REPORT #32

PROJECT N

30 NOVEMBER 1959

HUMAN FACTORS IN AIR TRAFFIC CONTROL SYSTEMS DESIGN

SUMMARY REPORT

PART 2

COURTNEY AND COMPANY

HUMAN FACTORS IN AIR TRAFFIC CONTROL SYSTEMS DESIGN

Summary Report
Part 2

Report #32
Project N

30 November 1959

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FOR

Bureau of Research and Development
Federal Aviation Agency
Washington 25, D. C
Contract FAA/BRD-27

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ACKNOWLEDGMENTS

It would be impossible to acknowledge all of the individuals who have contributed to the work described in this summary report An accurate list would read like a roster of the Federal Aviation Agency and many of their contractors Such a list would have to include the many air traffic controllers in centers and towers around the country who provided the research staff invaluable background in air traffic control techniques and problems It would have to include the staff of the FAA Aeronautical Center at Oklahoma City who contributed their time and skill to training psychologists in some of the intricacies of the strange new world of air traffic control. It would certainly have to include the two men who have acted as Project Manager for this program--Mr. Jack Grewell, Chief, System Planning Branch, Systems Analysis Division, and Major Richard L Webb, USAF, Executive Officer, Systems Analysis Division

To all these individuals, and to the many others who have given support and encouragement to this study of the human being as a key element in air traffic control system design, we hereby express our appreciation

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CHAPTER I

INTRODUCTION

At the time of writing of this report the Federal Aviation Agency has completed its first year of operation. It has been a year of vigorous growth and accomplishment. Like its predecessor, the Airways Modernization Board, the Bureau of Research and Development of FAA has conceived of air traffic control as a complex man-machine system and has assembled a select team of specialists from many fields to cope with the tremendous task of designing a system capable of meeting the nation's rapidly expanding aviation requirements The recognition by the Federal Aviation Agency of the importance of the human being in such a system has provided both a challenge and an opportunity to the human factors specialist working as a member of the research and development team

The work of the human factors specialist is often carried out at a level of abstraction that deprives the individual of the very real satisfaction of seeing the tangible evidence of his contributions But in this instance, as the programs of the Federal Aviation Agency near completion of the hardware development stage, abstract concepts have become real objects which can be seen and felt, used and abused. These prototype components evoke mixed feelings--a feeling of astonishment at seeing electronic replicas of what were only ideas a few months previous, and along with it a feeling of frustration This feeling of frustration comes partly from the experience of seeing "obvious" solutions to problems which appeared insoluble during early design studies and partly from the realization that development is still a large part "art" and only a small part "science "

Particularly in the comparatively new and rapidly expanding field of human factors is this true The body of science and even the technology of studying man as a component in complex systems is still in its infancy Even the most ardent advocate of giving attention to human factors in systems design is forced to acknowledge the gaps in our knowledge of man's capabilities, and to recognize the vast need for basic studies of human behavior within the context of large systems There are few opportunities for studying man s performance in such large-scale systems The Federal Aviation Agency has provided an unparalleled opportunity to add to the basic fund of knowledge on human behavior within the framework of a complex system. This addition to basic knowledge is an important byproduct of the FAA's team approach to system design

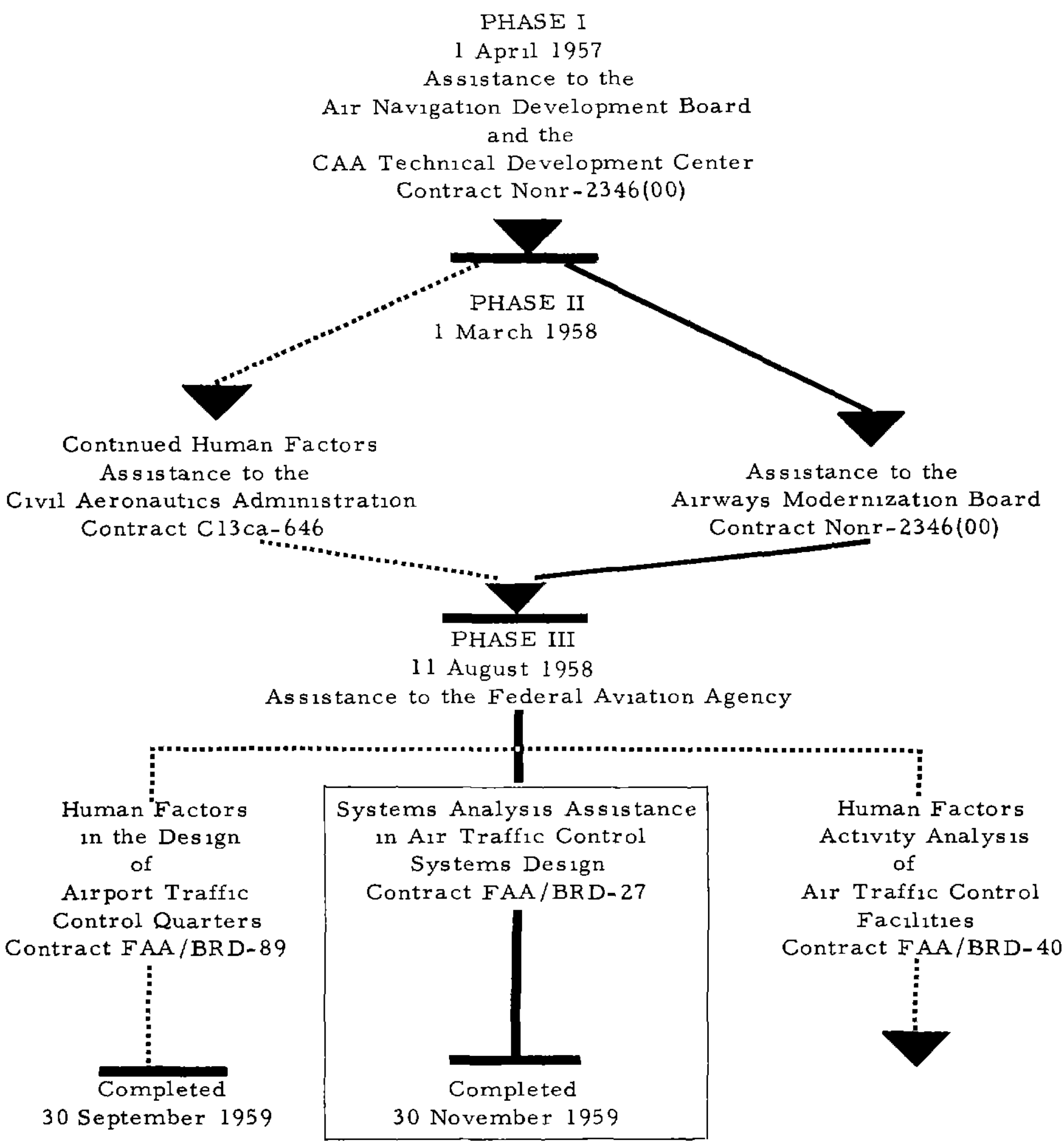
The qualms generated by the first look at prototype hardware are somewhat like those which beset the new father viewing his squawling offspring for the first time (Although perhaps our own role is more nearly analagous to that of the distant cousin who introduced the couple.) In spite of these qualms, there is a feeling of pride and accomplishment on viewing the first tangible representation of the development team's efforts

Although it is evident that the job of developing a finished, smoothly-operating system of semi-automatic air traffic control has only begun, there is ample evidence that a close and continuing working relationship among many disciplines, including human factors, can bring to fruition the promise of maximum safety in the air

An earlier report "Human Factors in Air Traffic Control Systems Design," Courtney and Company Report #24, dated 1 December 1958, outlined the human factors research in air traffic control carried out during a revolutionary period in American aviation. This report is a sequel to that earlier publication and outlines the continued assistance given to the Federal Aviation Agency during the last twelve months. Although it is primarily a summary of work performed on Contract FAA/BRD-27, the report reflects some of the interaction with other air traffic control research projects in which Courtney and Company has been engaged. The major on-going air traffic control research projects and their genealogy are shown in Figure 1 Planned project interaction has been an important characteristic of the year's effort, making possible a maximum contribution by the human factors members of the research and development team.

This report is a summary in every sense of the word Since a major portion of the work has been described in detail in other technical reports, this report will only briefly summarize the tasks performed during the contract period The interested reader who desires more complete technical data should refer to the technical memoranda and reports listed in the Appendix.

HUMAN FACTORS IN AIR TRAFFIC CONTROL SYSTEMS DESIGN



Work Covered by This Report

Figure 1 Genealogy of Human Factors in Air Traffic Control Program

CHAPTER TWO

PHASE III
SYSTEMS ANALYSIS ASSISTANCE IN AIR TRAFFIC CONTROL SYSTEMS DESIGN
11 AUGUST 1958 - 30 NOVEMBER 1959

TASK I -- ASSISTANCE IN THE DEVELOPMENT AND EVALUATION OF AIR TRAFFIC CONTROL SYSTEMS

Item 1 Program Planning

A considerable portion of the over-all effort has been devoted to providing consulting services to the staff of the Federal Aviation Agency in the area of human factors in systems design In general, the assistance rendered has not followed the usual concept of "expert" consultation, rather it has meant a close working relationship with members of the System Planning Branch of the Systems Analysis Division The intent of this work has been to add professional human factors inputs to the professional air traffic control and engineering skills of the FAA staff.

The assistance given has ranged over a wide field of operational problems. Some of the most significant work has been in the development and evaluation of fast-time simulation plans for testing ATC system design concepts One of the byproducts of this work was the recommendation that computer generated flight plan samples be employed in dynamic simulation and in testing prototype ATC data processing equipment. Besides developing the basic concept of computer-generated flight plan inputs, an optimum format for data print-out was specified

In another area of program planning, Courtney and Company personnel participated in the preparation of operational requirements for various data acquisition, processing, and display systems. One such project was the preparation of a memorandum report on the operational requirements for interim automatic ground-air-ground communications in air traffic control. This jointly prepared report* was based on an extensive literature search and an analysis of the basic factors influencing the exchange of control information in readily usable form

Some of the other planning projects on which Courtney and Company personnel were used to supplement FAA staff efforts are

(1) The outlining of a program of mathematical analysis and fast-time simulation to determine the effects of air vehicle standardization on ATC system operation

(2) The preparation of an experimental design for determining the validity of certain fast-time simulation programs with emphasis on the accuracy of the simulation of controller decision-making behavior.

(3) The specification of research requirements for ATC facility lighting.

(4) The preparation of operational requirements for ATC weather displays.

(5) The analysis of intelligibility problems associated with communications techniques (Reported in Courtney and Company Memorandum Report #24)

*Memorandum from Ralph F Link, Chief, Operations Divisions, to Major Lawrence C. Wright, Director for Development, dated October 27, 1958

Item 2 Information Requirements for Air Traffic Control Displays

A major part of the work performed on Task I was devoted to a basic study of information requirements for terminal air traffic control displays. The initial approach to this problem was a descriptive analysis of information transmission links between the aircraft pilot and control positions at a typical high-density, controlled airport. Flow diagrams were developed for inbound and outbound traffic under both IFR and VFR conditions.

However, it was suggested by the staff of the Systems Analysis Division that it might be possible to identify the essential elements of aircraft separation and sequencing through a study of the least complex terminal area operation, and to then apply these principles to the more complex, controlled terminal area situation. Consequently, a study was undertaken of the kinds and qualities of information used by the pilot in terminal area situations in which he must provide his own separation and sequencing. The results of this study have been reported in Courtney and Company Report #31, entitled "Capabilities and Limitations of the Pilot Operating in a Terminal Area Without Tower Control " The major conclusions of this study are as follows

Conclusion #1. In the pilot-to-pilot control situation, the pilot must perceive and integrate a complex set of sensory cues These sensory inputs must in turn be correlated with an appropriate set of expectancies derived from experience, regulations, and publications. Only in the presence of such expectancies do sensory cues become control information

Conclusion #2. To some extent expectancies are a function of internal factors, such as the uniformity of performance characteristics of aircraft operating in the system, but to a larger degree they are a function of the rigidity imposed by regulations. Both undegraded sensory inputs and the expectancies which make possible the prediction of future behavior of other aircraft are essential to successful operation in an uncontrolled terminal environment

Conclusion #3. Where the primary sensory cues are obliterated or seriously degraded, the pilot has inadequate information on which to base his exercise of control function. It should be noted, however, that the same conditions of weather which restrict the pilot's visual capacity to obtain control information similarly restrict the air traffic controller's visual capacity. In the controlled situation, however, artificial sensors such as radar and radio restore at least the minimum information required to effect control Direct access to this information is restored only to the controller and is only indirectly transferred to the pilot in the form of clearance instructions or traffic advisories

Conclusion #4. The analysis of the threshold tasks of the pilot, and of the nature of the pilot's decision-making activities, clearly indicate that mere visibility is not sufficient to permit pilot-to-pilot control of air traffic. Even under VFR conditions the capability of the pilot to act on the sensory inputs available is severely impaired when a measure of ground control is introduced. The flexibility added by the air traffic controller negates the ability of the pilot to anticipate the behavior of proximate aircraft. The controller may modify traffic patterns of particular aircraft to permit such variations as straight-in approaches, right-hand turns, and 360 degree turns Thus, although the visual sensory inputs available to the other pilots may be identical to those in the uncontrolled VFR terminal situation, the expectancies which provide the framework for the pilot's decisions will no longer be appropriate. As noted earlier, cues become information only when perceived and integrated in a consistent and meaningful context It is paradoxical that the inherent rigidity of the terminal operation without tower control is most closely approximated in the completely IFR operation of the terminal with tower control.

Conclusion #5. There is, in fact, no such thing as an uncontrolled terminal area Regulations governing the operation of aircraft in the vicinity of airports without towers consitute a very rigid form of control

Conclusion #6 The difference between the wide separation standards established by regulations and those dependent upon pilots' subjective estimates of what consitutes safe separation is the major factor in the unusually high aircraft movement rates accomplished on occasion at airports without tower control

In addition to the specific activities in program planning and basic research which have been mentioned, the staff of Courtney and Company has participated in the deliberations of a number of special working committees and task groups established by FAA to cope with special problems One such task group was the Terminal and Transition Task Group appointed to study the requirements for automatic track-while-scan radar displays for use in the semi-automatic air traffic control system. Another such group was established to outline specifications for the dynamic simulation tests of prototype Data Processing Central equipment. As indicated in the "Guide to Specifications for DPC Exercises," published by FAA in August 1959, Courtney and Company personnel worked closely with this group to outline aspects of the man-machine relationship which required testing in the DPC exercises

As can be seen, the work performed under Task I has ranged over many facets of air traffic control system design The broad coverage of this work has given the human factors specialists on the design team a greater depth of understanding of the Federal Aviation Agency's over-all programs than would have been possible if the effort had been restricted to the usual narrow concept of "dials and knobs" human engineering Consequently, each of the other tasks has benefited from a more thorough understanding of their place in the "big picture." Thus the accomplishments of Task I are of interest not only for their own sake, but for their impact on the other work performed as well.

TASK II. ASSISTANCE IN THE DESIGN OF AIR TRAFFIC CONTROL DATA PROCESSING AND DISPLAY SYSTEMS

Item #1. Human Engineering Assistance

A. Data Processing Central (DPC). The major equipment development efforts of the Federal Aviation Agency have been centered in the Data Processing Central System being built by the General Precision Laboratory. It is only natural then that the bulk of the effort devoted to Task II has been associated with the human factors in the design of the Data Processing Central. Actually, this task is a continuation of earlier work outlined in "Human Factors in Air Traffic Control Systems Design" (Part 1), and reported in detail in Courtney and Company Memoranda #1 through #11. The magnitude of this continued effort is reflected in the additional twenty technical memoranda on various aspects of the Data Processing Central which have been issued during the current contract period A repetition of the material contained in these memoranda would not be in keeping with the summary character of this report The reader who wishes a technical account of the human engineering recommendations made on the DPC should check the list of memorandum reports contained in the Appendix.

However, there are some general considerations regarding this work that should be brought out in this summary. In July 1959 the Federal Aviation Agency carried out a review of the entire Data Processing Central program which led to major change in approach to the DPC Basically this change represented a return to the original concept of the DPC as an experimental assembly of equipment rather than a prototype operational system. Out of this review came the SATCAN and SAPO programs of the Bureau of Research and Development which are currently in effect

This realignment has been reflected in the human engineering assistance rendered Under the concept of the DPC as an experimental system, it becomes possible to defer some human factors decisions until an adequate opportunity has been afforded to test some of the concepts in simulation However, during the intermediate period in which the Data Processing Central was being designed for almost immediate operational application, much display and control design flexibility was lost so that changes in concept made now cannot be reflected in changes to equipment design An example of this is a major revision in the assignment of functions to operators of the radar sector console so that the radar controller will track aircraft and, even in the normal load conditions, will not operate either a keyboard or tabular bay equipment. Such revisions obviously have some far reaching implications for the design of the consoles The consoles were not designed with this allocation of functions in mind In fact, the consoles were designed to optimize the man-machine relationships for a previous assignment of duties to the controllers It is somewhat axiomatic that if one configuration optimizes the man-machine relationship for one set of duty assignments, the same configuration will downgrade the man-machine relationship with a different set of duty assignments

There are also some aspects of the Data Processing Central which involve human functions to which little attention has been given to date These include factors affecting the maintainability of the system and the requirements for operator training which must ultimately be developed for an operational system

Up to now no work has been done on examining the maintenance controls, procedures and provisions for detection and correction of equipment malfunctions. The present ratio of operators to controllers in New York is probably about 12 controllers to 1 maintenance man. The present duties of the maintenance personnel are solely with the radar and communications equipment since virtually everything else is manual. With the installation of some future semi-automatic system, this ratio might begin to approximate 3 or 4 to 1 Thus, the importance of human factors in maintenance will increase enormously

There is an excellent opportunity currently during the building of the equipment and its de-bugging to see how tests of it are made, the defective components isolated, etc

It is not certain what might be found, It seems likely, however, that recommendations about test points and procedures and layouts might result For example, there has been within recent years some stress laid on changing the trouble-shooting pattern from a logical step-by-step approach to one which maximizes the amount of information obtained on each test. For example, if we had printed cards placed in series, the most efficient checking procedure would not be to start at the beginning and test each one. Although this is logical, the most efficient procedure would be to start in the middle and work to either side. If one side is dead then the next step is to go to the middle half of the blank side, etc Anyway, since maintenance will become so critical it would appear that some emphasis should be given to it now

In this connection it might also be mentioned that the General Precision Laboratory approach has been to make more adjustments possible than would be available in production hardware. Their raison d'etre is that so little is known about the optimum characteristics of the system that extra flexibility to manipulate them should be made available on this experiemental gear. The same is also true in another way. Many adjustments can be made merely by changing the value of a resistor This information is going to be lost as the various project engineers' work on the DPC is concluded. This information should be codified and assembled, probably by engineers, although human factors personnel would be able to ask incisive questions about those factors which affect human performance. The way to adjust the control optimally could then be spelled out.

2. Training. A first step in developing a training program would be to attempt to write a complete set of procedures for use with the DPC General rules are not permissible, especially during system evaluation, since human errors could not be distinguished from human idiosyncracies and techniques Many of these procedures can, of course, be developed during simulation, but a significant start could be made now. Certainly such a collection would have many uses other than training. It could also be used for evaluation of individual proficiency and workload, but also extremely useful for concretizing how the system operates This will certainly be necessary for any careful evaluation. Such a review and detailing of procedures would point up many of the inadequacies in the present system and also lead to concepts useful in writing the specifications for Model No 2.

A second step would be to assess the unique requirements for the DPC For example, a tremendous system knowledge is required by controllers, since with this information the computer can be made to play certain tricks and the controller's job simplified In addition there are different types of skills required than in the present system. The position of tracker, for example, as contrasted with the position of radar controller requires quite different skills and knowledge As a result of this work useful selection tools could be specified, and also an improved training program could be developed assuming Model No 2 does not deviate too much from Model No 1

These are two of the directions which future human factors support of this and other data processing and display programs should take

B Automatic Ground/Air/Ground Communication System (AGACS)

Although the major effort under Task II was devoted to the Data Processing Central System, several significant contributions were made to another of the Bureau of Research and Development's equipment design projects This project is the Automatic Ground/Air/ Ground Communications System (AGACS) being constructed by the Radio Corporation of American for the Development Directorate The human factors assistance provided on the AGACS project had four parts:

1 Layout of the AGACS Ground Console and Display. A completely revised version of the controller's ground console and display was recommended The revised design (Figure 2) was based on present controller work habits and a functional arrangement of the information to be displayed.

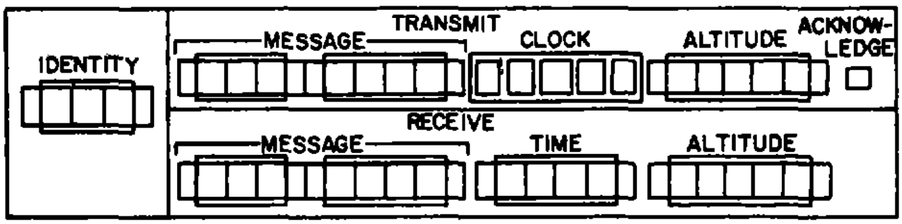


Figure 2 Recommended Design for AGACS Controller's Console

2 Design of the AGACS Airborne Display and Entry Unit The proposed design was analyzed from the standpoint of pilot activities required to operate the airborne equipment while transmitting or receiving data link messages. It was felt that the proposed design required an excessive amount of manipulation and visual monitoring by the pilot Courtney and Company Memorandum #22 contains recommendations for an extensive redesign of the airborne unit Figure 3 shows the original design and Figure 4 the recommended version Of major importance was the recommendation to regard the alpha-numeric read-outs as a flexible part of the message structure rather than regarding them as simply FIX identifiers

This change in concept was made possible by a decision to provide a complete alpha-numeric capability on each indicator A remarkable amount of information can be encoded in four such displays, each having 36 positions By combining this variable display with the 31 discrete messages, the first model of AGACS can be used far more effectively to assess the value of different message structures and the applicability of data link to ATC functions other than position reporting For example, Figure 4 shows the display of a ground/air message in which the discrete message has become, in effect, a prefix for the numeric information, identifying the numbers as the altimeter setting These numbers might also be used as an altitude with a discrete message reading "CLIMB TO " This concept of the alpha-numeric indicators as simply variable parts of the message structure opens up many possibilities for discrete messages which would otherwise be relegated to a voice channel Requests for changes in speed, heading, altitude, etc., become possible under this concept This greatly increases the latitude of the information which can be handled via automatic air-ground communications

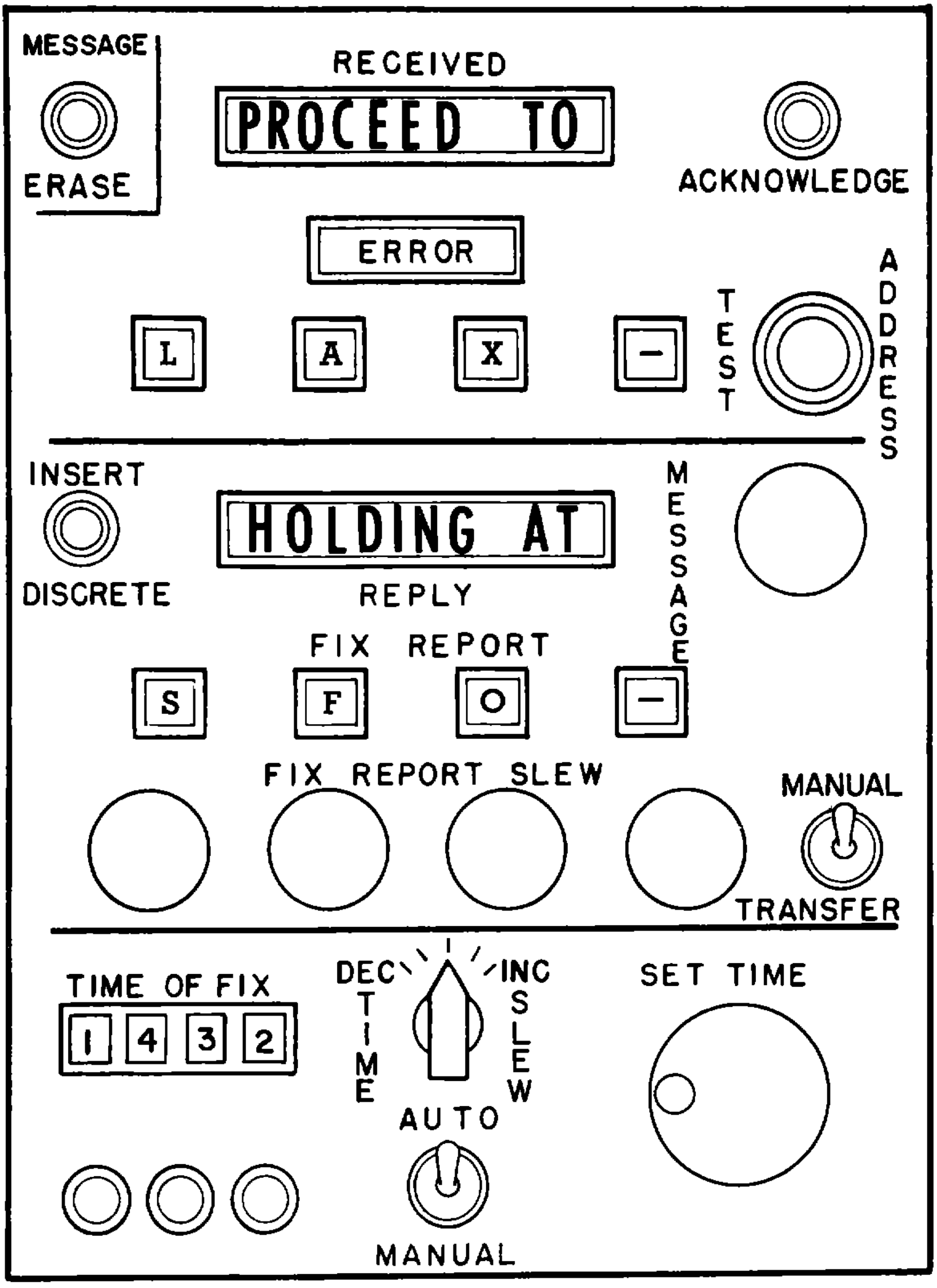


Figure 3. Original Design for AGACS Airborne Display and Insertion Unit

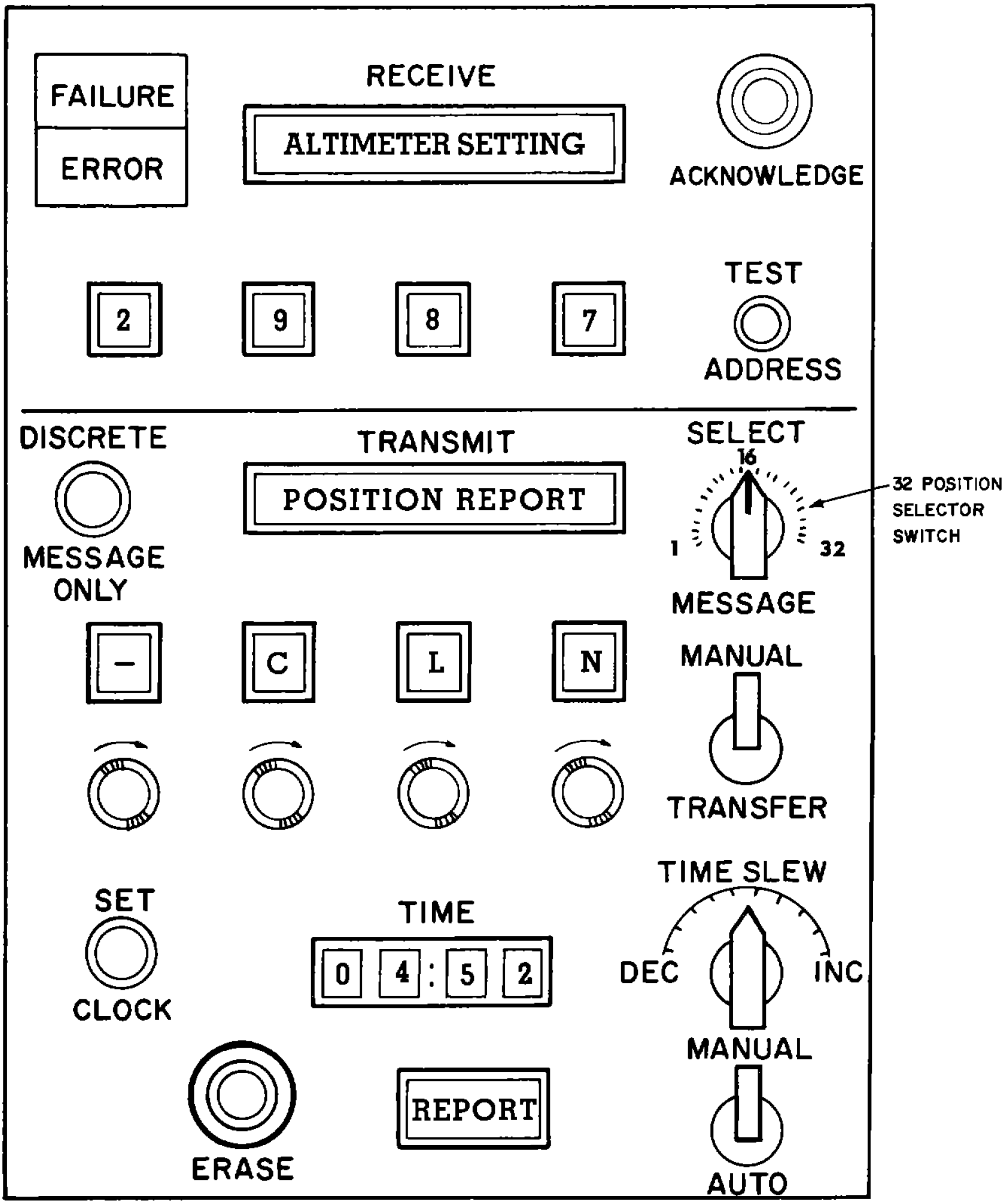
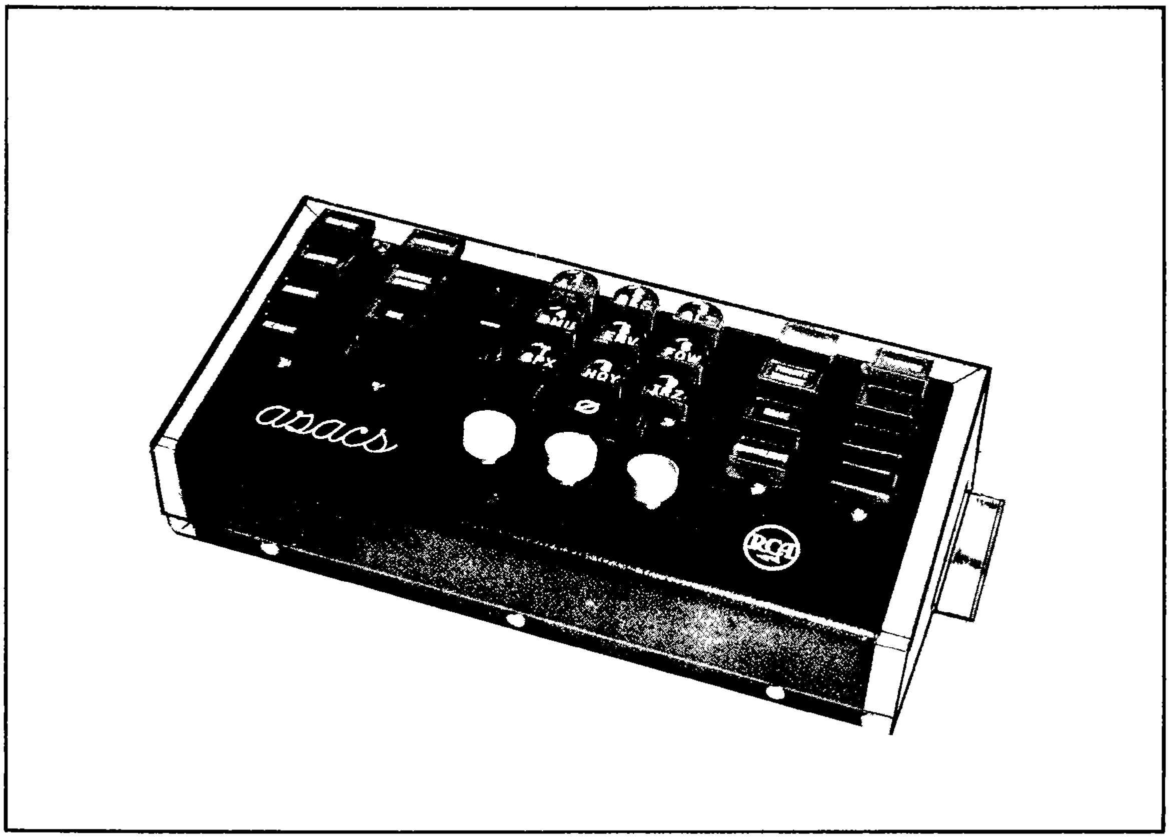


Figure 4. Proposed Redesign for AGACS Airborne Display and Insertion Unit

3 Discrete Messages for Use with AGACS, Mod. I A comprehensive survey of the message content of air traffic control radio communication was made in order to arrive at a selection of discrete messages which would maximize the information transmission capabilities of AGACS Courtney and Company Memorandum #23 listed the recommended discrete messages for both the airborne unit and the controller's console and gave the rationale for the selected messages and the recommended sequence of presentation The discrete messages recommended in the memorandum were discussed and modified with the help of members of the Systems Planning staff to achieve a list of messages to be incorporated in the prototype equipment It was strongly recommended that the simulation period be used to evaluate the frequency of use and functional value of the various messages to determine both an optimum number of messages for future models of data link and to determine those messages with the greatest operational value

4 Design of Keyboard Entry Device for Use with AGACS Several possible keyboard designs were evaluated from a human factors standpoint and a final design requirement established in conjunction with RCA and FAA personnel The keyboard (Figure 5) uses a unique zone coding design which keeps the number of keys at a minimum but still supplies a complete alpha-numeric capability to the controller Since this keyboard differs markedly from that used in the DPC, it was recommended that the designs be carefully evaluated during simulation tests and that a standardized entry device be developed



RCA PHOTOGRAPH

Figure 5. AGACS Keyboard Design

There is no doubt that communications is a major problem in air traffic control and, since the human controller is at the center of this vast information network, his capabilities and limitations will continue to be an important factor in the design of communication systems

TASK III. ASSISTANCE IN THE SIMULATION OF AIR TRAFFIC CONTROL SYSTEMS

Item 1. Human Engineering Assistance

One of the advantages of dynamic simulation in air traffic control research is that it includes the human controller as a functioning component of the system under test Simulation thus becomes an operation of great interest to the human factors specialist The role played by Courtney and Company in the simulation programs of the Bureau of Research and Development has followed almost a classic approach in man-machine system design It began first with participation in the design of simulation equipment to meet specified operational requirements This participation at the design stage was to insure that those parts of the system which were to be manipulated by human operators were designed to take maximum advantage of human capabilities and to minimize the effects of human limitations. The majority of this simulator design effort was carried out under a previous contract, but the work was brought to completion during the present contract period. The simulator is now being installed at the National Aviation Facilities Experimental Center, Atlantic City, New Jersey, and, as can be seen in Figure 6, is rapidly nearing completion

Courtesy of FAA

Figure 6. The Radar Target Generators (Aircraft Armaments Simulator)

<u>Item 2 Development of a Selection and Training Program for Simulator Operators.</u> But equipment design can only accomplish a part of the task of optimizing the man-machine relationships Once the machine has been "fitted" to the man, through the application of established principles of human engineering, man must be "fitted" to the machine. This "fitting" is accomplished first by the selection of operators with the necessary abilities to perform the required tasks, and secondly by developing these latent abilities into specific skills through training. Basic to both these techniques is a thorough description and analysis of the job to be performed

Such a comprehensive analysis of the simulator operator's task was prepared and reported in Courtney and Company Report #25, "The Simulator Pilot in a Dynamic Air Traffic Control Simulator An Activity Analysis." In this report the over-all simulation system is described and illustrated, with special emphasis on the role of the operators as "pilots" of simulated aircraft A typical hypothetical simulated flight was synthesized to illustrate the manipulative skills, communicating abilities and varying workload requirements involved All operator activities were listed and recommended sequences for accomplishing the various sub-tasks were provided. Other recommendations were made for (1) an operator selection system, (2) an operator training program, (3) problem script formats for operators and simulation director, and (4) improvements in future ATC simulator designs

The activity analysis provided a reliable basis for the development of an operator selection system and for the structuring of an effective training program The development and preliminary validation of several predictors of candidates' potential success as simulator operators was only a part of the major study made of the selection system. A complete selection system was proposed, including recruiting and job performance evaluations in Courtney and Company Report #30, "Prediction of Operator Effectiveness in Dynamic Air Traffic Control Simulation."

In addition to these major efforts, Courtney and Company personnel worked with the staff of the Simulator Operations Branch during the formulation of an operator training program. The activity analysis became an important segment of the Simulator Operator's Manual prepared by the Federal Aviation Agency.

All of the work described in this summary report has been building toward the test and implementation of an air traffic control system into which the human component has been optimally fitted It has been said that research is never completed, it is merely ended This statement is at least partly true of this program, for the research is only beginning, but it can end only when human beings cease to design, fly, and control aircraft.

APPENDIX

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
Memorandum #4	Enroute Radar Supplement	15 May 1958
Memorandum #5	The Pneumatic Tube System	16 May 1958

Phase II (Continued)
Contract Nonr-2346(00)

Number	Title	Date
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 Positions	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

Contract FAA/BRD-85

Report #29	Staff Development in Systems Research Techniques	15 August 1959

Phase III
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
Memorandum #24	Comments on Blonder-Tongue Laboratories, Inc. Proposal--Human Factors Aspects of Intelligibility in ATC Voice Communications Systems	2 February 1959

Phase III (Continued)
Contract FAA/BRD-27

Number	Title	Date
Memorandum #25	Preliminary Recommendations for the Sit and Sit-Stand Position Seating to be used with the FAA Data Processing Central System	13 February 1959
Memorandum #26	Flow Control Supervisor's Keyboard	12 March 1959
Memorandum #27	Sequence Console and Keyboard Readouts	12 March 1959
Memorandum #28	Orientation of Matrix, Compass and Radar North and Special Displays	20 March 1959
Memorandum #29	Cab Configuration	19 March 1959
Memorandum #30	Activities During 30-31 December 1958	31 December 1958
Memorandum #31	Activities During Week of 12 January 1959	16 January 1959
Memorandum #32	Switch/Indicators on Radar Sector Console and Approach/Departure Console	19 March 1959 (Rev. 9 April 1959)
Memorandum #33	Flight Strip Paper	23 January 1959
Memorandum #34	Format Display for Speed Reduction	8 April 1959
Memorandum #35	Departure Display in Idlewild Cab	12 May 1959
Memorandum #36	Review of FAA/BRD Fast-Time Simulation Program	20 August 1959
Memorandum #37	Assistance in the Selection of AOS Personnel as Simulation Project Team Members at NAFEC	23 September 1959
Report #25	The Simulator Pilot in a Dynamic Air Traffic Control Simulator An Activity Analysis	15 February 1959
Report #30	Prediction of Operator Effectiveness in Dynamic Air Traffic Control Simulation	1 November 1959

Phase III (continued)
Contract FAA/BRD-27

Number	Title	Date
Report #31	Capabilities and Limitations of the Pilot Operating in a Terminal Area Without Tower Control	15 November 1959

Human Factors in the Design of
Airport Traffic Control Quarters
Contract FAA/BRD-89

Number	Title	Date
Report #26	Human Factors Considerations in the Design of Airport Traffic Control Quarters (Interim Report)	15 April 1959
Report # 27	Human Factors Considerations in the Design of Airport Traffic Control Quarters (Second Interim Report)	1 June 1959
Report #28	Human Factors Considerations in the Design of Airport Traffic Control Quarters (Final Report)	1 August 1959

Human Factors Activity Analysis of
Air Traffic Control Facilities
Contract FAA/BRD-40

Number	Title	Date
Memorandum #1	Selection of a Sample for a Cross-Sectional Review of Job Structures in Air Traffic Control	11 September 1959
Memorandum #2	Methodology Used in Conducting a Cross-Sectional Review of Job Structures in Air Traffic Control	16 November 1959
