obtained, (2) initial data were coded and sent to Building 57 for keypunching, (3) textual fields such as objective, approach, and progress were sent to an outside keypunching firm, (4) input data were processed and merged, and (5) data were stored on magnetic tapes.

Operating procedures for updating the new data base were introduced These procedures included system flow charts pertaining to data switching, number changes, and special consideration for FGR data. The entire Divisional 1498 file was established and maintained on the IBM 7094.

f. Development of a New File Update Program

The objective was to develop software for processing (updating) FGRs present 1498 data bank utilizing the division punched cards. (This would make FGR storage and retrieval system available on an Air Force wide basis.) These cards were keypunched in accordance with the format specified in DSAM4185.5, which was not compatible with the FGR storage and retrieval system.

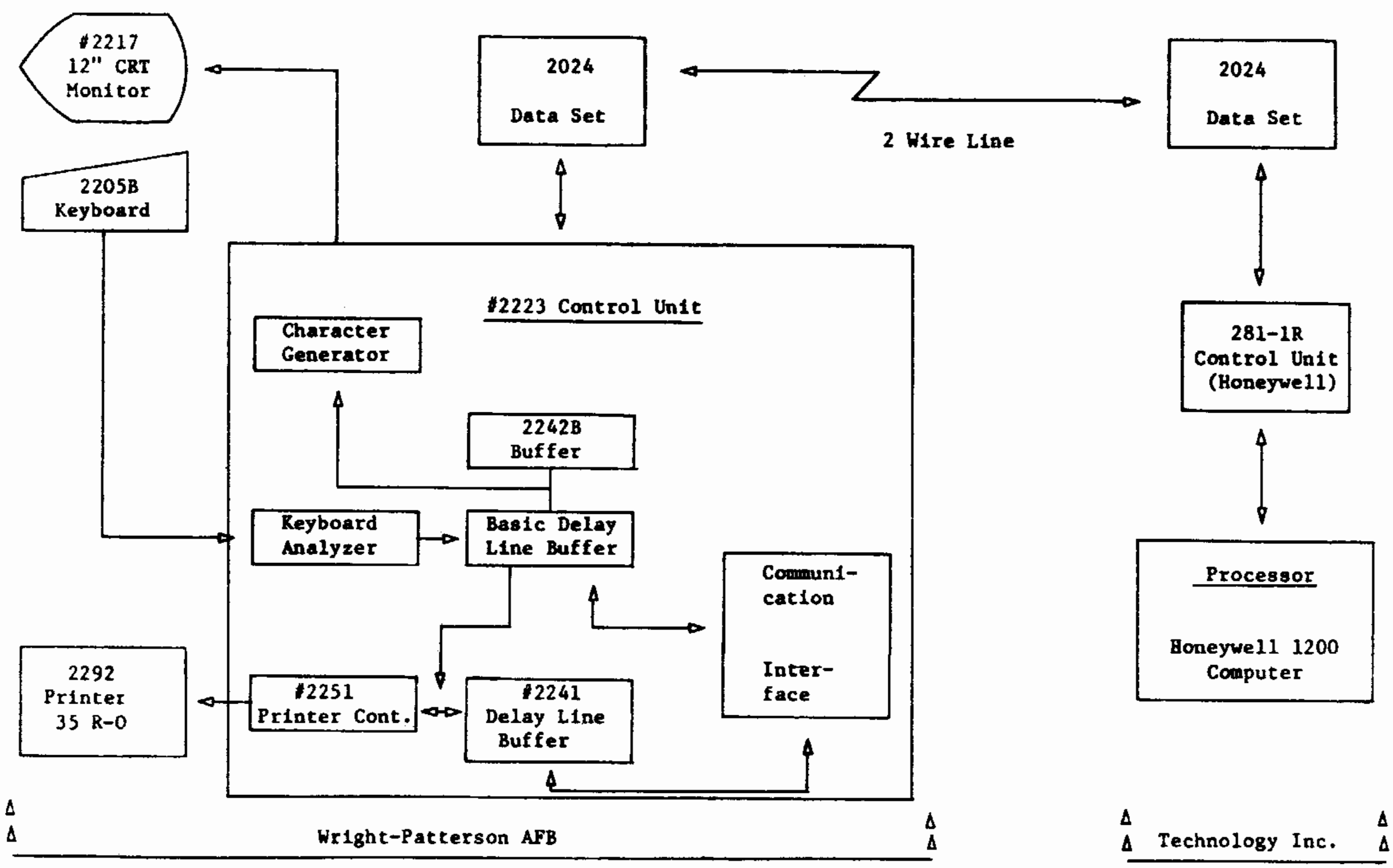


Figure 4. System Configuration

Two possible courses of action were considered: (1) conversion of laboratory punched cards to our format; that is, write a program to convert the data to a format compatible with the FGR system, either card to tape or card to card and (2) write new software to facilitate inputting data in its present format. This would entail writing a new update program.

The second course of action (write new software) was selected as being more desirable because (1) less computer time would be required and (2) turn-around time would be minimized by reducing number of runs.

The program was written and debugged in three weeks utilizing the services of three programmers. A system analyst was utilized for approximately four days and set up the major portion of the program. Two on-site programmers analyzed the initial card formats and debugged the final product.

At the present time, a complete storage and retrieval system is established for the laboratory 1498/1634s and for the FGR data base on the IBM 7094 computer. This software package consists of four modules: (1) preprocessor, (2) update, (3) number change, and (4) RPG.

A detailed new documentation package has been written. It is divided into two main parts: (1) User's Manual and (2) Operation of the System.

The "User's Manual" describes the general system operation and contains examples of reports which can be generated from the data base. The "Operation of the System" manual gives a detailed description of system maintenance and operation illustrated with flow charts and system procedures. All four modules are explained in detail with source deck listing. The RPG "Report Processor Generator" is explained in detail with program instructions regarding the generation of "User Query" reports.

g. Development of a Standard RPG Library

The objective was to write approximately 20 report generator programs to be run against the laboratory 1498/1634 data bank. The library would contain only the most commonly requested reports.

The reports were written and debugged. A system was established which enabled Laboratory and Branch personnel to merely submit the report decks to Building 57 (Computer Center) for processing and the desired reports would be generated from the most current data base. Program decks were duplicated which allowed Bunker Ramo to establish a set of programs for both the Branch (FGR) and the Laboratory.

h. Research Control Process Paper

The objective was to write a paper which would provide both the conceptual and operational considerations pertaining to project management in the Research and Development environment from the viewpoint of the people involved at the working level. Methodology developed in the area of cockpit engineering was cross-applied to studying the management problem confronting project scientists and engineers today.

The paper conveyed the experiences of Bunker Ramo and the Flight Deck Development Branch in applying a real-time simulation approach, developed for attacking cockpit design problems, to the understanding of management problems. It was pointed out that this approach was necessary as a prerequisite to specifying the requirements for a fully integrated and responsive system at the project level. This approach resulted in the problem being conceptualized as a man-machine interface problem in which the system is comprised of people and resources that must be controlled by the man (manager).

Four modules: technical scheduling, manpower, financial, and documentation storage and retrieval were described as the tools used for studying the management problem in its environment. The results of the study indicated that in Research and Development a responsive system must be built at the most detailed level and then information summarized upward. Attempts to implement the system from upper management will only result in partial and fragmented solutions.

The paper "Project Management in the R & D Environment: A Man/Machine Interface Problem" was presented at the Annual Project Management Institute Seminar/Symposium in Saint Louis on 23 October 1970.

i. Manpower Estimating Package

The objective was to develop a set of methods and procedures for estimating manning requirements for Flight Deck Development Branch work efforts. The system was designed to be usable at the branch level and also meet the requirements set forth in the Division "Manpower Utilization and Requirements" Report.

A set of procedures were developed for the collection and tabulation of Estimated Manpower Requirements for the Flight Deck Development Branch. The system consisted of five sections: (1) Manpower Requirements by Job Order Number, (2) Manpower Estimates by Individual, (3) Manpower Summary by Category, (4) Manpower Estimate Curves by Category, and (5) Division "Manpower Utilization and Requirements" Report. This system is now operational.

# SECTION VI

# FACILITY INTEGRATION PROGRAM

The general aim of this program is to develop a total research capability that will enable control-display researchers to expediently conduct studies in FGR facilities. The researcher ultimately will have available to him a capability covering an entire spectrum of experimental sophistication. To obtain the greatest potential from this program, each capability in the research facility must be designed for maximum flexibility so that a wide range of control-display problems can be investigated with minimum modification. The approach will ensure maximum responsiveness to new or additional research requirements. By careful planning and designing of an integrated research facility, the problems associated with changing research direction to meet new operational requirements will be minimized.

Work on the Facilities Integration Program was initiated under AF33(615)-5225 and was completed under this contract. The objectives and status of each of the facility integration tasks for which Bunker Ramo has provided human engineering support are presented below.

## 1. ADMINISTRATIVE PROCEDURES FOR UTILIZATION OF THE MULTI-CREW SIMULATOR (MCS) FACILITY

As a part of the development of a ground-based control-display research facility which will have the capability for rapid and efficient conduct of research activities, it is necessary that procedures appropriate for its utilization be established. The objective of this task was to provide support to FGR in establishing such procedures for the MCS facility. As a result of this support effort, an administrative procedures guide was prepared. The procedures guide documented the proposed procedures, and suggested control documents for approval and scheduling of research tasks utilizing the MCS. Included in the guide were standardized formats for the proposed control documents, preparation of research proposals and simulation plans, and for documentation of study results.

## 2. MCS SAMPLE STUDY

A final phase in the development of the MCS facility is the accomplishment of a total system test. Such a test provides a final operation check of the system that serves as a basis for assessing the adequacy of the total facility toward meeting its design objectives. The system test also provides a medium for the future users to gain experience in the operation of the total system under conditions similar to those that will be encountered during the conduct of the planned control-display research program. As such, the system test serves as a training exercise for the research team.

The primary objective of the Sample Study was to exercise to the maximum possible all combinations of the hardware, software, data gathering routines, and experimental procedures. The Sample Study has also provided basic performance data which has assisted in the identification of the simulation vehicle dynamics.

To preclude undesirable delays that might be encountered due to a subsystem malfunction or failure to checkout satisfactorily, the approach used in the Sample Study was multi-phase. The initial phase consisted of operational checks of individual subsystems. A second phase consisted of operational checks of selected combinations of subsystems that checked satisfactorily in the first phase. The third phase consisted of a brief experimental study employing the total system capability. Through this systematic "building blocks" approach to the total system test, assessment of each system element is possible, both independently and as they interact with other system elements. This approach to the system test has resulted in the identification of the five separate testing functions listed below.

a. Sample Study Test Planning

The objective of the Sample Study test planning task was to develop the technical approach to the accomplishment of the system test and to prepare detailed research proposals and test plans for each of the individual subsystem tests. As such, this task served as an operational check and verification of the adequacy of the administrative procedures established for utilizing the facility. A sample study overall test plan was prepared and submitted to FGR for review and coordination with other participating on-site contractor personnel. Subsequent to the review and approval of the overall plan, responsibilities for each of the tests was assigned to the participating team members, with system management for each of the system tests provided by the Air Force and human engineering support to each test provided by Bunker Ramo.

b. Control Response Tests

The purpose of this test was to determine and document the static and dynamic characteristics of the control system model in the MCS. The test plan for this test was completed and approved by the Air Force project engineer. The input/output relationship of each axis of the control system was defined by measurement of output parameters in response to control inputs. Results in the form of dynamic and static response plots (output versus input) for pitch, roll, yaw, and the collective axes of the MCS were reported. Analysis of these data established the degree of fidelity of the control system model. Bunker Ramo provided support to this test in the preparation of the test plan and the conduct of the tests. Results were analyzed and reported by the assigned engineering personnel of the on-site engineering support contractor.

c. Stability and Control Test

The purpose of this test was to empirically establish and document the stability control and handling qualities of the MCS. Standard stability and control parameters, both dynamic and static, were defined by using stability and control flight testing techniques. Bunker Ramo support was provided to the Air Force project engineer and to the responsible test engineer in preparing the test plan, conducting the stability and control tests, and reducing the test data. Handling qualities data from these tests were limited due to scheduling conflicts of the particpating flight test pilot. It is anticipated that further evaluation of the handling qualities will be undertaken during the initial utilization phase of the facility. Documentation of the results of the stability and control tests was provided by the on-site engineering contractor.

d. Motion and Visual System Tests

The objectives of these tests were to determine the operational characteristics of both the motion and visual system to establish their contribution to the vehicle simulation and to determine the compatibility of the simulation cues provided by the separate systems. Tests were conducted by the simulation contractor individually on each system as well as in combination. Human engineering support was provided to assist in the design of the tests and in the collection and analysis of information concerning techniques employed to evaluate visual and motion cues. Results of these tests were documented by the simulation engineering contractor team member.

e. MCS Steep Angle Approach Evaluation

The objective of this test was to demonstrate the research capabilities of the MCS by conducting an evaluation of a display concept in steep angle approaches. The display concept selected for this "simulated" control-display research study is the Flight Profile Indicator which has been developed by FGR. A second objective of the steep angle approach evaluation is to exercise the total system in a context representative of that to be encountered in the utilization of the facility and to develop and exercise the methodology and associated data analysis software necessary to conduct research on the MCS. Bunker Ramo has provided support in preparation of the experimental design, specification of measurement requirements with associated input/output requirements of the operators console, preparation of the simulation test plan, and initiation of the study. Subsequent to the initiation of the pre-experimental phase of the study, work efforts on the conduct of the Steep Angle Approach Evaluation were stopped due to maintenance requirements of the facility. It was decided by the Air Force project engineer at this time that an effort would be undertaken by the simulation contractor to accomplish minor modifications to the facility in conjunction with the necessary maintenance to rectify several limitations of the visual and motion systems that were uncovered during the previous tests and the Sample Study.

## 3. MCS FACILITY ORIENTATION AIDS

As the development, installation, and checkout phases of the MCS facility approached completion, it became increasingly apparent that a need existed for the development of presentation materials that would aid in briefing potential users, study subject pilots and visiting dignitaries to the Flight Dynamics Laboratory. A task was therefore initiated with the objective of developing and preparing the necessary audio and/or visual aids. The two initial efforts in this task have been (1) the preparation of a "standardized" briefing and orientation flight and (2) the development of a video-tape recording of an orientation briefing on the MCS facility. The purpose of the orientation video-tape was to provide a brief overview of the MCS facility, its purposes, and capabilities. The video-tape recording has been tailored so that it can "stand-by-itself" to orient the visiting dignitary type, whose time is usually limited, or can be followed up with more detailed briefings appropriate for the orientation and training of intended users or participants in the research studies. Bunker Ramo supported the Air Force project engineer in the development of the script and visual aids for the film, and prepared the video-recording of the briefing. A pilot-qualified member of the Bunker Ramo human engineering staff developed the orientation flight and has been serving as dmonstration pilot for all demonstrations of the facility.

## 4. MCS DEVELOPMENT HANDBOOK

The objective of this task was to consolidate the documentation of technical activities conducted during the development of the MCS facility. This activity required the structuring of the program working documents to clearly record the development logic of this research simulation facility. This task was initiated under Contract No. AF33(615)-5225 and a draft version of the handbook was prepared. Due to priority of other facility integration tasks, preparation of the handbook in its final format was delayed until other work efforts of this contract could be finished. The handbook draft was reviewed by the Air Force project engineer and determination of its contents for final submittal resolved.

## 5. FACILITY INTEGRATION PROGRAM CONSULTING

In addition to the specific tasks within the facility integration program noted above, continuing human engineering consultation was provided on a variety of simulation facility and V/STOL projects. Additional support was provided in the form of assistance in dissemination of information concerning laboratory programs through several presentations of technical papers at various symposia.

## 6. DOCUMENTATION

Documentation of the Facility Integration Program activities during the contract has made extensive use of working papers for communication between team members and FGR management.

# SECTION VII

# TECHNICAL DOCUMENTATION

All technical documentation produced during this contract by the support group is listed in this section. This documentation has been published in a variety of forms appropriate to the context of the material. The types of reports produced were:

(1) AFFDL Technical Reports

(2) AFFDL Technical Memoranda

(3) IPIS/AFFDL Technical Reports

(4) IPIS/AFFDL Technical Notes

(5) Bunker Ramo Reports

(6) Presentations

(7) Working Papers

(8) Monthly Progress Reports

(9) Interim Progress Report

Copies of all technical documents referenced are available for review in the Control-Display Information Center (CDIC), Building 193, Area B, Wright-Patterson Air Force Base, Ohio. A description and listing by type of report follows.

## 1. TECHNICAL REPORTS

Air Force Flight Dynamics Laboratory Technical Reports (AFFDL-TR) were prepared when it was determined that the technical information involved warranted Air Force wide dissemination. Reports issued were:

| | |
|---|---|
| AFFDL-TR-72-25 | Control of Avionic Subsystems: The Crew Station Management Problem, March 1972, R. Moss, J. Reising, and W. Swartz |
| AFFDL-TR-69-56 | A Study of Displaying Rate-of-Closure Information, March 1970, W. Dalhamer and K. Woodruff |

| | |
|---|---|
| AFFDL-TR-70-109 | Single-Theodolite Tracking of Aircraft Approaches. Methodology. August 1970. Dr. A. C. McTee, G. Mey |

2. AFFDL TECHNICAL MEMORANDUM REPORTS

Air Force Flight Dynamics Laboratory Technical Memorandum Reports (AFFDL-TM) were prepared when it was determined that technical information of an exploratory nature warranted Air Force wide dissemination. The following reports were issued:

| | |
|---|---|
| AFFDL-TM-71-2-FGR | SAR Helicopter Problem Assessment. June 1971, R. Burgin and R. Bondurant |
| AFFDL-TM-72-1-FGR | Remote Terminal Overall System Specification - Design, Installation, and Testing, November 1971, T. Snyer |
| AFFDL-TM-72-2-FGR | Evaluation of the Remote Terminal Data Entry Concept. November 1971, T. Snyder |

3. IPIS/AFFDL TECHNICAL REPORTS

In recognition of the cooperative nature of the inflight evaluations performed by the USAF Instrument Pilot Instructor School (now the USAF Instrjment Flight Center) with technical direction and support of the Flight Deck Development Branch, Air Force Flight Dynamics Laboratory, joint reports of research are issued. This system was adopted during this contract, and one report was issued:

| | |
|---|---|
| IPIS-TR-71-2 | Evaluation of Externally Mounted Head-Up Display. August 1971; Captain R. K. Taylor and A. C. McTee |

4. IPIS/AFFDL TECHNICAL NOTES

For evaluations less formal or of narrower interest, joint IPIS/AFFDL Technical Notes may be issued. Two joint technical notes were issued during the contract term:

| | |
|---|---|
| IPIS-TN-70-3 | Utility of DME Information for Final Approach and Rollout. July 1970; A. C. McTee, Lt. Col. D. M. Condra, Major D. L. Carmack |
| IPIS-TN-71-3 | Lateral Axis Control Display Requirements. June 1971; Major D. L. Carmack, Lt. Col. D. M. Condra and A. C. McTee |

5. BUNKER RAMO REPORTS

Bunker Ramo reports were prepared as an additional means of disseminating technical information on an unlimited distribution basis. The following reports were issued:

Problems Associated with Fighter Aircraft Operations, March 1970, R. Burgin

Considerations for Integrated Aircraft Monitoring and Display Systems, Report No. SA-70-6, July 1970, A. C. McTee

6. PRESENTATIONS

Presentations given by Bunker Ramo personnel provided informal technical information to the aerospace community. Presentations given were:

"Project Management in the R&D Environment: A Man-Machine Interface Problem." Paper presented to the Annual Meeting of the Project Management Association, Saint Louis, Missouri, October 1970. T. Snyder and W. Swartz

"V/STOL Displays and All-Weather Operations." Paper presented to the Technical Conference on V/STOL, sponsored by the USAF Flight Dynamics Laboratory, Las Vegas, Nevada, September 1969. W. Swartz

"Progress of the USAF Inflight Program: Low Speed Control to Landing on Instruments in Helicopters." Paper presented to the 12th Guidance and Control Panel Symposium on Helicopter Guidance and Control - AGARD, Konstanz, Germany, 6-9 June 1971. W. Swartz

7. WORKING PAPERS

Working Papers (WP) provided informal documentation of program status, requirements, and recommendations resulting from day-to-day contact with project team personnel.

a. STOL

1. Review of Mr. Townsend's Memo of 19 June 1970, MCS STOL Program, 2 July 1970. W. Swartz

2. MCS STOL Mag Tape Parameters and Wind Shear Implementation, 6 July 1970. D. Eldredge

3. XC-142 STOL Simulator Power Curve for Pitch Angles of 0°, 3°, 6°, and 9°. 6 July 1970. D. Eldredge

4. Preliminary Report on MCS STOL Approaches Varying Aircraft Configuration and Glide Angles. 16 July 1970. R. Burgin and W. Swartz

5. MCS - STOL Glide Slope, 16 July 1970, D. Eldredge

6. STOL Approach Problem Definition Study, 21 July 1970, R. Walchli

7. Preliminary Analysis of 6° and 9° Approaches (10°/60° wind/flap configuration) with and without Flight Path Angle and Vertical Velocity Displayed, 23 July 1970, D. Eldredge

8. Silent Incapacitation Study - Support to Lt. Col. Shaud, 8 February 1970, D. Eldredge

b. Display Elements

14. Design Considerations for Radio Altimeter Selection, 18 February 1970, R. Burgin

15. Alternate Proposal for Conducting the Rate of Closure Study Using CRT, 18 February 1970, R. Walchli and K. Woodruff

16. Technical Assessment of the Final Report on the "Simulation Evaluation of the Flight Profile Indicator," 18 February 1970, R. Walchli and K. Woodruff

17. Development of a Pilot Opinion Data Collection Package for Display Problem Orientation, 18 March 1970, R. Burgin

18. Recommended Procedure for Generating Follow-Up Plans for the Development, Test and Evaluation of the Flight Profile Indicator, 18 April 1970, K. Woodruff

19. Overview: FPI Developments and Evaluation, 5 May 1970, R. Burgin

20. Overview: Display Elements Program Planning Activities, 5 May 1970, R. Walchli

21. Overview: Rate-of-Closure Display Developments, 5 May 1970, R. Walchli and D. Eldredge

22. Overview: Peripheral Command Indicator (PCI) History, 13 May 1970, D. Eldredge

23. Test Plan for the Use of Pilot Opinion to Determine Aircraft Display Information Requirements, 30 June 1970, R. Burgin

c. Cross-track Rate

1. Progress on the Equipment, Facilities, and Manpower Needed to Conduct the Cross-track Rate Study, 24 June 1971, J. Reising

d. Search and Rescue Project

1. Selection of Methods and Techniques for Evaluating the Search and Rescue Mockpu, 31 March 1971, R. Moss

2. Results of the Evaluation of the HH-53 Before Engine Start Checklist, 17 May 1971, R. Moss and J. Reising

e. EL Landing Display

1. Reasons for the Conditions Specified in FOC of 8 March 1971 and Additional Suggestions for Phase I, 12 March 1971, J. Reising

2. Areas of Investigation to be Considered During the Outer Marker to Decision Height Portion of Phase I, 22 March 1971, J. Reising

f. Facility Integration

24. MCS Steep Angle Approach Evaluation - Pre-Experimental, 24 March 1970, D. Eldredge

25. MCS-STOL Evaluation of Flight Director Concept, 15 June 1970, D. Eldredge

g. Mode and Function

31. Failure and Switch Position Information to be Utilized in the MCM Performance Measurement System, 5 February 1970, R. Moss

32. Experimenter's Console Panel Configuration Modification, 10 February 1970, R. Moss

33. The Mode and Function Program - What it is and where it is going, 17 March 1970, R. Moss and J. Reising

34. Evaluation of the Adequacy of the Proposed MCM Configuration for Meeting the Goals of the Mode and Function Program, 6 April 1970, R. Moss and J. Reising

35. Pilot Tracking Task Requirements for the Multi-Crew Mockup, 1 May 1970, R. Moss

36. Preliminary Evaluation of Caution/Warning Information Contained in Pilot Opinion Questionnaire, 9 November 1970, R. Moss and J. Reising

37. Multi-Crew Mockup Acceptance Test, 29 October 1971, R. Moss

38. Summary and Evaluation of LTV's Simulation Model for Predicting Human Performance, 18 January 1972, R. Moss

h. CDIC

10. Guidelines for Indexing and Coding Information Intended for the CDIC Computerized Data Base, M. Baisden, 24 December 1969

11. Audio-Visual Concept, 16 December 1971, W. Swartz and T. Snyder

i. Memo for Record

Memos for Record were prepared in order to document the technical information on a semiformal basis. The following memos were issued:

Report on Initial Coordination Meeting for FPI Evaluation Study held on 10 September 1969. 16 October 1969, K. Woodruff

Film Documenting Results of Search and Rescue Helicopter Cockpit, 30 August 1971, R. Moss

EL Landing Display Phase I, 8 March 1971, J. Reising

Report on Procedures for Test Conductor's Console - MCS Facility and Data Reduction, 11 March 1971, J. Reising

Definition and Measurement of Workload, 16 July 1971, J. Reising

Bunker Ramo's effort in applying the Crew Station Management Program's technology to the cockpit proposed for the Search and Rescue Vehicle, 6 November 1970, J. Reising and R. Moss

Impact of Elimination of "Servo Package" upon Phase I of Crew Stations Management Program, 18 February 1971, R. Moss

SAR Mockup Configuration, 14 April 1971, R. Burgin and R. Moss

8. MONTHLY PROGRESS REPORTS

Thirty-six monthly progress reports were prepared and submitted, one of the 15th of each month of the contract period. These reports contained a listing of reports issued, visitors received, manpower utilization, and program progress for each month. Distribution was in accordance with contract requirements.

9. INTERIM PROGRESS REPORT

One Interim Progress Report was prepared and submitted at the completion of the first year of Contractor performance. The report which summarized Contractor activities in support of the subject contract is listed below:

Human Engineering for the Air Force Control-Display Program, Contract No. F33615-69-C-1716, Interim Report No. 1, 25 June 1969 to 24 June 1970

Unclassified
Security Classification

## DOCUMENT CONTROL DATA - R & D

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY *(Corporate author)*<br>Bunker-Ramo Corporation<br>Electronics System Division<br>Westlake Village, California 91361 | 2a. REPORT SECURITY CLASSIFICATION<br>Unclassified<br>2b. GROUP |

3. REPORT TITLE

Human Engineering for the Air Force Control-Display Program

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Final Report, 25 June 1969 - 24 June 1972

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13. ABSTRACT

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. The Mode and Function Program activities centered around the specification and development of the pilot performance measurement system to be used in the Multi-Crew Mockup for the study of cockpit management problems. Related activities included the establishment of the criteria to be used in the determination of aircraft subsystem simulation requirements and the selection of the controls and displays to be made operational in the implementation of those requirements. The Display Elements Research Program continued to assure that appropriate engineering and human engineering considerations and skills were applied throughout the development cycle of cockpit display systems. This was accomplished through the application of analytical and empirical techniques in the conduct of research using dynamic flight simulators and test aircraft as research tools. The Facility Integration Program was involved primarily in the planning and execution of the Multi-Crew Simulator Facility Sample Study which was designed to exercise selected combinations of the hardware, software, data gathering routines, and experimental procedures as well as provide basic vehicle performance data.

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| Man-Machine Interface | | | | | | |
| Information Storage and Retrieval | | | | | | |
| Cockpit Design Analysis | | | | | | |

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