HUMAN FACTORS IN AIR TRAFFIC CONTROL SYSTEMS DESIGN

(SUMMARY REPORT)

REPORT #24
PROJECT K
CONTRACT NONR 2346(00)

1 DECEMBER 1958

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HUMAN FACTORS IN AIR TRAFFIC CONTROL SYSTEMS DESIGN

(Summary Report)

Report #24
Project K

1 December 1958

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FOR

Engineering Psychology Branch
Office of Naval Research
Washington 25, D. C.
Contract Nonr-2346(00)

BY

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FOREWORD

The period of slightly over one year covered by this report has been a time of unparalleled progress in the field of air traffic control. The public has been stimulated, as never before, to an awareness of the problems of air travel in an age where demand and technological developments in aviation have already taxed the capacity of the air traffic control system--a system designed to meet far less stringent requirements. This increased awareness has been due in part to the dramatic arrival of the commercial jet on the air traffic control scene. But more than anything else public awareness and, even more important, public activity have been aroused by the series of tragic mid-air collisions which vividly demonstrated the consequences of apathy toward "our crowded skies."

In a rapid series of developments came the report of Mr. Edward P. Curtis, Special Advisor to the President, recommending a program for modernizing the nation's aviation facilities. Congressional support of funds for immediate implementation of CAA facilities' improvements was finally obtained and the Congress quickly acted to establish the Airways Modernization Board, an agency formed exclusively to bring to air traffic control system design the very latest in technological developments. But the Airways Modernization Board did not live out its legal three year life, as Congress acted to create a single agency responsible for fostering the development and administration of all aspects of domestic and international aviation policy. With the creation of the Federal Aviation Agency, a new chapter in the history of American aviation was begun.

It has been a stimulating and a rewarding experience to have been a part of this revolutionary period in air traffic control. We hope that our work has contributed in some small way to the evident progress in this vital field.

A summary of our activities in air traffic control would not be complete without mention of the impression made on us by the controllers in the centers and towers, the airways operations specialists engaged in research and development, the administrative personnel and program planners, in fact, all of the people in air traffic control with whom we have been privileged to work. They comprise a group of the most sincere and dedicated professional men encountered in any line of endeavor--achieving remarkable performance under the most difficult and trying conditions. It has indeed been a privilege to know and work with these men.

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Mr. Robert Sorenson	Mr. Leonard Moore
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Mr. Charles Dowling	Mr. Donald Schlots

Mr. Russell Andrews

... Mr. Lyle Brown, former Chief of the Indianapolis Air Route Traffic Control Center, and

... the many other air traffic controllers in centers and towers around the country who provided the research staff invaluable background in air traffic control techniques and problems.

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whose continuing support of human factors research in air traffic control systems design has made this report possible.

... Miss Elizabeth Bowman, Mrs. Anne Portenar, and Mr. John B. Freeman of Courtney and Company for the technical production of this report.

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INTRODUCTION

Air traffic control is a complex and much-studied subject. According to recent estimates by the Library of Congress over 40,000 articles, papers, and reports have been written on facets of "the air traffic control problem." This phrase, "the air traffic control problem," is a common one in the literature but rarely if ever is this "problem" defined in a manner which could lead to "a" solution. Without minimizing the importance of a systems approach to air traffic control, it is probably more fruitful, from a research standpoint, to avoid the abstract collective, "air traffic control problem," and instead to delineate and attack specific air traffic control problem<u>s</u>.

One entire class of such problems involves the human element in air traffic control. As passenger, pilot, and air traffic controller the needs, abilities, and limitations of the human being affect the operation of the system. It was the recognition of this important area by the Air Navigation Development Board that led to the establishment of Project ANDB/Navy 6.12, entitled Human Factors in Air Traffic Control Systems Design. The objective of this project, as outlined in the project specification, was

> "to provide for the consultive services of experts in the field of Human Factors in order to insure adequate consideration is being devoted to this important phase of the man-machine complex. These experts are to assist in conducting the air traffic control research and development programs that are under ANDB sponsorship."

Courtney and Company was selected to provide these services in cooperation with the Naval Research Laboratory.

The role of an expert is often a difficult one to fill--and the air traffic control field has seen more than its share of "experts." People who have spent a lifetime working in a field are understandably skeptical of the "expert" who presumes to propose solutions based on the most superficial knowledge of the requirements of the system. Sound counsel from the sponsors of the human factors research project helped greatly to overcome the liability of being cast in the role of an expert. The basic concept of the project which was adopted, stressed that members of the Courtney and Company staff were to participate as members of the research team on projects designated by the Air Navigation Development Board. In this role they would supplement the considerable experience and skills of other professional team members--whether engineers or active air traffic controllers. There was no intent to conduct independent studies or in any other way supplant rather than supplement the skills of the other team members.

A corollary of this basic premise was that written reports were incidental to the major objective of the project. With the many requirements for assistance which evolved during the project, this emphasis on action rather than exposition became both an asset and a liability--an asset in that it freed the research staff of the time consuming task of writing and editing numerous reports, a liability in that the sometimes excessive demands for assistance which developed were not immediately evident. In general, however, it is believed that the approach was correct and necessary to make a significant impact on the many human factors problems which exist in air traffic control.

The fundamental philosphy of team participation has guided the human factors effort throughout the period covered in this summary report. Since the work conducted has been a joint effort it is extremely difficult to identify specific contributions of Courtney and Company. Ideas generated within a group are very often the product of simply having people with different skills and points of view interacting. In the chapters which follow, the descriptions of projects in which the human factors members of the team have participated do not imply that the accomplishments of the team are due solely to the participation of human factors personnel. It is believed, however, that an important contribution has been made by the human factors members and this belief is supported by the greatly expanded program of human factors research in air traffic control which has evolved from the relatively modest beginnings under ANDB/Navy 6.12.

Actually two distinct phases existed in the work performed under Contract Nonr-2346(00). Phase I involved services performed for the Air Navigation Development Board and the CAA Technical Development Center, Indianapolis, Indiana from 1 April 1957 to 1 March 1958. Phase II began soon after the creation of the Airways Modernization Board. These expanded services in support of the Airways Modernization Board's crash program began in March 1958 and are continuing in conjunction with the Federal Aviation Agency. In August 1958 the Airways Modernization Board (now the Bureau of Research and Development of the Federal Aviation Agency) took over direct administration of the human factors program formerly covered by contract with the Office of Naval Research. The genealogy of the Human Factors in Air Traffic Control Systems Design program is shown in Figure 1.

The organization of this report follows the natural phases into which the work was divided Chapter Two describes the work performed in support of the Air Navigation Development Board and the CAA Technical Development Center, while Chapter Three describes the human factors effort carried out in support of the Airways Modernization Board.

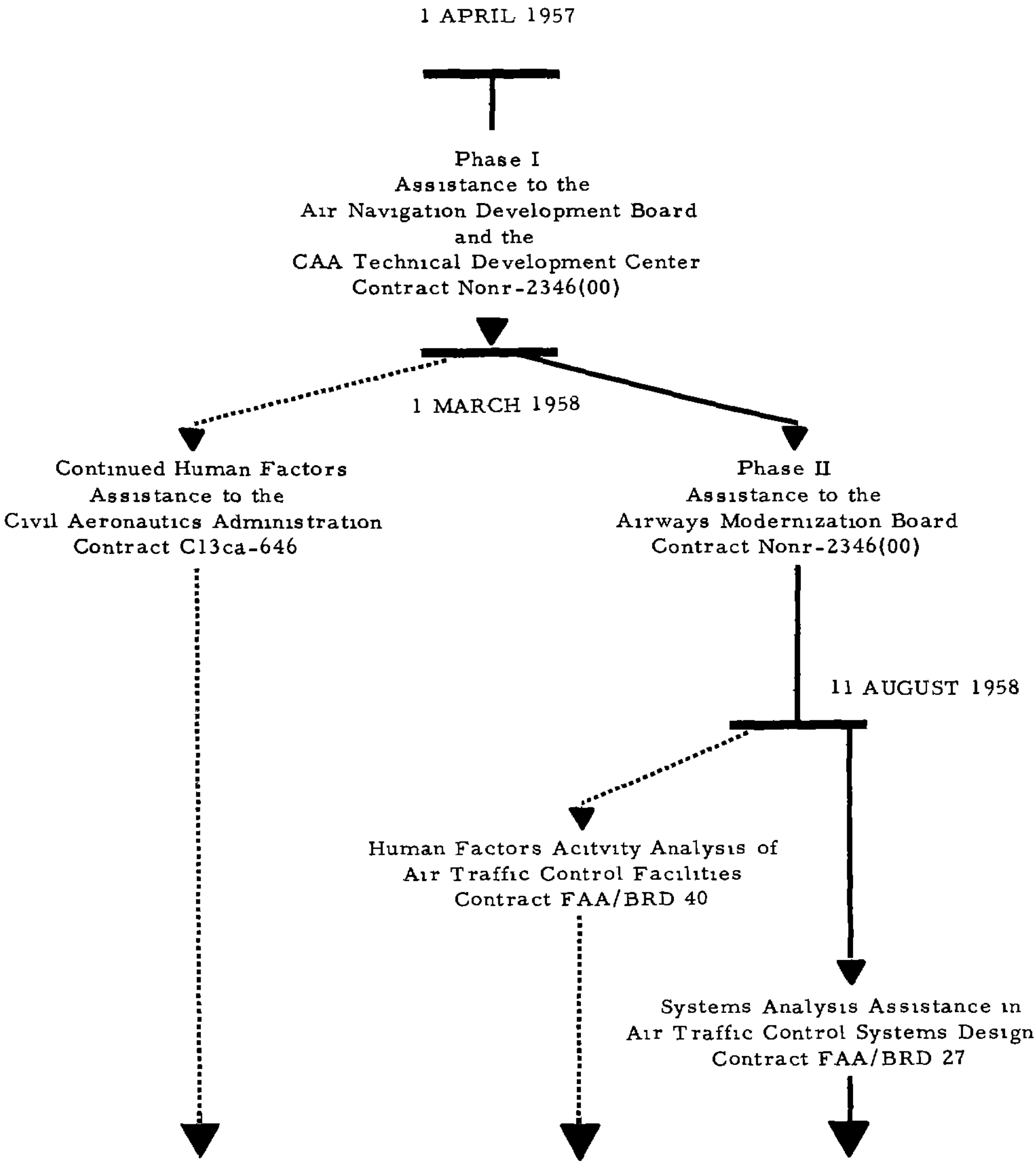


Figure 1. Genealogy of Human Factors in Air Traffic Control Program

CHAPTER TWO

PHASE I -- SERVICES TO THE AIR NAVIGATION DEVELOPMENT BOARD AND THE CAA TECHNICAL DEVELOPMENT CENTER 1 APRIL 1957 - 1 MARCH 1958

The major research effort sponsored by the Air Navigation Development Board was carried out at the CAA Technical Development Center, Indianapolis, Indiana. One of the Board's major concerns was the application of simulation techniques to the study of air traffic control problems. It was in this area of simulation that the Board particularly desired assistance. Human factors personnel, trained in the measurement of human workload and skilled in experimental design and criterion development, could contribute these skills as a part of the team of airways operations specialists at Indianapolis who organized and conducted the simulation studies for ANDB.

Another area of interest was in the design and development of air traffic control equipment--particularly displays. This work was also carried out primarily at the Technical Development Center. It was felt that Courtney and Company staff members, working with TDC engineers and designers, could bring to bear on display problems the accumulated knowledge in human engineering relative to the optimum characteristics of displays and workspaces for the human operator.

Human factors specialists can make their most far reaching contribution at the conceptual level of system planning. If the needs and skills of the human component in the system are considered from the beginning, expensive redesign and retrofitting in the hardware stage can often be avoided. The Air Navigation Development Board also desired consulting assistance in this broad area of system design and program planning.

Before work could be undertaken in any of these areas it became apparent that a thorough indoctrination in air traffic control was essential. This indoctrination, which occupied the greater part of the first three months of the project, took two forms

(1) An intensive study of the literature on air traffic control to insure that the research staff was fully cognizant of problems and solutions attempted in the past, and

(2) Actual training and supervised experience in the work of the air traffic controller in order to provide a first-hand knowledge of the day-to-day stresses and requirements of the air traffic controller's job.

It was not the intent of this indoctrination to make air traffic controllers out of research psychologists, but to provide the research staff, who already had extensive backgrounds in other aspects of aviation, with a working, practical approach to the research program. It also would provide the staff with some of the basic language of air traffic control in order that they might communicate more effectively with other members of the research team.

In addition to attendance at classes for controllers, and observation in air route traffic control centers and in towers, liaison was established with the simulation group at TDC to become familiar with the techniques employed. From this period of orientation came a much clearer conception of the specific areas in which the human factors effort could be most fruitfully concentrated. With a limited effort available it was essential that the effort not be spread too thinly across the many air traffic control development projects in which the human operator was involved. The end product of this orientation period was a research plan which was recommended to the Office of Naval Research and the Air Navigation Development Board. Basically, this plan emphasized the importance of the consulting role, working actively with TDC personnel on the practical everyday problems encountered in their research, and consulting with ANDB in the area of program planning.

AREA 1 -- HUMAN ENGINEERING CONSULTATION

The work at the Technical Development Center on new display techniques presented an excellent opportunity to initiate a program of human engineering assistance Of particular interest was the work being done in the area of bright tube radar displays, work which could greatly improve the environment of the radar air traffic controller. One development which looked particularly promising was a display known as SPANRAD--Superimposed Panoramic Radar Display. SPANRAD is basically a television picture of a radar display with information relative to radar targets superimposed on the scan-converted radar video using a closed circuit television technique. Since SPANRAD presented certain display problems in resolution, brightness, and orientation, as well as problems in target detection, identification, manual tracking, and workspace layout, it represented an excellent focal point for the human engineering phase of the consulting work.

Designated Project 1.1, SPANRAD Development, the team effort resulted in the display system shown in Figure 2. The photograph shows SPANRAD being used in conjunction with simulation studies to determine an optimum location for a second Washington, D. C., airport.

At the present time operational scan-converted radar systems are scheduled for installation in 20 CAA facilities within the United States. The Navy has also adopted a version of SPANRAD for use in several RATCC's (Radar Air Traffic Control Centers) now being implemented.

In addition to the major human engineering effort expended on the SPANRAD program, six other display projects were participated in during the period of this report. This number does not include many instances where informal assistance was rendered to TDC personnel relative to display and control problems, and problems of workspace layout.

Project 1.3 consisted of assistance in the development of a three-dimensional pictorial planning display for the control of high altitude, high speed traffic. This display employed movable layers of glass, representing altitude strata, on which tapes depicting the aircrafts' predicted flight paths were

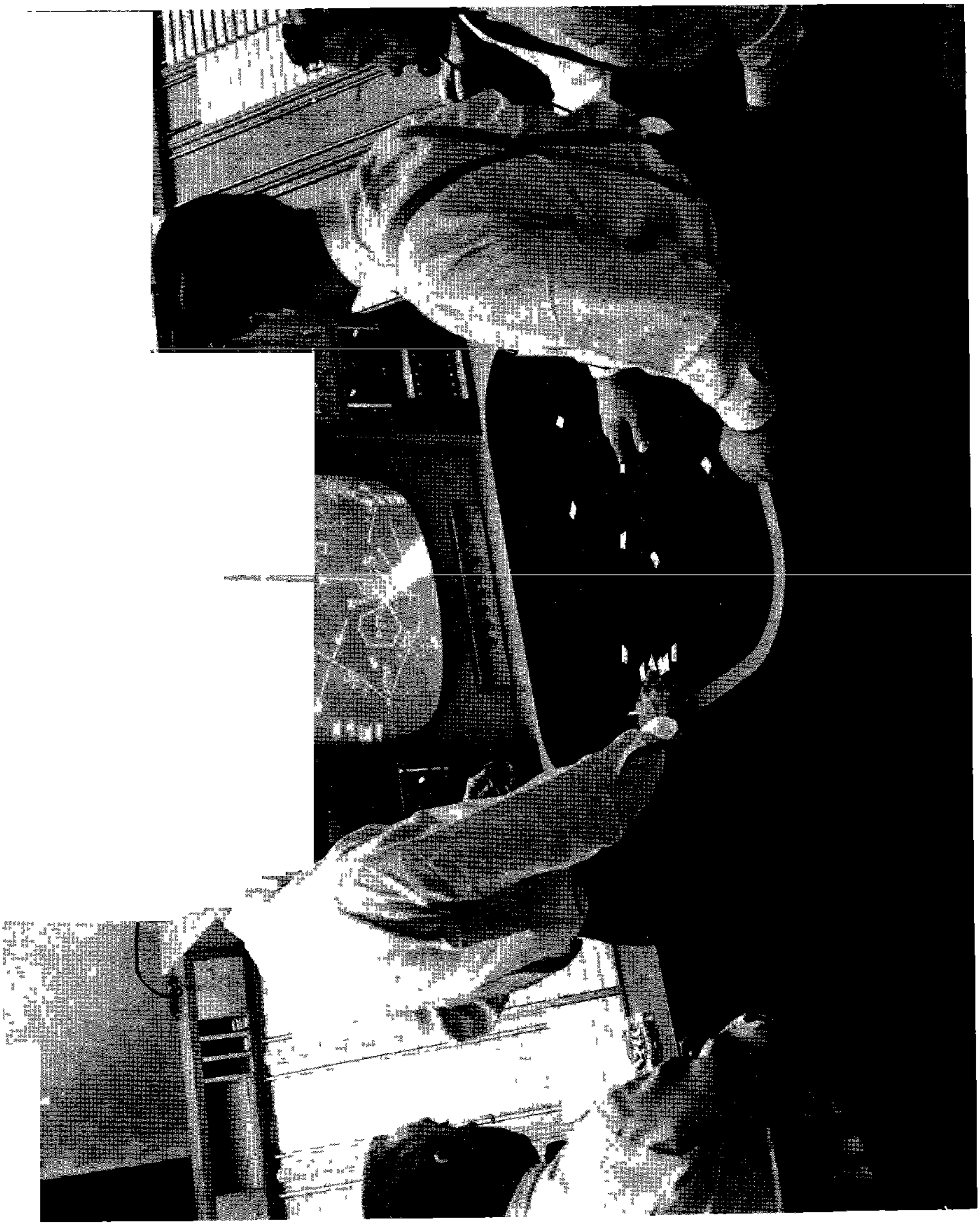


Figure 2. SPANRAD Incorporating Human Factors Recommendations

posted. Several problems in posting and read-out were encountered and human factors recommendations were made to improve the display.

Project 1.4, Human Factors Recommendations for Flight Progress Strips, was one of the few tasks carried out almost entirely as an independent staff study. The use of computer-generated, printed flight progress strips was causing serious problems in reading on the part of controllers in the Indianapolis Air Route Traffic Control Center. At the request of Mr. Lyle Brown, Chief of the Center, a concentrated study of the printed flight strip and the conditions under which it was used was made. The findings of this study were reported in detail in Memorandum Report #1 dated 1 October 1957. As a result of the recommendations contained in that report, the entire flight strip printing operation was shut down, pending the development of a suitable uniform flight strip format. Figure 3 shows the former handsritten strip and Figure 4, the printed flight strip then in use at the Indianapolis ARTCC Figure 5 shows the present flight strip in use with the IBM 650 RAMAC computer at Indianapolis and Figure 6 shows the printed flight strip produced by the Remington Rand UNIVAC File One computer scheduled for installation in the New York and Washington Centers. These strips incorporate many of the recommendations made in Memorandum Report #1.

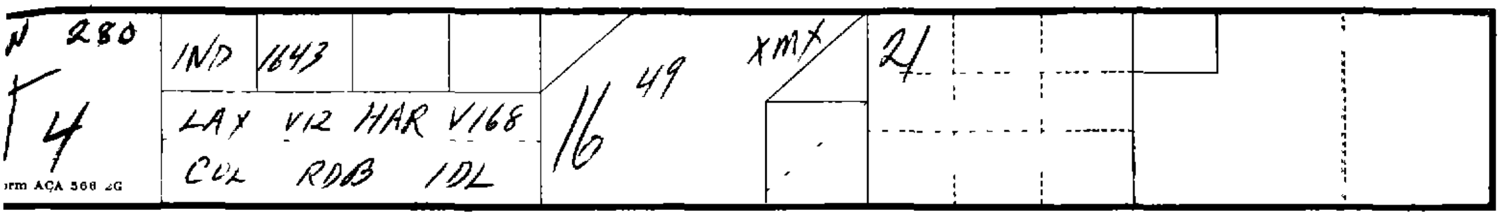


Figure 3. Original Handwritten Flight Progress Strip

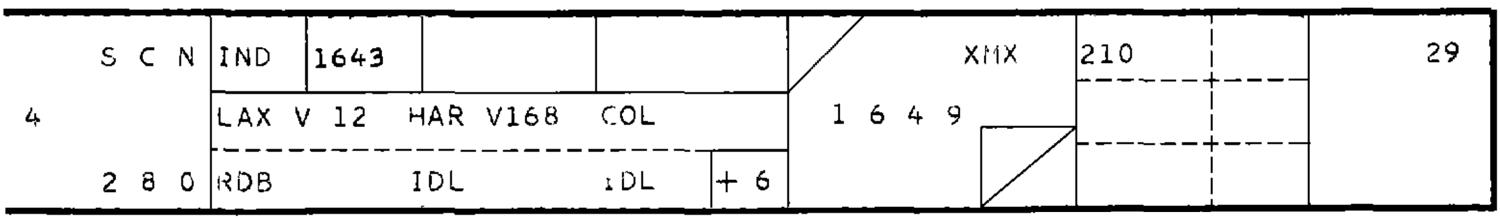


Figure 4. IBM Printed Flight Progress Strip -- First Version

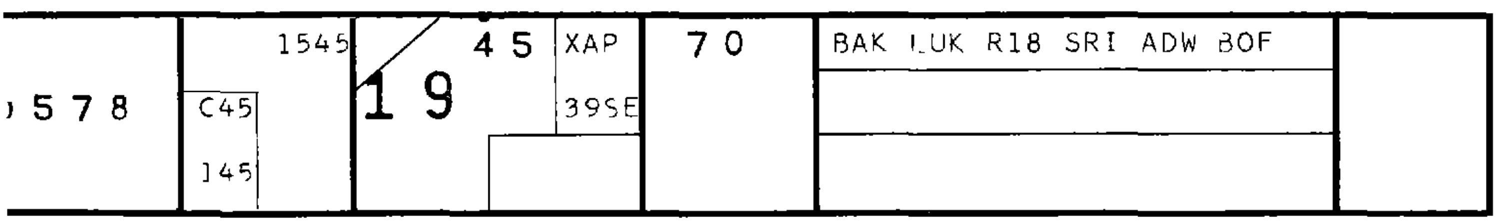


Figure 5. Present IBM Printed Flight Progress Strip (Project 1.4)

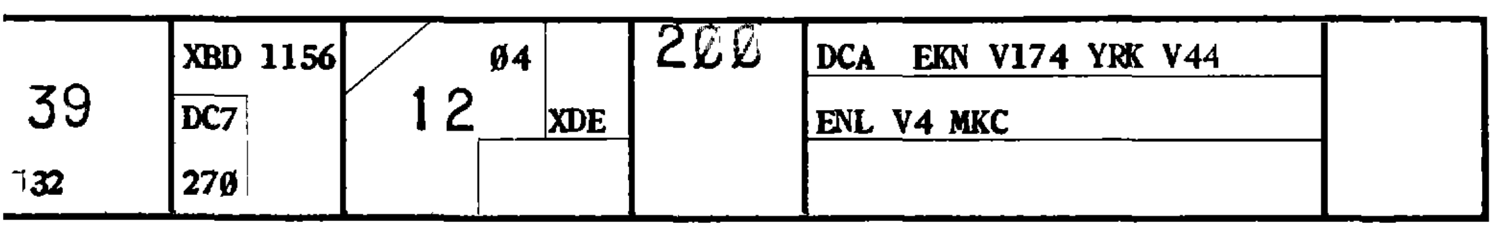


Figure 6. Present UNIVAC Printed Flight Progress Strip (Project 1.4)

The staff of Courtney and Company was asked to participate in operational tests of the Air Traffic Control Radar Beacon System to be conducted in the New York area. This participation, designated Project 1.5, took two forms (1) a human engineering evaluation of the prototype beacon control panel with recommendations for modification and (2) participation in beacon test planning. It was anticipated that further participation in the actual field evaluation would be required, but equipment delays prevented further effort on this project.

Another project concerned with bright tube displays was initiated at the request of the Airways Operations Evaluation Center at TDC. Project 1.6, Study of Methods for Reducing Specular Reflections from CRT Tubes, resulted in the development of a reflection attenuating device which markedly improves the signal-to-noise ratio of targets displayed in high ambient light conditions. The severity of the reflection problem is shown in Figure 7. The bright tube radar monitor installed in Indianapolis Tower clearly shows the effect of the excessive brightness required to overcome specular reflections from the tube face. Figure 8 shows the effect of a prototype reflection attenuator installed on the radar monitor.

Figure 8. Prototype Reflection Attenuator Installed on Radar Display

The literature search and theoretical study which led to the development of the reflection attenuator (RAT) have been reported in Courtney and Company Technical Report #23 dated 15 November 1958. A proposed production version of the reflection attenuator which is described in the above report is shown in Figure 9.

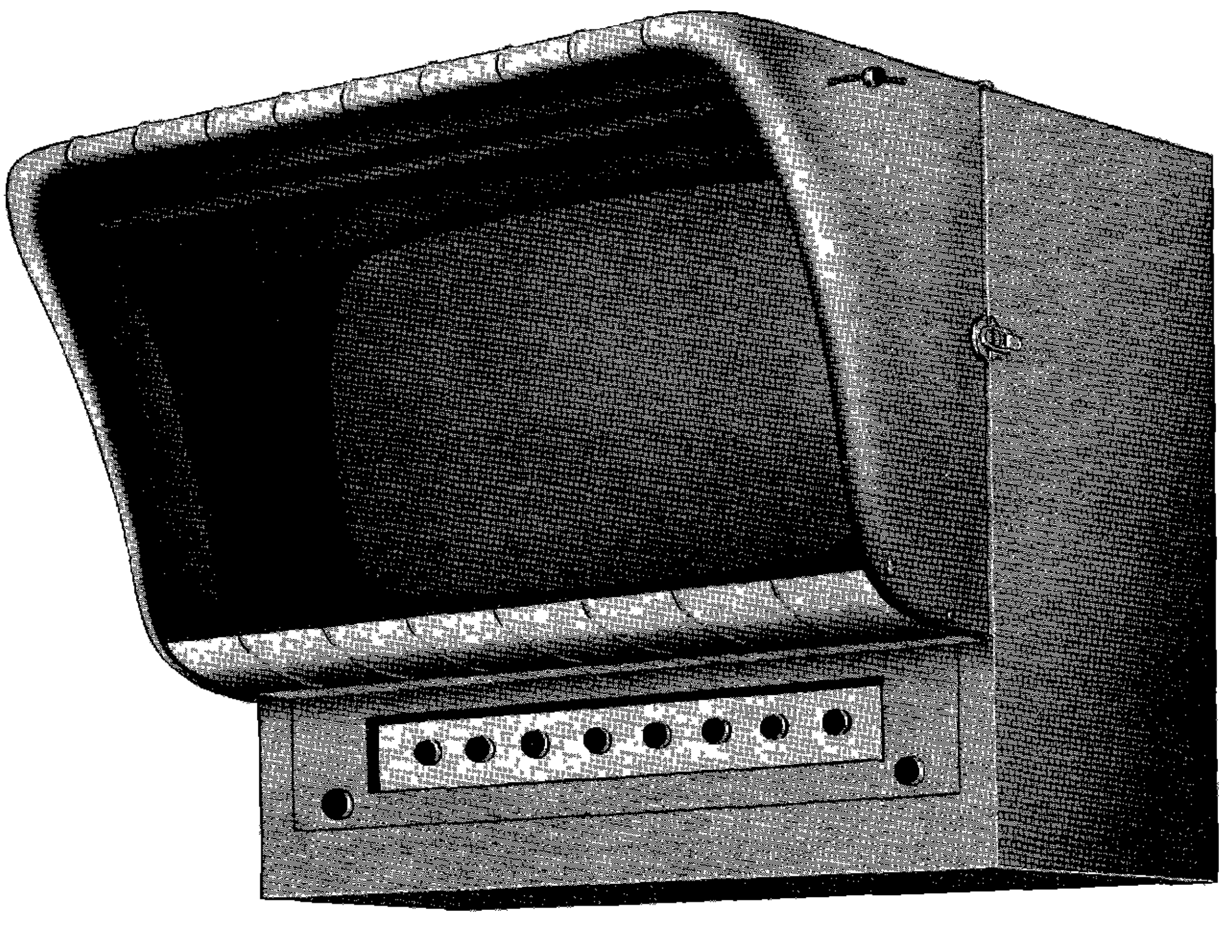


Figure 9. Proposed Production Version of Reflection Attenuator

The expansion of the TDC Dynamic Air Traffic Control Simulator presented an interesting problem in console design and workspace layout. The existing simulation room, shown in Figure 10, was already crowded and it was proposed to remote the display picture via closed circuit television to an adjacent space where operator consoles would be provided to control the optical target generators.

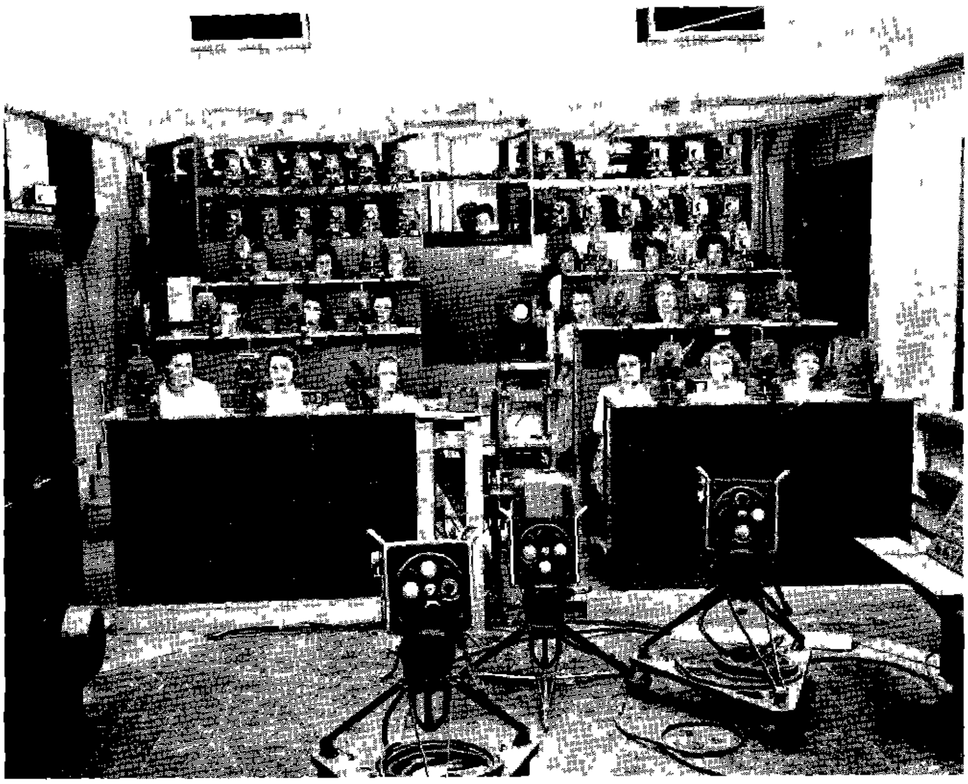


Figure 10. Main Simulation Room at CAA Technical Development Center

At the request of Mr. T. K. Vickers, Project 1.7 was established to develop an optimum layout for the remote simulator room and an improved version of the simulator pilot's console. The principal contribution of the

Figure 11. Remote Simulation Room Layout

Courtney and Company staff was in applying basic anthropometric data to the design of the simulator room. The resulting layout is shown in the photograph (Figure 11) of the completed installation.

The design of the pilot's console presented a somewhat different problem, although anthropometric considerations were still important as shown in Figure 12, illustrating the cramped working conditions created by the existing design.

Figure 12. Original Version of Simulator Pilot's Console

An analysis of the operator's task was made to determine common errors and to develop a functional basis for redesigning the console. The resulting layout (Figure 13) was necessarily a compromise with engineering feasibility, but it

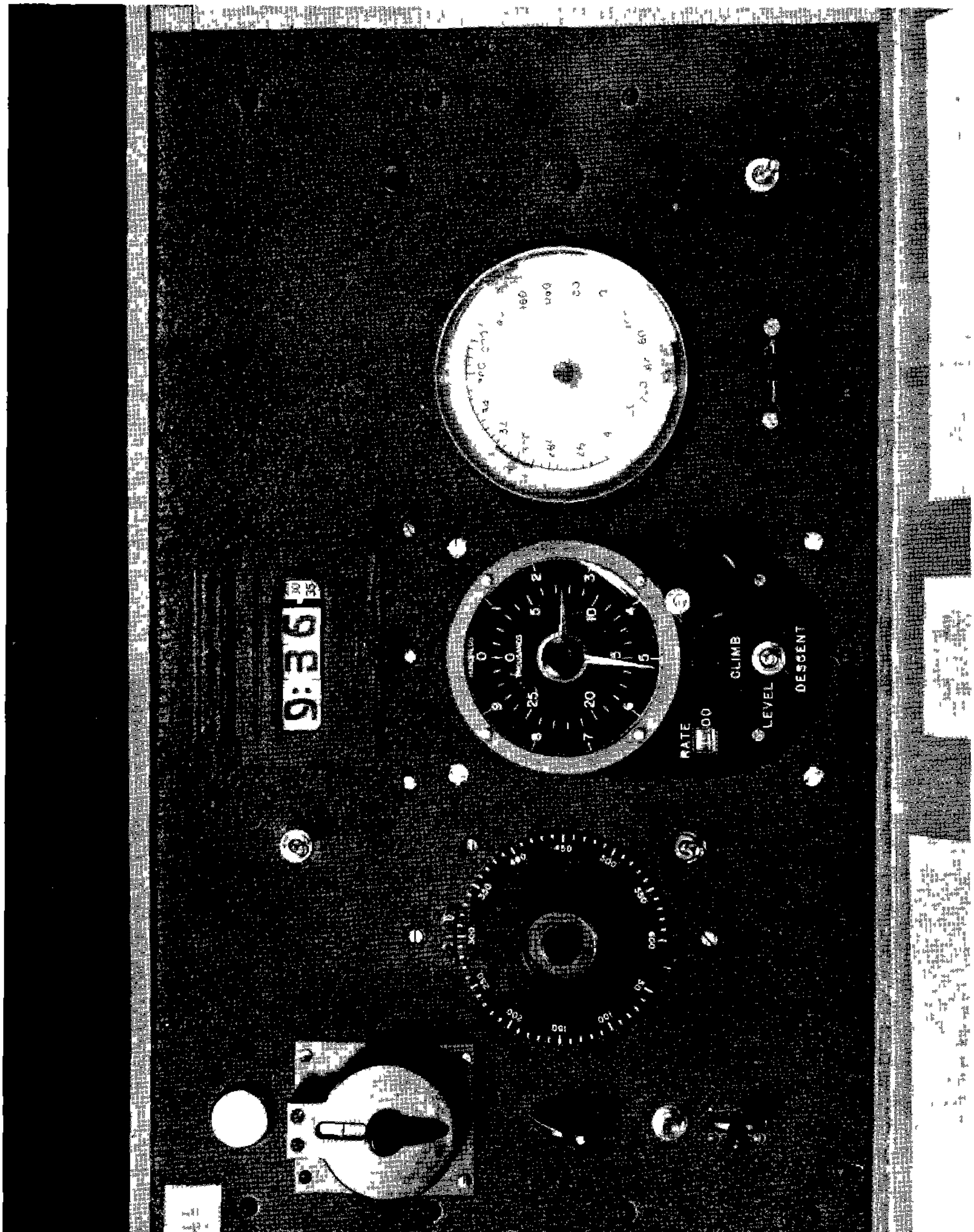


Figure 13. Redesigned Simulator Pilot's Console

is believed that it represents a substantial improvement over the earlier control console. It incorporates a redesigned altimeter, a heading indicator modified to prevent common errors in direction-of-turn operations, stowage space for personal items, increased shelf space with a transparent cover for essential reference data, and a completely functional arrangement of indicators and controls.

Although the simulator design project was the last human engineering task for TDC carried out under Contract Nonr-2346(00), human engineering services have continued under direct CAA sponsorship.

AREA 2 -- CRITERION DEVELOPMENT

The development of criteria for the evaluation of system performance is a difficult task. A great deal of the research effort available under the present contract was devoted to the study of criteria applicable to the evaluation of air traffic control systems. The results of this work are, as yet, unpublished, however, the research is continuing under CAA and FAA support and, although unpublished, the effort has nevertheless had important effects on the conduct of dynamic air traffic control simulation studies and the development of data recording systems for sophisticated air traffic control simulators now being constructed.

The ultimate criterion of the effectiveness of any system of air traffic control is, of course, the ability of the system to move aircraft safely and efficiently. However, it is often impossible to measure the effects of traffic control in terms of these ultimate criteria, particularly in an operational environment. In some cases the necessary data are inaccessible, but in most cases the limitations of the ultimate criteria are due to their lack of sensitivity. Even a major change in a system of control may not be reflected in the ability of that system to prevent conflictions between aircraft or in its ability to minimize delays in the flow of traffic. The key to this lack of sensitivity lies in the remarkable adaptability of the human component in the air traffic control system--the air traffic controller.

A greatly simplified schematic of the air traffic control loop is shown in Figure 14.

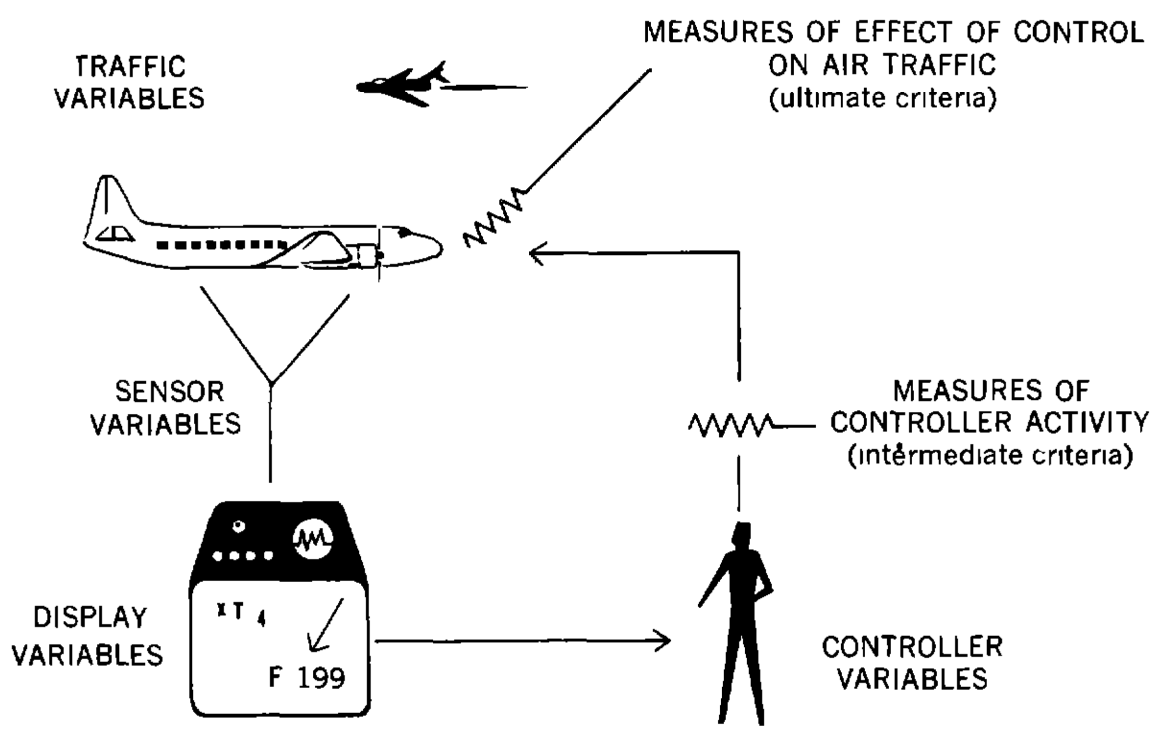


Figure 14. Schematic of the Air Traffic Control Loop

Traffic variables are the initial inputs into the air traffic control system. Traffic density, type and speed of aircraft, number of arrivals and departures, air route structure, weather conditions, and the intermixture of VFR and IFR aircraft are a few of the traffic variables that will affect measures of system performance. In actual operations, it is impossible to manipulate all these traffic variables simultaneously, consequently it is impossible to duplicate conditions for the purposes of comparing alternative systems of control. Simulation provides a means for creating comparable air traffic control problems under a variety of experimental conditions. Thus, with constant inputs into the system, it is possible to vary components or methods of air traffic control and to determine the ultimate effect on system output.

One component in the system which can be varied is the display used to present information about the air traffic situation to the controller. But the effect of varying the display is not directly reflected in the ultimate criteria of system effectiveness. The controller who acts on the information presented in the display can completely obscure real differences in systems for displaying information. We would expect that with an optimum display of air traffic control information, the controller would be able to control traffic without conflictions and with little or no enroute delay. The fact is that even with the most inadequate method of display the controller is still able to move traffic safely and expeditiously if conflictions and delays are used as measures of these ultimate criteria. But this equivalent performance is not achieved without cost--

the difference between displays is readily apparent when the controller's workload is compared in each of the two systems. The controller is a highly adaptable component in the air traffic control system and consequently is able to compensate for many deficiencies in system design. Thus any evaluation of over-all system performance must include the determination of this compensatory effort on the part of the controller. The measure of a good system of air traffic control then becomes the ability of the system to satisfy the ultimate criteria of safety and efficiency with the least stress imposed on the controller or, conversely, it is the ability of the system to move a greater volume of air traffic without sacrificing safety and without making excessive demands on the controller. To obtain measures of the demands made upon the air traffic controller we must turn to observable aspects of the controller's activity--what does he do in the process of controlling air traffic. The purpose of the work at TDC was to explore some of these activities and to investigate methods for measuring them.

Some of the more promising criteria developed in a comparison of three simulated display systems (SPANRAD, Slant-scope Radar, and ANC Flight Progress Boards) were

1. Measures of Coordination Activities
   a. Message frequency
   b. Message length

2. Measures of Communications Activities
   a. Message frequency
   b. Message length
3. Measures of Flight Disruptions
   a. Heading changes
   b. Speed changes
   c. Altitude changes
4. Requirements for Supplemental Control Information
   a. Frequency of requests for aircraft position information
   b. Frequency of requests for aircraft altitude information

Since the number of variables affecting system performance is quite large, no single study could hope to explore all aspects of the problem. The principal value of the criterion studies conducted at TDC was in pointing out promising avenues for further research, research which it is hoped will lead to the development of reliable intermediate criteria of the performance of simulated air traffic control systems.

Additional studies of some of these variables, such as the effect of problem difficulty, length of run, and size of the controller sample, are currently being undertaken in conjunction with TDC and FAA simulation projects. The ultimate goal of this research is to develop a controller workload index which will be a reliable intermediate criterion of the performance of simulated air traffic control systems.

AREA 3 -- PROGRAM PLANNING

In anticipation of increased assistance to the Air Navigation Development Board in the area of human factors in air traffic control systems design, an intensive program of study was undertaken by the staff. This study was done, in part, from the extensive literature on air traffic control, but the major emphasis was on a field survey of problems in active air traffic control facilities--problems of equipment design and workspace layout, and problems of personnel recruiting, selection and training.

The anticipated advisory service to the Air Navigation Development Board never materialized as this organization gave way to the Airways Modernization Board. The work of this intensive study has, however, proven of great value in the continuing work with CAA, AMB and currently with the Federal Aviation Agency. Projects, such as the present research effort in the application of human factors concepts to the design of air traffic control towers for the CAA, and the conduct of an activity analysis of air traffic control facilities, are directly traceable to this preparatory phase of the program planning task. The subject of program planning is covered more fully in Chapter Three, outlining services performed for the Airways Modernization Board under Contract Nonr-2346(00).

AREA 4 -- BIBLIOGRAPHIC RESEARCH

The bibliographic support provided by the Courtney and Company library has been indispensable to all of the work performed, both in support of the effort at the CAA Technical Development Center and, later in support of the work with the Airways Modernization Board. The collection and organization of the voluminous literature on air traffic control has been a major accomplishment But even more significant is the rapid retrieval system installed during this project which made specific items of information available to the research staff literally on a moment's notice This service has not only been used to support the research activities of the Courtney and Company staff but has frequently been called upon to provide documentation for work being performed by the sponsoring agencies

CHAPTER THREE

PHASE II -- SERVICES TO THE AIRWAYS MODERNIZATION BOARD 1 MARCH 1958 - 11 AUGUST 1958

The creation of the Airways Modernization Board resulted in a redirection of the human factors research effort and an increase in its scope The amended work statement to Contract Nonr-2346(00) states the objectives of the expanded work very clearly

"SECTION A - The Contractor shall furnish the necessary personnel and facilities for and, in accordance with any instructions issued by the Scientific Officer or his authorized representative, shall conduct research on human factors in air traffic control systems design which shall include the following

1 Application of human factors concepts in determining the informational requirement for air traffic control displays, establishing methods of presentations, and in their design that will result in the most effective employment of human beings in the system.

2. Application of human factors concepts to the detailed design of components and for their integration into an efficient traffic control center

3 Active participation in the conduct of system simulation tests to improve the evaluation criteria of the man-machine being investigated This participation shall include recommending the nature and scope of tests to be conducted at the Technical Development Center, Indianapolis, Indiana, at the Airborne Instruments Laboratory, Mineola, New York, at the International Business Machines Computer Center, Kingston, New York, and with the General Precision Laboratories, Pleasantville, New York."

AREA 1 -- HUMAN FACTORS IN AIR TRAFFIC CONTROL DATA PROCESSING AND DISPLAY

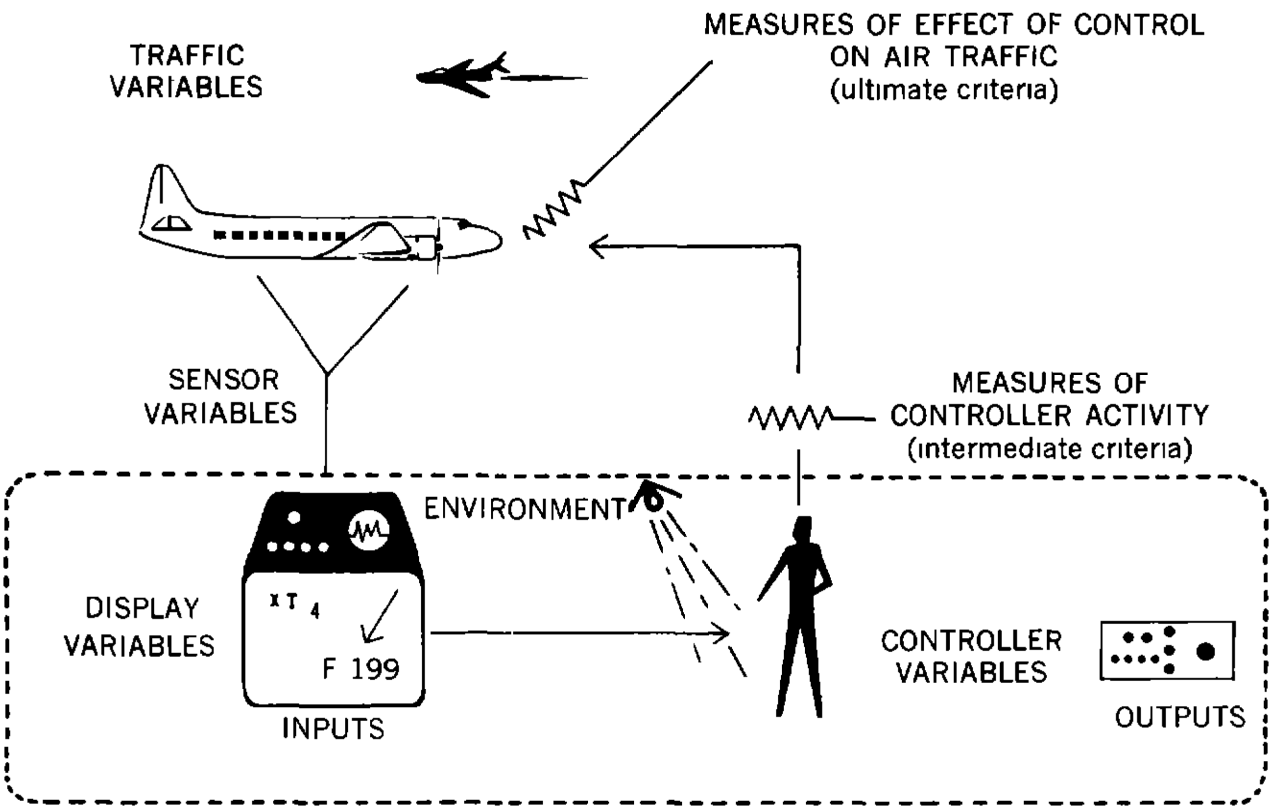
The stated goal of the Airways Modernization Board was to provide an immediate improvement in the processing and display of air traffic control information The major effort of the AMB program centered around the development of a semi-automatic data processing and display program. Quite naturally, this emphasis on ATC Data Processing and Display has been reflected in the program of human factors assistance

Dr. Wallace H Wallace was assigned to the General Precision Laboratory, Pleasantville, N Y to provide staff assistance to the Airways Modernization Board representatives supervising the development of the AMB/GPL system Because of the "crash" nature of this program, most of the human factors assistance has drawn heavily upon prior research and has been concerned primarily with the human engineering aspects of equipment design

When Courtney and Company began giving assistance to AMB on the data processing and display system, the philosophy behind the system had been formulated The greatest and immediate need was to apply human factors to the prescribed consoles and displays This work has evolved into consideration of three aspects the consideration of informational inputs to the controller, the outputs from him, and the controller's environment See Figure 15 Typical examples of the human factors activities on the system are described in the subsequent paragraphs in order to give a sample of the recommendations and suggestions which have been made

A Inputs

In considering the inputs at the various control positions, an attempt has been made to determine (1) what information is required, (2) what sources there are for the information,(3) what form the information should take, and (4) how best to present it



igure 15. Schematic of Input, Output, and Environmental Factors in Air Traffic Control

Several examples of previous recommendations follow, many of which have been incorporated into the Data Processing Central system

(1) What information is required?

Example The supervisor must regulate the flow of traffic to the terminals by giving orders to other centers to restrict traffic into overloaded terminals After discussions it was realized that there would be an extensive

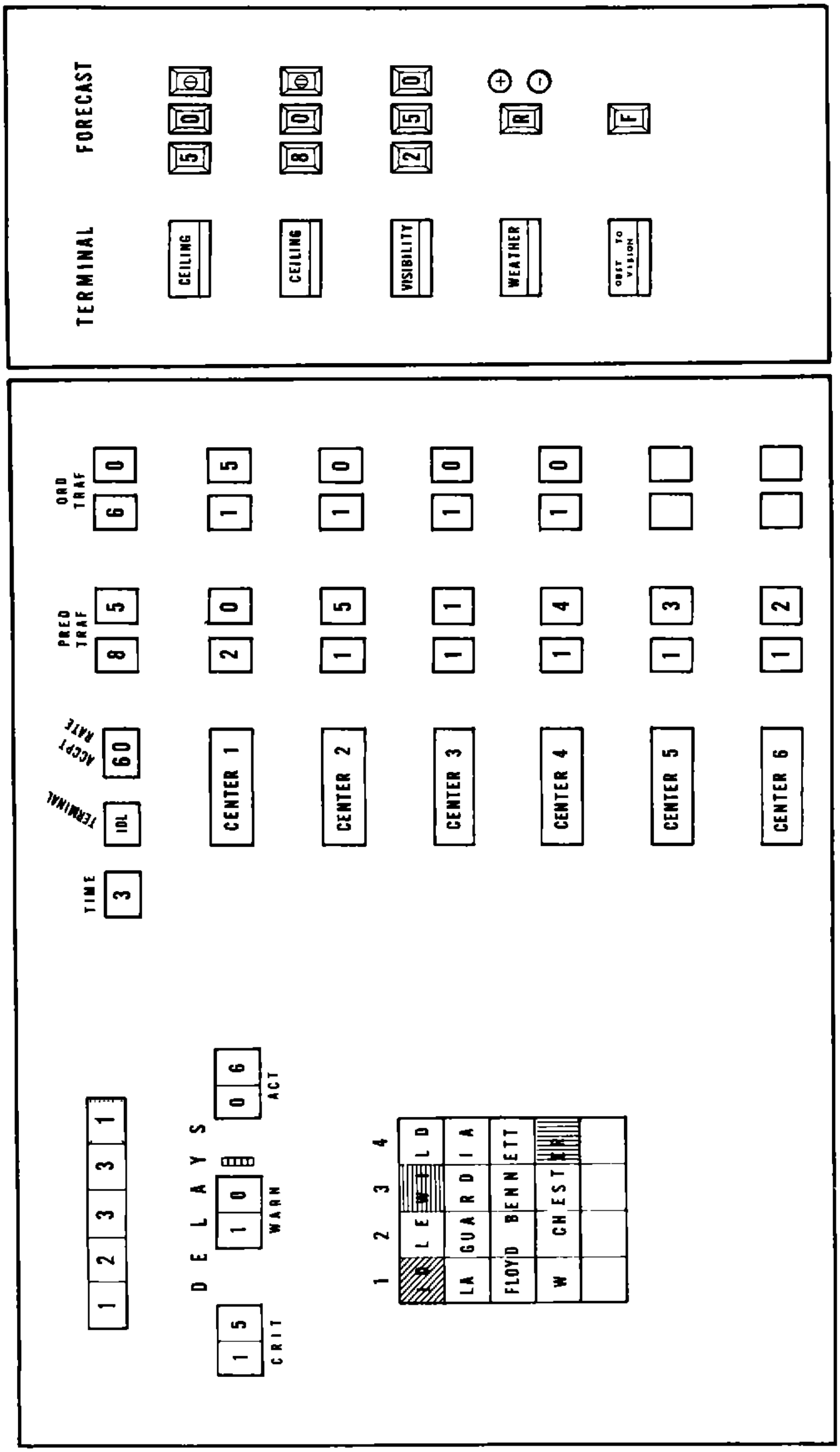


Figure 16. Proposed Supervisor's Flow Control Display

time delay between giving the order and compliance Therefore, a new informational requirement was a display not only of predicted traffic but also of ordered traffic (One configuration incorporating the suggestion is seen in Figure 16)

(2) What sources are there for the required information?

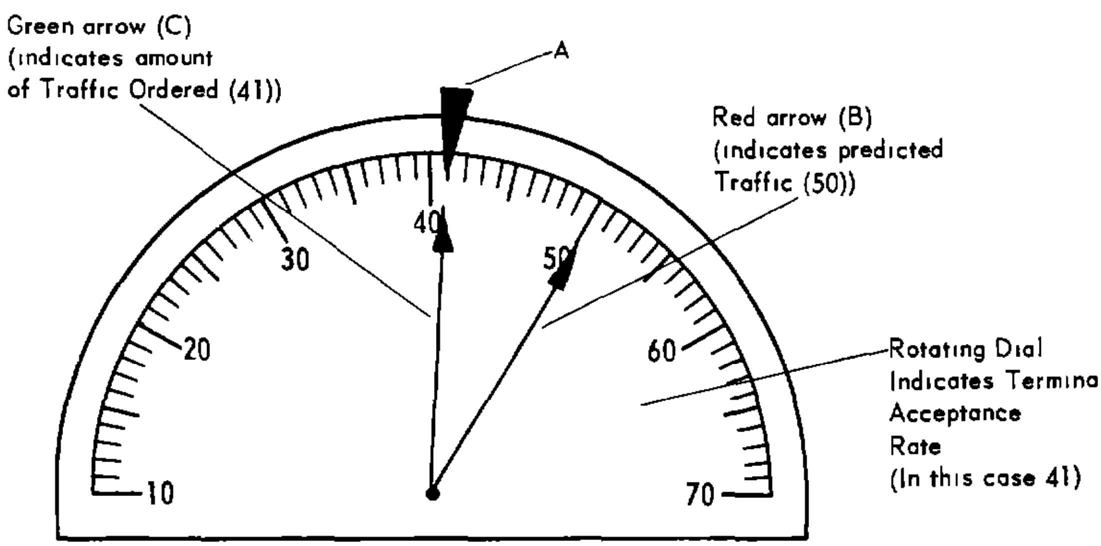
Example In the tower, one controller must estimate the takeoff time of aircraft so that conflict probes can be made of their route The accuracy of the probe depends on the accuracy of the controller's estimate Elsewhere in the system, landing times are scheduled Since landing times affect departure times, it was recommended that this information be provided to the departure controller in the tower to increase the precision of his estimates.

(3) In what form should the information be presented?

Example In one display, digital information was presented However, the controller needed to know only the relationship between two variables, i e , whether one was greater or larger than the other It was recommended that the precision of the digital display should be replaced by an easier to scan and easier to comprehend analogue display Two of the suggested displays are shown in Figure 17

(4) What is the best way to present the information?

Example The design of the characters on flight strips was similar to Mackworth type to insure high legibility, even under very oblique viewing angles.



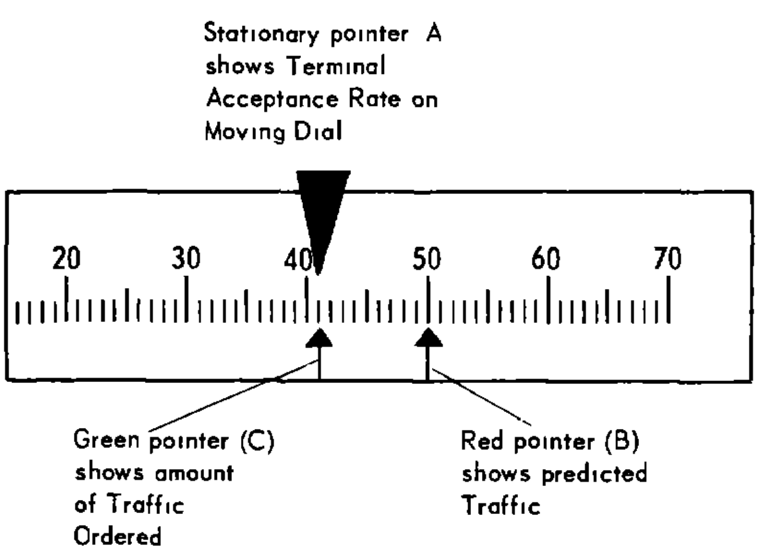


Figure 17. Analogue Flow Control Displays

B Outputs

The outputs from the controller have been examined in a manner similar to the inputs The approach is to determine what information is needed by the recipient of the controller's action, what kinds of responses are feasible, what form of response is required, and how best to require the response

(1) What information is required from the controller?

Example The controller uses the sequence console to assign landing times to aircraft It is necessary to inform the computer of his decisions. Originally, the computer was told by reference to the aircraft's identity and the desired landing time This required over 13 keyboard operations

The computer could be informed of the controller's decision by reference to the position of the aircraft and the landing slot on the display Making this the information required from the controller reduced his operations to two button depressions

(2) What kinds of responses are feasible?

Example One proposed flight strip holder required considerable, forceful manipulation of clamps to hold the flight strip in place The use of materials other than paper required a different kind of response, and so a plastic and a pressure sensitive tape were recommended which could replace paper and adhere strongly to the holder without clamps

(3) What form of response is required?

Example: In entering fix reports into the system with a keyboard, the sequence of operations is to manipulate.

(a) the address key, then

(b) the digital information keys, and then

(c) the command keys

Recommendations for the layout of the keyboard suggested placing the keys so as to follow this sequence of operation

(4) What is the best way to require the response?

Example The punch and printer prepares strips for loading and ejects them into a hopper To avoid strips being lost or posted after the aircraft had passed through the system, it was recommended that the hopper be redesigned so that the earliest strip printed had to be the first removed This limitation of responses to one type, lowers the chance for errors.

C. The Environment

Many considerations of the controller's working environment have influenced the design of equipment The recommendations discussed in Chapter Two, relative to the control of specular reflections from displays, have been suggested for incorporation in the GPL equipment In addition, the console's dimensions have been designed on an anthropometric as well as functional basis, permitting the controller to reach his controls and providing space for future developments Figure 18 shows GPL and Courtney and Company staff members working on full-scale mock-ups of several of the display consoles for the semi-automatic system Work on this activity at GPL is continuing For a more complete sample of the kinds of topics treated in the data processing and display work, see the list of titles of technical memoranda issued in connection with this effort (Appendix B)

AREA 2 -- HUMAN FACTORS IN THE DEVELOPMENT AND EVALUATION OF AIR TRAFFIC CONTROL SYSTEMS

The Airways Modernization Board was conceived as a systems oriented group Their approach to the solution of air traffic control problems was inter-disciplinary, including the contributions of operational specialists, engineers, economists, and, of particular interest, human factors specialists. The Directorate of Systems Analysis assumed responsibility for managing the Courtney and Company human factors effort and has made maximum use of the human factors members of the team The preparatory work in program planning mentioned in Chapter Two became an invaluable asset to the Courtney and Company staff in advising AMB on the human factors aspects of future system design

One of the earliest requests for assistance was in the preparation of transition and terminal area specifications for the semi-automatic data

Figure 18. GPL and Courtney and Company Staff at Work on Console Layouts (GPL Photograph)

processing and display system In this project, members of Courtney and Company worked directly with the staffs of AMB and the General Precision Laboratory to develop a complete set of system requirements for this first major step into the semi-automatic control of air traffic

In attempting to anticipate requirements for a system yet undeveloped, questions invariably arise Another important area of program planning assistance was in setting up research projects, either internal or external, to obtain answers to such questions For example, a program of real and fast time simulation was outlined for AMB to obtain necessary inputs into the Data Processing Central program Knowledge of experimental design techniques and prior experience in dynamic air traffic control simulation were extremely valuable in this phase of work with the Airways Modernization Board

Once the Data Processing Central system reaches the hardware stage, a comprehensive period of testing and evaluation of the equipment will be carried out by the Directorate of Systems Analysis and the Directorate of Systems Experimentation Both simulated and live testing of the system are to be accomplished before introduction of the equipment into the operating environment. Courtney and Company has participated in many phases of the planning for these system tests, including recommending types of tests to be conducted, communications requirements, and data recording facilities needed during the test period One of the most important of these planning services was in connection with the development of an advanced air traffic control dynamic simulation capability for the Directorate of Systems Analysis.

AREA 3 -- HUMAN FACTORS IN AIR TRAFFIC CONTROL SIMULATION

The human factors effort in simulation during the period of this summary report has, in many respects, paralleled the work in data processing and display. The chief demand for assistance has been in the application of human engineering principles to equipment design This has included extensive work with Aircraft Armaments, Inc in the design of the pilot's console for the simulator, in the development of consoles for supervisory positions, and in the organization of a simulator director's display The pilot's console is the key to the entire simulator operation and is the direct source of human inputs into the traffic portion of the simulated air traffic control system Experience gained by Courtney and Company while working on the design and layout of the addition to the TDC simulator greatly expedited the development of a satisfactory console design for AMB A modified engineering model of the pilot's console is shown in Figure 19

An even more important contribution to the simulator program has been the inclusion of modern high speed data recording and processing capabilities in the AMB simulator as a result of Courtney and Company recommendations It will be possible to obtain many of the criterion measures of system performance discussed earlier, automatically, and in a form for rapid data reduction by computer It will no longer be necessary to wait for the laborious manual reduction of simulation data to determine the results of an experiment Another contribution to improve the simulator as a tool for systems

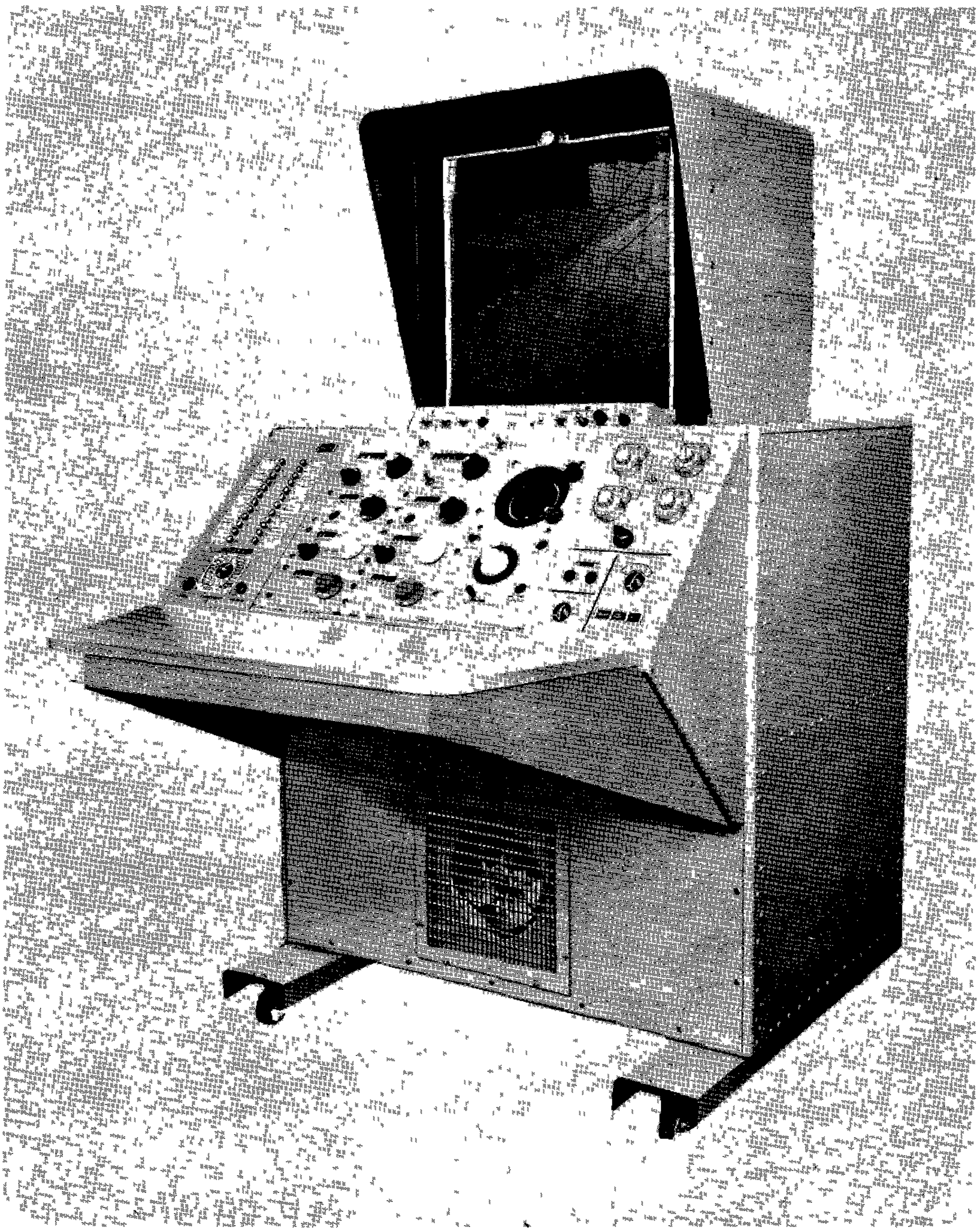


Figure 19. Pilot's Console for FAA Air Traffic Control Simulator

experimentation resulted from Courtney and Company recommendations that AMB develop a capability for computer generation of flight plan samples incorporating clearly defined parameters This project, already beginning to produce such samples, will enable closer experimental control of one of the most significant classes of variables in air traffic control simulation Work on this program is continuing in cooperation with IBM and the FAA Bureau of Research and Development

The degree to which simulator operators can perform as "pilots" is another variable which can be a source of serious experimental error. The original effort in optimizing the operator's console has naturally evolved into the development of a selection and training program for simulator operators. To this end, a detailed activity analysis of the simulator operator's task was undertaken and is now nearing completion

In all areas of the work outlined above, the human factors effort is continuing, and, so long as the human being remains a key component in the air traffic control system, the contribution of the human factors specialist to the systems research team will remain a vital one

APPENDICES

APPENDIX A

LIST OF COURTNEY AND COMPANY PERSONNEL WHO HAVE WORKED ON CONTRACT NONR-2346(00)

Dr William H Angoff

Mr A T Bazer

Miss Rosa Bernstein

Mr Kenneth W Colman

Dr Douglas Courtney

Mr J. W Danaher

Mrs Lois-ellin Datta

Dr Myron A Fischl

Mr John B Freeman

Dr J. S Kidd

Dr Omer Lucier

Mrs. Anne Portenar

Dr George E Rowland

Dr Wallace H Wallace

APPENDIX B

LIST OF COURTNEY AND COMPANY REPORTS AND MEMORANDA ON AIR TRAFFIC CONTROL

Phase I
Assistance to the
Air Navigation Development Board
and the
CAA Technical Development Center
Contract Nonr-2346(00)

Number	Title	Date
Report #16	Human Factors Recommendations for Flight Progress Strips	1 October 1957
Report #23	The Control of Specular Reflections from Bright Tube Radar Displays	15 November 1958

Phase II
Assistance to the
Airways Modernization Board
Contract Nonr-2346(00)

Number	Title	Date
Report #24	Human Factors in Air Traffic Control Systems Design	1 December 1958
Memorandum #1	Consulting Activities at General Precision Laboratory	12 May 1958
Memorandum #2	Enroute Radio Sector Console	13 May 1958
Memorandum #3	Flight Strip Holders	14 May 1958

Number	Title	Date
Memorandum #4	Enroute Radar Supplement	15 May 1958
Memorandum #5	The Pneumatic Tube System	16 May 1958
Memorandum #6	Alpha-Numeric Character Matrix for Pictorial Displays on Enroute Radio Sector Console	21 May 1958
Memorandum #7	Specification of Type Style for Flight Strip	23 June 1958
Memorandum #8	Data Entry Keyboard	16 July 1958
Memorandum #9	The Enroute Radio Console	20 June 1958
Memorandum #10	Recommended Dimensions for Consoles Employing the Sit Position	1 July 1958
Memorandum #11	Supervisor's Flow Control Console	19 June 1958

Continued Human Factors
Assistance to the
Civil Aeronautics Administration
Contract C13ca-646

Number	Title	Date
Report #21	Selected Alpha-Numeric Characters for Closed-Circuit Television Displays	1 July 1958
Memorandum #1	Design of Alpha-Numeric Symbols for SPANRAD	15 May 1958

Systems Analysis Assistance in
Air Traffic Control Systems Design
Contract FAA/BRD-27

Number	Title	Date
Memorandum #12	The Dials on Clocks	13 August 1958
Memorandum #13	Selection of Ink and Paper to be Used With the Flight Strips	18 August 1958
Memorandum #14	Reduction of Specular Glare from Displays	15 October 1958
Memorandum #15	Activities at GPL 21-22 August 1958	22 August 1958
Memorandum #16	Recommendations During the Week of 9 September 1958	12 September 1958
Memorandum #17	Recommendations for the AMB Data Processing and Display System During the Week of 15 September 1958	18 September 1958
Memorandum #18	Activities During the Week of 6 October 1958	9 October 1958
Memorandum #19	An Account of Acceptance Tests on the Prototype Model of the Aircraft Armaments, Inc Target Generator and Pilot's Display	20 October 1958
Memorandum #20	Material for Flight Strips	29 October 1958
Memorandum #21	Tracking Controls for FAA Data Processing and Display System	10 November 1958
Memorandum #22	Airborne Display for AGACS	17 November 1958
Memorandum #23	Discrete Message Categories for Use in AGACS, Mod I	8 December 1958