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HUMAN FACTORS ASPECTS OF AIR TRAFFIC CONTROL

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16. Abstract

This report presents an overview of human factors problems associated with the operation of present and future air traffic control systems. A description is included of those activities and tasks performed by air traffic controllers at each operational position within the present system. Judgmental data obtained from controllers concerning psychological dimensions related to these tasks and activities are also presented. The analysis includes consideration of psychophysiological dimensions of human performance. The role of the human controller in present air traffic control systems and his predicted role in future systems is described, particularly as that role changes as the result of the system's evolution towards a more automated configuration. Special attention is directed towards problems of staffing, training, and system operation. A series of ten specific research and development projects are recommended and suggested work plans for their implementation are included.

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TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

TABLE OF CONTENTS--Continued

LIST OF FIGURES

LIST OF FIGURES--Continued

LIST OF TABLES

LIST OF TABLES--Continued

SUMMARY

This report provides an overview of problems concerned with the role of the human in present and future air traffic control systems. The demands placed upon the air traffic control system (the equipment, personnel, and operational procedures involved in facilitating the safe and expeditious flow of air traffic) have multiplied enormously during the past two decades. While there have been many innovations in air traffic control equipment, research dealing with the manner in which human beings interface with this equipment has not kept pace. This report identifies major areas where these human factors problems are of concern in the air traffic control system as it now exists, and discusses difficulties which are likely to emerge as new and more sophisticated equipment is introduced into the system.

A recommended program of research and development activities dealing with the role of the human in air traffic control systems is formulated and discussed. The research recommendations are designed to be relevant regardless of specific future decisions made concerning the design of the equipment and its associated software. Although the exact configuration of equipment and facilities which will eventually comprise the system is not well defined at this time, it is clear that for many years to come, human beings will continue to perform the most essential functions of processing information and making decisions.

The proposed research program suggests that NASA efforts focus on the more basic research activities rather than on applied studies, in order to develop a body of fundamental knowledge in support of the development program planned by the FAA for the National Aviation System. NASA can effectively provide assistance in the area of carrying out longer range, generalized research as a supplement to FAA efforts which evolve as a result of the necessity to provide solutions for day-to-day problems in operating the system.

CHAPTER 1

INTRODUCTION

During the past few years, there has arisen an increasing awareness that the National Aviation System (NAS) is confronted with critical problems and that a major cooperative effort by government and industry is required to solve them. A recent report by the Department of Transportation, Air Traffic Control Advisory Committee (Alexander et al., December 1969) stated:

> Air traffic is in crisis. The crisis now manifest at a few high density hubs is the direct result of the failure of airports and air traffic control capacity to keep up with the growth of the aviation industry... Unless strong measures are taken, forces presently in motion will blight the growth of American aviation.

This report provides an overview of the human factors aspects of the air traffic control (ATC) system. The impetus for the study came from recognition on the part of the National Aeronautics and Space Administration (NASA) that many of its facilities and capabilities could be brought to bear in helping to solve the problems of the air traffic control system. This view is shared by the National Academy of Engineering, Aeronautics and Space Engineering Board (NAE, ASEB, Ad Hoc Committee on Air Traffic Control, December 1968), which issued a series of recommendations suggesting that an increased effort by NASA in support of air traffic control research and development would be highly desirable. A basic tenet of the NASA and NAE approach is that efforts to find solutions to air traffic control problems must involve not only engineering and technological development but also a corollary study of the human elements of the system, the air traffic controllers.

The past decade has seen the emergence of serious deficiencies in the ability of ATC equipment and personnel to cope with ever-increasing performance demands. This report focuses on human factors problems in the ATC system as it now exists and on those which are likely to emerge as new, more sophisticated equipment is introduced into the system. It should be recognized that personnel at all levels of the Federal Aviation Administration (FAA) are acutely aware of these problems and are striving to find solutions. However, as a variety of FAA documents have pointed out over the past several years, research and development efforts have been hampered by budgetary limitations and personnel shortages. Thus, this report is meant to be critical of neither FAA procedures and practices nor the quality of their efforts. Rather, its intent is to review the overall situation and thereby assist in defining problem areas which can be alleviated by human factors research.

The demands placed upon the air traffic control system have multiplied enormously in the past two decades. While there has been appreciable increase and innovation in the equipment used for air traffic control, human factors research required to support this growth has not kept pace. The last broad survey of air traffic control problems from a human factors viewpoint was conducted nearly twenty years ago (Human Engineering for an Effective Air Navigation and Traffic Control System. Fitts, P. M. (Ed.), March 1951.) There have, of course, been many reports on specific air traffic control studies published since that time. However, until now there has been no attempt to provide a systematic review of the human factors problems in air traffic control such as this report undertakes.

Several methods were employed in compiling the information presented in this report. At the outset, a careful review was made of the technical literature. Visits were made to several operational ATC facilities both to gather factual material and to obtain the views of controllers at the working level. Interviews were also conducted with personnel at the National Aviation Facilities Experimental Center (NAFEC), the FAA Academy, and various units within FAA headquarters. Many of the recommendations in this report derive from the expert judgment of FAA personnel, and NASA officials who were also consulted. While their views did much to shape the findings of this study, the BioTechnology, Inc. staff takes full responsibility for the conclusions drawn and for the substance of the recommendations.

This report is organized as follows:

Chapter 2 presents an overview of the ATC system with special attention to those aspects considered most amenable to analysis through human factors research. This chapter describes en route, terminal, and flight service station operations and points out the direction which the system appears to be taking in evolving toward a more automated configuration.

Chapter 3 examines the ATC system with respect to those human factors problems which arise in the areas of staffing, training, and operations. Recommendations are presented for human factors activities to assist in solving the problems which are identified.

Chapter 4 contains an analysis of the activities and tasks which must be performed at each of the controller positions. This chapter also includes judgmental data solicited from a group of controllers concerning the important psychological dimensions of these activities and tasks.

Chapter 5 consists of two parts: (1) a consolidation of the specific research and development activities which are recommended throughout the preceding chapters; (2) a detailed outline of the suggested work program to implement the major recommendations.

Much of this report deals with judgments by operational personnel and with expert opinion of those engaged in research. While it would be highly desirable to support such conclusions with objective experimental data, the fact is that little such supportive evidence exists. Paradoxically, although there is clear recognition that the human factors aspects of air traffic control represent a massive problem area, there is only limited factual basis for establishing the dimensions of the problem or the parameters of the solution.

On the other hand, several recently published documents contain valuable information for planning research to improve the air traffic control system. Especially important among these are:

The Air Traffic Controller Career Committee Report, January 1970, provides an excellent statement of the major personnel and training problems related to the air traffic control system. Detailed management, research, and development recommendations concerning staffing, training, operations, and management are included. Many of these recommendations are now being implemented.

The National Aviation System Policy Summary and the National Aviation System Ten-Year Plan for 1971-1980, March 1970, are two companion documents which contain an excellent presentation of policy and plans relating to all aspects of the National Aviation System. Much of the material of Chapter 2 of this report was adapted from these documents.

The Report of the Department of Transportation Air Traffic Control Advisory Committee, December 1969, considers system configurations primarily from an equipment and facilities point of view with detailed analyses of future alternatives.

Buckley, Edward, O'Connor, William F., and Beebe, Tom. A Comparative Analysis of System Performance Indices for the Air Traffic Control System, NAFEC, 1970, is the most important human factors study in recent years. It contains detailed analyses of experimental techniques for evaluating controller proficiency utilizing simulation and other procedures. Since the development of reliable and valid methods to measure proficiency is critical to almost all other human factors efforts, it is anticipated that this study will have substantial significance for future work.

Hopkins, V. David, Human Factors in the Ground Control of Aircraft, AGARD, 1970, is probably the most comprehensive review of the literature in this field. This report provides an integrative and evaluative analysis of most of the relevant literature (960 reports are included).

In summary, the development of the ATC system in the United States has, for a variety of reasons, failed to keep pace with the requirements placed upon it. Clearly, there must be substantial changes in equipment, facilities, procedures, staffing, training, and all other aspects of the system to remove existing deficiencies and to promote progress consistent with the goal of moving air traffic expeditiously and safely. Although the exact configuration of equipment and facilities which will eventually make up the National Aviation System (NAS) is not well defined at this time, it is clear that for many years to come human beings will continue to perform the most essential functions of information handling and decision making. Consequently, it is vital that a substantial program of human factors support be planned and implemented as promptly as possible.

A variety of recommendations are made throughout this report concerning human factors efforts that should be undertaken. Some involve basic research; others are more applied in nature. It is suggested that NASA efforts in human factors focus on the more basic research activities rather than on developmental or applied studies. Human factors researchers in the FAA are quite limited in number, and the pressure for solution of day-to-day emergency problems will be so great during the foreseeable future, that it would be difficult for them to carry out longer range, more generalized research programs. NASA could provide assistance in undertaking, on a cooperative basis, a program to develop a body of basic research knowledge in support of the planned development program for NAS.

CHAPTER 2

THE AIR TRAFFIC ENVIRONMENT

The ATC system as considered in this report is that portion of NAS responsible for the operation of the air traffic control and navigation facilities in the United States. NAS, itself, contains many other elements, such as those responsible for management and maintenance of facilities, development and promulgation of regulations, certification of aircraft and airmen, and promotion of the national system of airports. The activities of these other components are considered in this report only insofar as they relate to the human factors problems of air traffic control. Figure 1 shows a graphic representation of the entire NAS. This report is concerned only with those elements included within the en route control, the terminal control, and the flight service station systems.

The En Route System

The present en route system is designed to provide control for the variety of types of aircraft passing through the system. The radar system now in use provides two-dimensional information on a given aircraft to the ground controller, thus requiring him to determine aircraft identity and altitude information by radio communication with the aircraft. Status information concerning the aircraft is maintained by placing a marker ("shrimp boat") near the blip designating that aircraft on the display. This marker is them moved manually as the aircraft indicator moves across the face of the display. Additional information on the aircraft is recorded on flight progress strips which are maintained on racks near the radar display. The process of manually acquiring, processing, and transmitting flight progress information

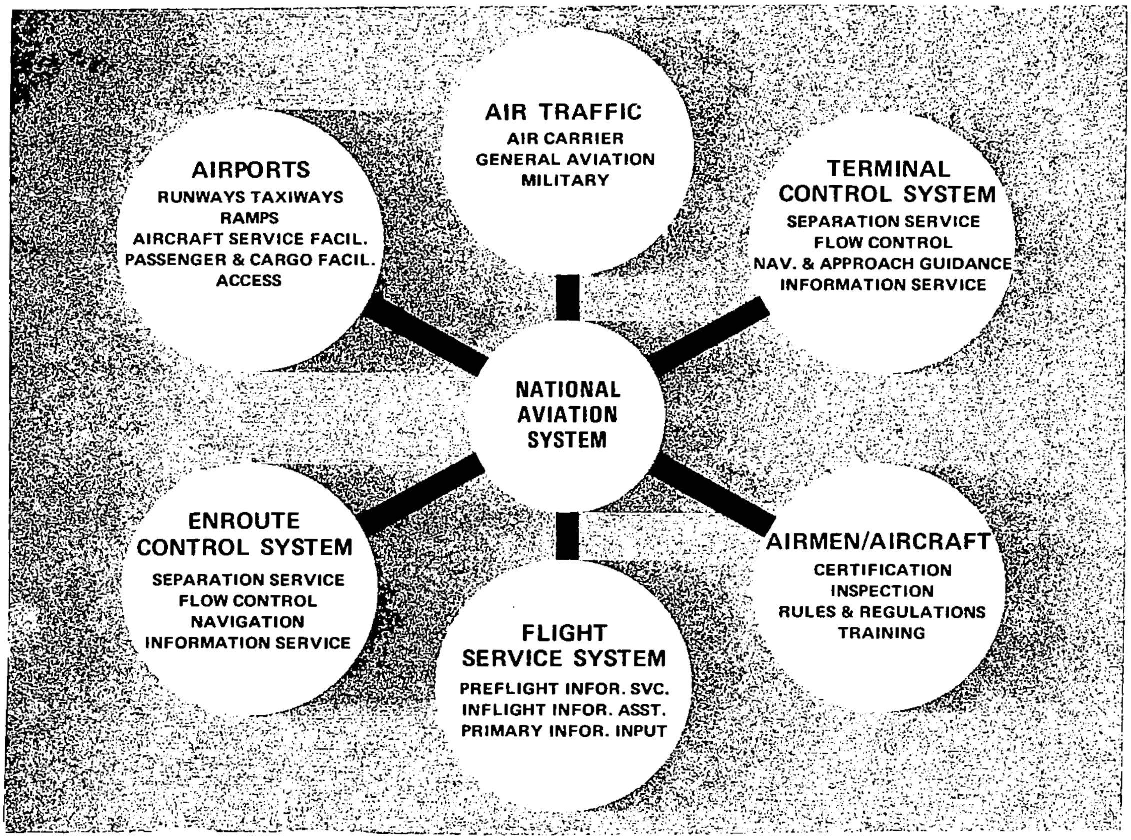


Fig. 1. Elements of the National Aviation System.
(From: FAA, NAS Summary, 1970.)

tends to be cumbersome and time-consuming. Consequently, any one controller can handle only a limited number of aircraft at any one time.

Typically, one controller is responsible for all aircraft in a given geographical area (sector). Each controller also has one or more assistants working with him. As aircraft move from sector to sector, information is passed between adjacent sectors by voice communication. This system is quite limited with respect to its traffic handling capacity, and a series of steps leading to greater automation of the system is well under way at this time. The automated en route system will, over a period of years, evolve into one in which many of the activities now performed manually will be performed automatically by the equipment. Thus, the controller will be free to perform more decision making and controlling activities.

Figure 2 is a stylized representation of a NAS Stage A air route traffic control center. In automated systems, the basic mechanism for obtaining information about the aircraft will continue to be primary and beacon radar systems. Aircraft will be equipped with transponders which will provide a constant input of information concerning altitude and identity. This information should substantially reduce the requirement for extensive communications between controller and pilot. Eventually, it is planned that computer processing of all information will provide the controller with a display on which the flight data pertaining to each aircraft will be presented in alphanumeric form and on which the aircraft will be tracked automatically. Figure 3 describes the present manual system and the characteristics of the automated system anticipated for 1980. Figure 4 illustrates the data input and display console for the radar controller in the NAS Stage A system.

Unfortunately, it is not feasible to close down the present manual system and install a new automated system all at one time. Consequently, there will be an overlap of several years where some facilities will be using manual

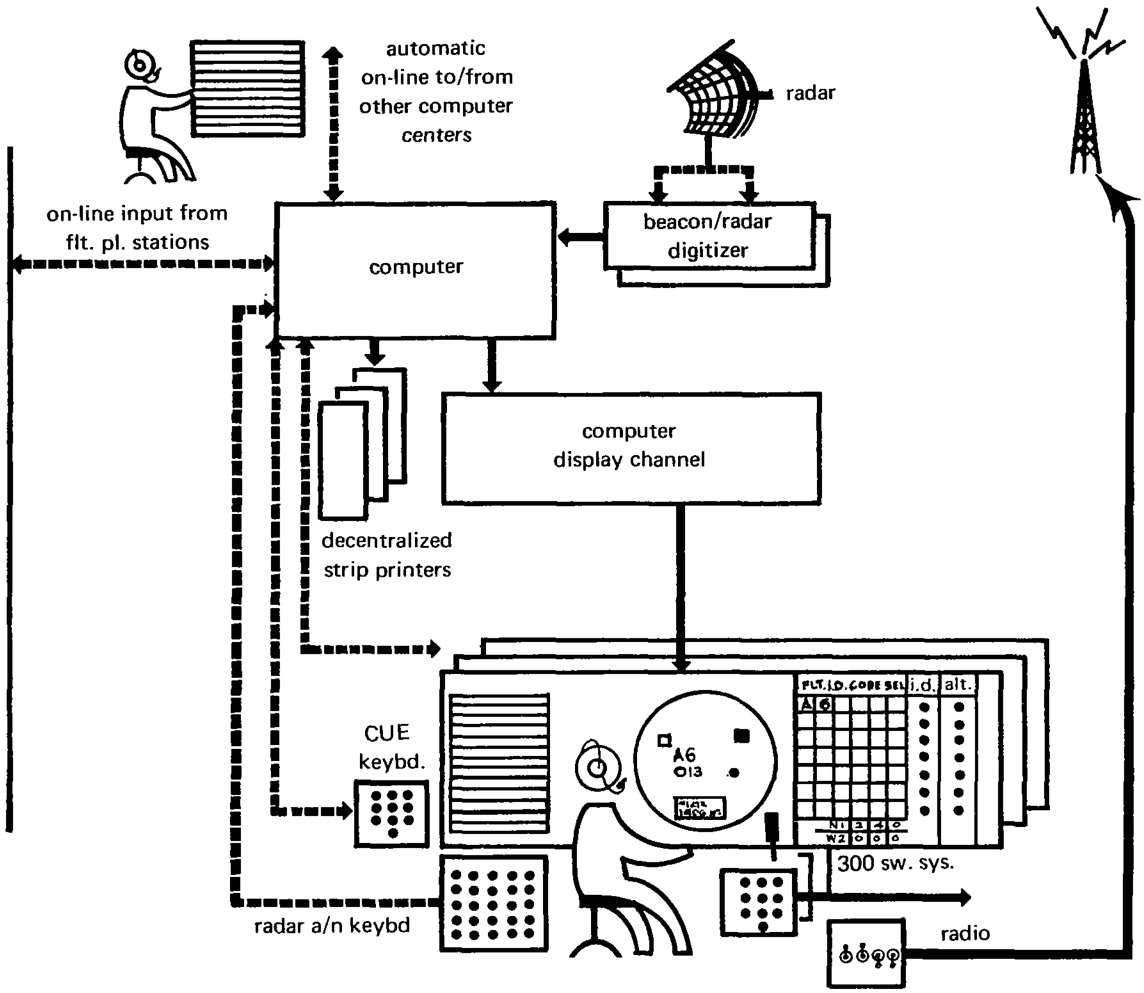


Fig. 2. NAS Stage A Air Route Traffic Control Center. (From: FAA, NAS Summary, 1970.)

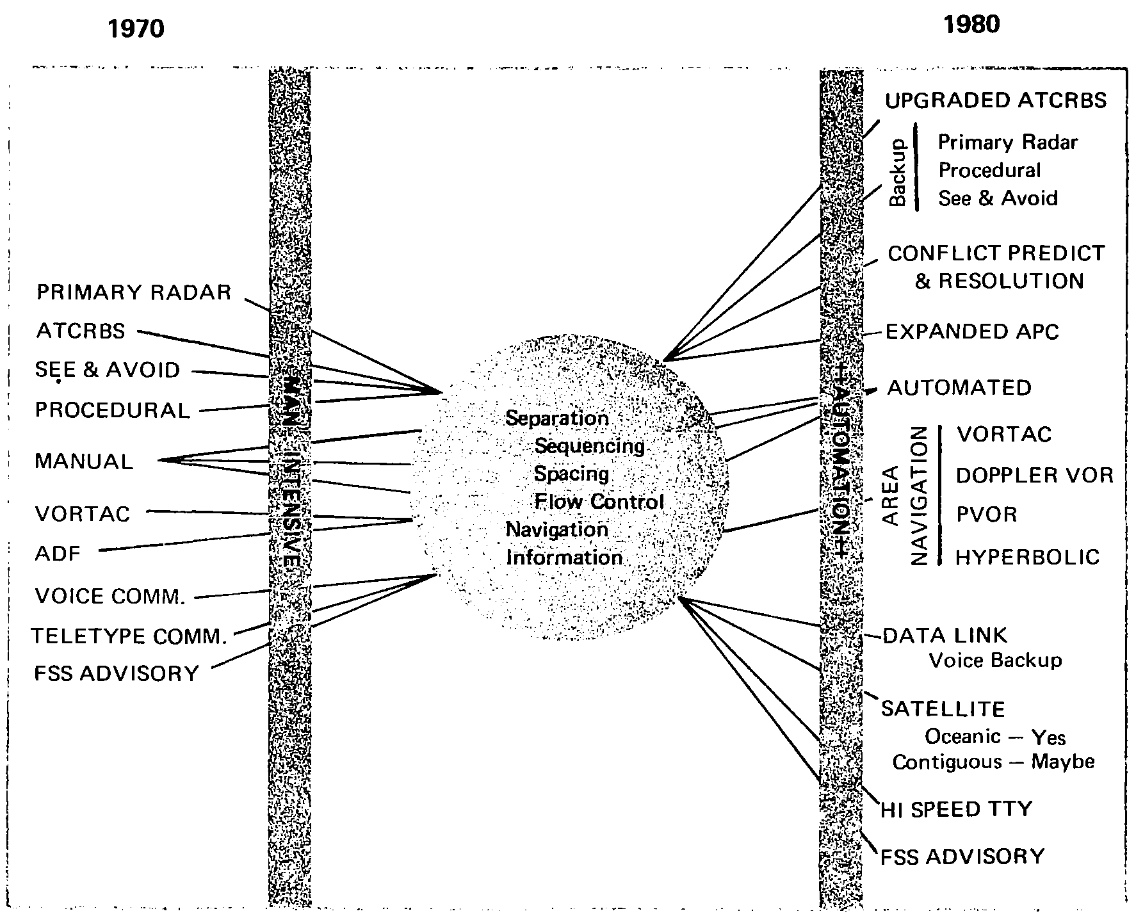


Fig. 3. Present and planned en route system.
(From: FAA, NAS Summary, 1970.)

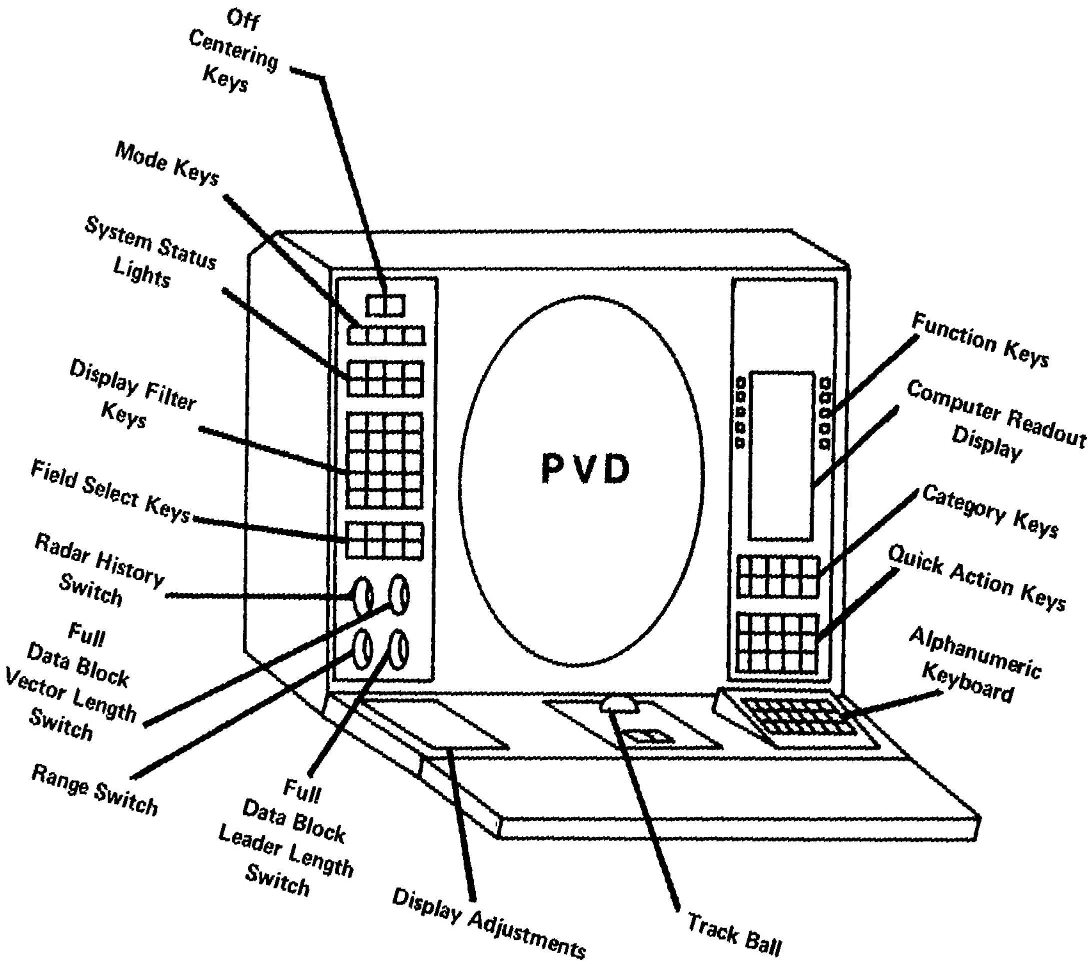


Fig. 4. Data input and display console for the radar controller in the NAS Stage A system. (From: FAA, NAS Summary, 1970.)

systems, while others are using automated systems, and still others some combination of the two. The first phase of the automated en route system is commonly referred to as the NAS Stage A system. This stage provides for automated flight data processing and the automatic generation of flight progress strips. The second phase will provide an alphanumeric display system. Subsequent phases will provide additional capabilities in the areas of conflict prediction, data link, traffic flow planning, and message generation. Research and development involving such techniques as the use of satellites for improving communications within the system are presently under investigation.

The Terminal System

At present, control of aircraft in the areas surrounding FAA terminals is provided primarily by a manual system which insures the orderly separation of aircraft, sequencing, spacing, navigational assistance, and approach guidance. The system also furnishes general information on weather, barometric pressure, and the like. Equipment and techniques essentially similar to those in the en route system are used. These rely primarily on the use of radar for range and azimuth information and on voice communication for information concerning altitude, aircraft identity, and the like. As with the en route system, there is an automated radar terminal system, referred to as ARTS III.

Figure 5 shows a typical ARTS III display configuration incorporating a large bright tube. The ARTS III is a phased system. It will have the capability for radar tracking of transponder equipped aircraft and will eventually provide for the display of alphanumeric information on aircraft under positive control. The problems which exist for the ARTS III system are similar to those discussed earlier in connection with the NAS Stage A system. Figure 6 illustrates the present and planned terminal systems.

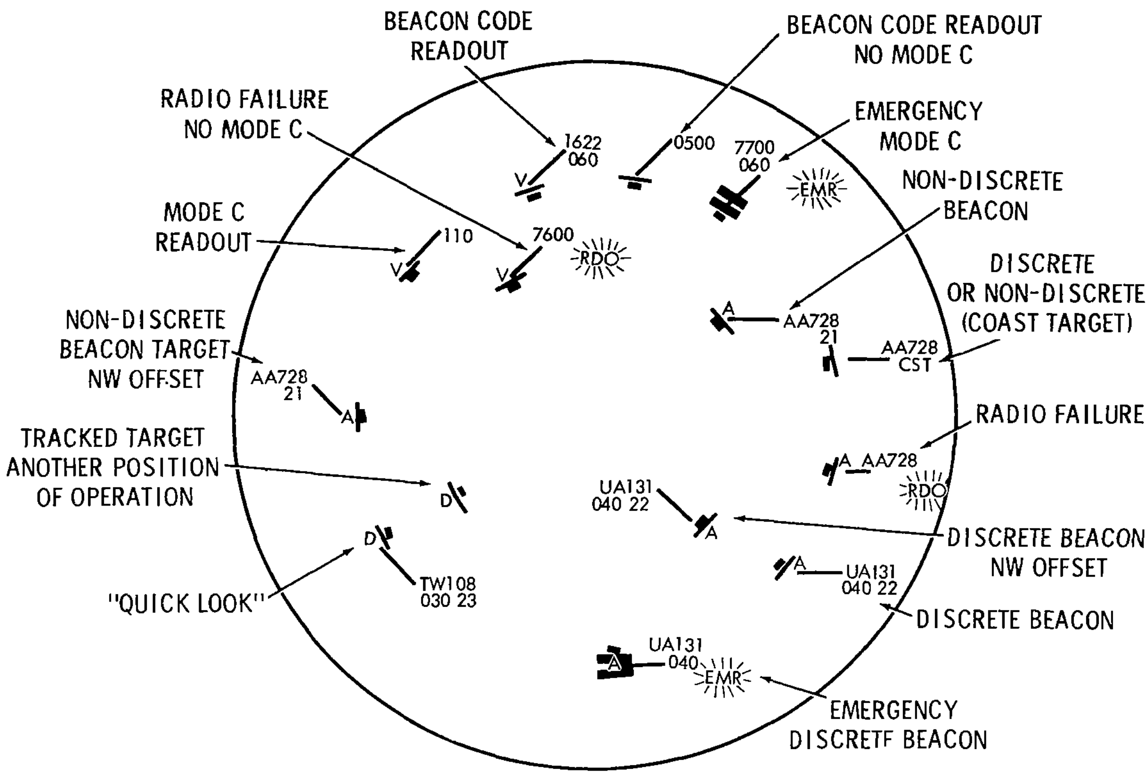


Fig. 5. Characteristic ARTS III display configuration. (From: FAA, NAS Summary, 1970.)

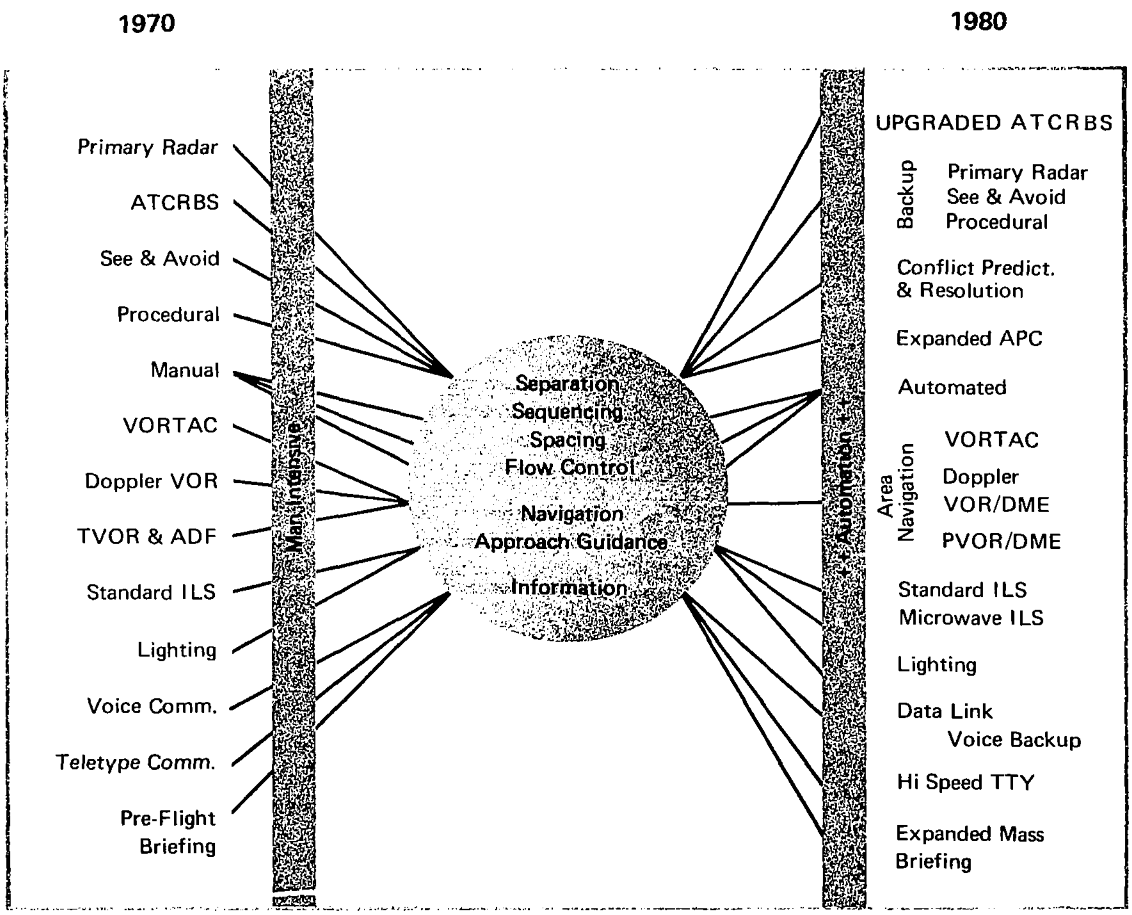


Fig. 6. Present and planned terminal system. (From: FAA, NAS Summary, 1970.)

The Flight Service Stations

The flight service station provides information to pilots, primarily those flying under visual flight rules (VFR), concerning such matters as weather, flight planning, and notices to airmen. The flight service station is available for providing emergency assistance to lost or disoriented pilots. It also provides support to the en route and terminal air traffic systems as required. Figure 7 portrays the variety of communications requirements placed on these facilities.

While the flight service station is an essential portion of the traffic control system, the human factors problems relating to en route and terminal control facilities appear much more pressing. Consequently, the flight service station has received only minimal attention in this report.

Aviation Forecasts

As of 1970, there are 27 en route centers, 384 FAA towers, and 334 flight service stations fully operational. It is predicted that the number of en route centers will remain essentially constant but that the number of towers and flight service stations will increase substantially over the next ten years. This increase in the number of facilities and automation of essentially all functions is planned in order to support the projected substantial increases in air traffic over this period. Tables 1 and 2 present information concerning the number of aircraft in service and projected through 1980. The combined general aviation and air carrier traffic at terminal area facilities during fiscal year 1969 was 55.9 million in aircraft operations. This is expected to increase to 89.6 million in 1975 and 156 million in 1980. Instrument operations at FAA tower airports are forecast to increase comparably, as shown by the data in Table 3. This will place an additional demand on

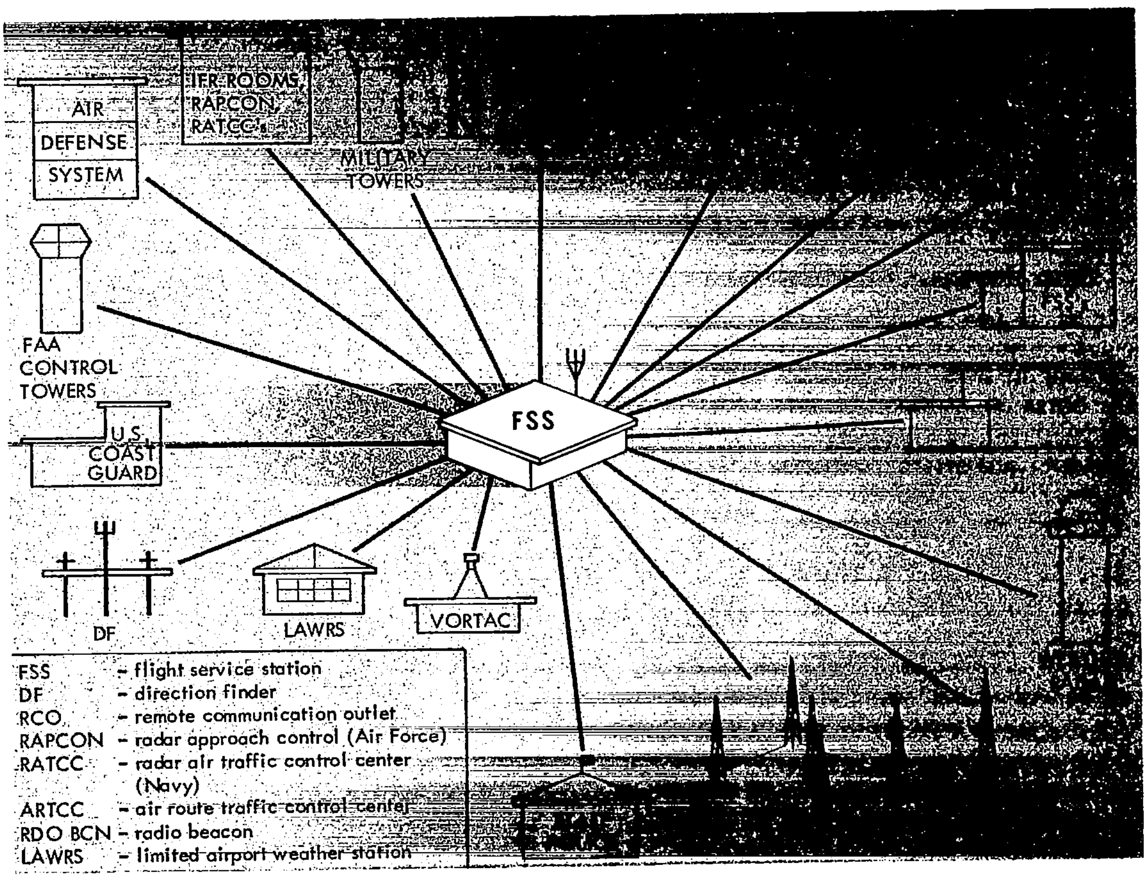


Fig. 7. Communications network for Flight Service Station. (From: FAA, NAS Summary, 1970.)

Table 1

Total Aircraft in Service of U. S. Air Carriers
As of January 1, 1970

Aircraft Type	1965	1969	1975	1980
Fixed-Wing				
Jet	564	1, 781	2, 678	3, 502
Turboprop	276	458	353	228
Piston	1, 221	331	135	40
Helicopters	20	16	24	30
Total Aircraft	2, 081	2, 586	3, 190	3, 800

(Adapted from: FAA, NAS Plan, 1970)

Table 2

Total Active General Aviation Aircraft

As of Jan. 1	Piston	Turbine	Rotorcraft	Other	Total
1963-------------	82, 434	213	967	507	84, 121
1969-------------	118, 734	1, 833	2, 350	1, 320	124, 237
1975-------------	166, 200	5, 200	4, 400	2, 200	178, 000
1980-------------	207, 800	8, 400	5, 900	2, 900	225, 000

(Adapted from: FAA, NAS Plan, 1970)

Table 3

Instrument Operations at Airports with FAA Traffic Control Service

(In Millions)

Fiscal Year	Instrument Operations
1963	7.4
1969	16.7
1975	25.5
1980	39.3

(Adapted from: FAA, NAS Plan, 1970.)

Table 4

IFR Aircraft Handled by FAA Air Route Traffic Control Centers

(In Millions)

Fiscal Year	Total	Air Carrier	General Aviation	Military
1963------------------	10.2	5.3	.9	3.9
1969------------------	20.6	12.6	3.2	4.7
1975------------------	29.6	17.9	6.8	4.9
1980------------------	42.0	22.5	14.7	4.8

(Adapted from: FAA, NAS Plan, 1970.)

en route centers and on terminals as indicated in Table 4. Services provided by FAA flight service stations and combined station/towers are projected to have comparable increases as indicated in Table 5.

The sizable increases in facilities and equipment will have substantial impact on requirements for new personnel, particularly air traffic controllers. Table 6 indicates projections of air traffic control personnel required to support these new facilities in the next decade. The estimates are based on a three percent per year controller productivity increase in the second half of the ten-year period as a result of system improvements presently being implemented. It is hoped that technological improvements can result in additional productivity increases in the order of 20%. This last estimate is conjectural, however, and has not been used by the FAA in making its manpower projections. There will, of course, be substantial requirements for additional training capability, numbers of instructional staff, and improvements in training methodology. Additionally, it is felt that a substantial increase in human factors effort can have significant cost-benefit tradeoff in optimizing the manpower application required to support this vastly expanded air traffic control system.

Table 5

Total Flight Services at FAA Flight Service Stations and Combined Station/Towers

(In Millions)

Fiscal Year	Flight Services
1963	19.3
1969	42.2
1975	75.5
1980	136.2

(Adapted from: FAA, NAS Plan, 1970.)

Table 6

Air Traffic Control Personnel Required During the Next Decade

Fiscal Year	1971	1972	1973	1974	1975	1980
En Route	11,981	12,300	12,650	12,950	13,300	16,300
Terminal	10,493	10,950	11,500	12,000	12,550	17,700
Flight Ser. Sta.	4,566	5,700	6,000	6,350	6,800	10,600
Totals	27,040	28,950	30,150	31,300	32,650	44,600

(Adapted from: FAA, NAS Plan, 1970.)

CHAPTER 3

HUMAN FACTORS ANALYSIS OF AIR TRAFFIC CONTROL

As can be seen from the preceding material, the air traffic control system is very complex. It involves a wide array of equipment, operational procedures, and many thousands of personnel in a variety of occupational categories. It is difficult to conceptualize the system as a whole and to discuss human factors problems relating to the entire man-machine system at one time without other difficulties intruding. Principal among these difficulties is the fact that the system is an ever changing mixture of men and machines. At the present time, many en route and terminal facilities are being equipped with new NAS Stage A and ARTS III hardware and software. However, much of the air traffic for the next few years will continue to operate within the context of older ATC systems. Consequently, for a substantial period into the future, there will be a mix comprised of manual, semi-automated, and fully automated operations for performing many of the most important functions. Thus, highly specific recommendations concerning studies to be conducted of particular panels and displays, operational procedures, communications techniques, and the like, would be inappropriate in a report of this type. Furthermore, FAA personnel (particularly those at NAFEC) have an excellent ongoing program for conducting such studies and the developing recommendations and concerning specific man-machine interface problems. It seems likely that those who are close to the operational situation on a day-to-day basis can most effectively identify, study, and recommend solutions to these highly specific human factors problems.

This report has two objectives. The first is to identify the major areas of human factors concern which have relevance to the present and planned system configuration for air traffic control. The second objective is to recommend generalized research and development activities necessary to support system development regardless of the specific future decisions which are made concerning equipment and software design. This approach has the additional merit of proposing research and development efforts which will generate useful data for other large man-machine communications and control systems over and above their applicability to specific ATC problems.

The vast complexity and the diffused nature of the air traffic control systems makes it necessary to adopt some organizing structure in order to obtain an overview for considering the system as a whole. Many such schemes of organization are possible. The one used here categorizes system functions into three phases, representing the three major areas of activity necessary to complete system function. First, it is necessary to provide the required personnel to man the system. This is the staffing phase. Second, given appropriately qualified recruits, it is necessary to train them. This is the training phase. Finally, trained staff must operate the system. Thus, the operations phase. Although this categorization is somewhat arbitrary, it serves to provide a logical framework within which to consider the multiple problems pertaining to the utilization of the principal human elements within the system--the air traffic controllers.

Some of the material in this section touches on aspects of the air traffic control problem which are not always included in discussions of human factors problems. Many of these are more typically thought of as general personnel and manpower problems. It is useful, however to consider the strictly human factors problems in a more generalized context of the overall manpower and personnel setting. Thus, this section includes sufficient explication of the manpower and personnel facets of the problem to provide a frame of reference for considering more detailed human factors problems.

Within the three major categories of activity there are several subsidiary functions (again, arbitrarily defined). These are:

SYSTEM FUNCTIONS

STAFFING	TRAINING	OPERATIONS
• Predicting manpower requirements	• Initial training	• Man-machine interface
• Analyzing task/skill requirements	• Qualification training	• Evaluation of performance
• Selecting personnel	• Simulation training	• Optimizing shift schedules and work-rest cycles
• Initial assignment of personnel	• General educational development	
• Reassignment of personnel	• Supervisory and management training	
	• Cross position/option training	

In the following discussion, the subsidiary functions within the staffing, training, and operations phases are treated individually. The problems related to each are described and recommendations for research and development activities are presented. The recommended research and development activities are structured in such a way as to provide an approach to the collection of useful data regardless of the specific configuration which the air traffic control system may take. Detailed research plans to implement these recommendations are presented in Chapter 5.

Staffing

Predicting Manpower Requirements

An orderly staffing program requires estimating requirements for controllers with as much precision as possible. This is especially important because of the long lead times involved. The normal sequence of training (classroom and on-the-job) requires approximately 18 to 36 months before journeyman status is reached. In many cases in high density centers, there is limited equipment available and limited time for journeymen to devote to training new controllers. Many trainees must work for seven or more years in high density facilities before being qualified to work the radar position.

The problem of projecting staffing requirements is compounded by the lack of specific system design information. It is often impossible to state with any precision what equipment, what procedures, and consequently, what personnel requirements will be forthcoming within the period of time required to recruit and train the controllers who must man the system. An additional factor which complicates the prediction of manpower requirements is changing personnel policies. Many policies relating to cross training, interfacility transfers, retirement, and so on, are now under intensive study, and important changes will almost certainly take place in the near future. Each of these policy changes will have important influence on manpower planning.

A fundamental step in predicting manpower requirements is the specification of skill and ability requirements for the various positions and options open to controllers. Past practice has made little differentiation among positions and options at the selection and classification level. This lack of differentiation has resulted in some wastefulness in assignment and in training. More intensive analyses similar to those presented in Chapter 4 of this report should be undertaken. These analyses should be especially concerned with more advanced systems such as NAS Stage A and ARTS III. In addition, as new system designs emerge, immediate steps should be taken to develop skill and ability requirements for the new functions involved.

An effort should be made to adopt and modify methodologies developed by the Department of Defense to predict manpower requirements in the military services. Such techniques as equipment task analysis and qualitative and quantitative personnel requirements information analysis have been used effectively in military jobs and should prove useful in the ATC setting.

In a situation as complex as the ATC system, it is likely that computerization of manpower prediction functions can be an effective tool. In addition to the advantages such techniques have in providing a capability for rapid simulation, they require, by their very nature, detailed analysis of the entire system and the explicit statement of assumptions. Thus, the existence of such a model imposes on all interested groups the requirement for the use of common techniques and for careful formulation of planning assumptions.

Analysis of Task and Skill Requirements

There is at present little differentiation among ATC candidates on the basis of their relative aptitudes and abilities for the three controller options. This is probably a consequence of the lack of detailed information concerning the requirements for differential capabilities, aptitudes, and skills demanded by these three options. There is a clear and pressing need for a detailed equipment task analysis of all positions and options. The development of such a body of information is fundamental to almost every other planning, selection, classification, training, and human factors activity in support of improved ATC operations.

At present, the most comprehensive description of the performance requirements for controllers is contained in the training manual for each of the three options: en route, terminal, and flight service station. Within these manuals, major activities for each position are listed together with a specification of the tasks required for their performance. These materials are used to structure the training programs both at the FAA Academy and at the facilities. More detailed information concerning these activity and task descriptions is included in Chapter 4 of this report. The manuals are designed primarily to provide training in the operation of "nonautomated" systems. Similar material is not yet available for NAS Stage A and ARTS III systems. Unfortunately, these activity and task classifications, while useful for structuring the training program, have only limited value for other human factors applications. More detailed and explicit analyses of the activities and tasks within each controller option are required to provide data appropriate for the purposes of man-machine interface design, performance evaluation, selection and classification, and system design.

An excellent example of the type of approach which is needed on a much wider scale is contained in a recent NAFEC document, Data Report on the Manual Operations at Jacksonville ARTCC. Busch, A. C., April 1970. This report contains measurements of the activities of en route air traffic controllers before and after the introduction of NAS Stage A. This information makes it possible to determine what changes have taken place in the requirements for controller activities. The methodology utilized in this effort focussed primarily on the analysis of communications activity. Samples of communications transactions were analyzed with respect to the following:

- Initiator (e.g., American Airlines 312, or the radar controller for Section D-10, or the adjacent facility).

- Ratio of pilot-initiated to controller-initiated communication transactions.

- Elapsed time for each transmission and transaction.

- Type of transmission.

- Characteristics of the initiator and addressee.

- Number of communications channels in use and number of users at any one time.

This method requires second-by-second analysis of a large number of communications transmissions and consequently involves manipulation of large masses of data with sophisticated computer methods. It appears, however, to offer a powerful tool for obtaining information useful for a variety of human factors and system design purposes.

Reassignment of Personnel

Since controllers tend to be recruited for and remain within one facility, there is, generally speaking, an immobile work force. This immobility results in shortages of personnel at some facilities and a surplus in others. The most pressing shortages, of course, exist in high density centers and in those facilities located near high cost of living areas. In addition, there are no provisions for retraining, reassignment, or retirement of so-called burnouts. It is likely that many personnel who, because of age or other factors, have become unable to operate efficiently in high density positions, could be retrained and reassigned to lower density, less high pressure tasks. This could result in the release of other personnel to absorb these higher pressure duties.

In general, an ordering of priorities has developed where personal preference in assignments outweighs the needs of the system. Thus, transfers from one facility to another are difficult to enforce and it is not always possible to achieve a balancing of work load by reassignment.

There is a requirement for the development of detailed information concerning the differential requirements of the various facilities in task-specific terms so that reassignments among facilities can be made on the basis of a systematic balancing of personnel capabilities with facility requirements.

Selection of Personnel

Personnel selection in this, as in any other technical setting, requires that specific information be available concerning tasks and activities and other human requirements involved in successful job performance. Such information is not available on the scale and with the degree of precision necessary to design optimum selection instruments and techniques. Task and skill analysis is a fundamental requirement in validating selection instruments and techniques against objective measures of proficiency. Because this analysis has been lacking, existing selection requirements have been criticized, and it is difficult to evaluate the validity of these criticisms. Recent experience indicates that attrition rates which exist among recruits are viewed as unacceptable, and many feel that prior experience is granted undue weight in the selection process. Personnel with prior experience as pilots and military air traffic controllers have tended to receive favorable consideration although evidence for the relevance of such experience is quite limited.

Air traffic controllers are selected from Civil Service Registers of qualified candidates, and some are qualified on the basis of prior experience, primarily military. Most candidates are required to take a battery of written tests, designed to measure aptitudes and abilities as is indicated below.

Test	Time (Mins.)	Weight
1. Arithmetic computation	10	1
2. Nonverbal abstract reasoning	35	2
3. Air traffic problems	10	1
4. Spatial relations	30	2
5. Ability to follow oral directions	20	1

A personality test is administered to those certified as acceptable on the basis of aptitude and ability, and interviews are conducted by supervisory personnel at FAA facilities. Medical examinations are also given, and a psychiatric examination is included where its appropriateness is indicated by responses to the personality inventory.

Analytical data available concerning the value of this selection process are limited. The only published comprehensive review is contained in Corson et al. (1970), which concludes:

> There is substantial evidence that passing these selection processes--Civil Service qualification, aptitude tests, personal interviews by controllers, physical and psychiatric examinations--taken together are not effective in selecting an extensive pool of individuals possessing the talents required by the job cited above and the requisite "staying power." The ineffectiveness of these processes is suggested by:
>
> The high attrition experienced among new recruits...
>
> Presence in the work force of a substantial but intermediate number of individuals regarded by their peers and their supervisors as marginal performers. Although the testimony of peers and supervisors is unvalidated evidence, the prevalence of this view prompts further doubt as to the efficacy of existing selection processes.

There are several problems which make it difficult to evaluate the effectiveness of selection devices in this situation. One of the principal methodological problems stems from the fact that trainees are preselected on the basis of the selection tests (and very frequently on the basis of previous experience). This makes for a constriction in the range of aptitude which, of course, tends to reduce the correlation obtained between test scores and training grades or on-the-job performance measures. It is also not clear whether the attrition rates now being encountered in facilities and in training at the FAA Academy can be significantly reduced by further refinements in selection testing. The most recent figures obtainable indicate that failure rate in the basic en route and terminal courses at the Academy was approximately 20 percent; failure rate in the flight service station option was approximately 11 percent. These rates may be, however, nearly as low as they can reasonably be gotten through refinements in paper and pencil testing.

Personnel at the Civil Aeromedical Research Institute (CAMI) are, however, continuing to experiment with new selection techniques in the hope of improving the predictive value of the test battery. The most promising approach being pursued at this time appears to be development of a multiple task performance battery. Preliminary findings with this battery indicate that additional variance over and above that accounted for by paper and pencil tests may be attributed to variables measured by the multiple task performance battery.

In general, the system has failed to recruit a satisfactory number of qualified applicants, and it is clear that current recruiting rates will not meet hiring goals. There is reason to suspect that the selection processes now in use discriminate against minority groups and thereby further curtail the potential candidate list. A significant proportion of those recruited are above the age of 30. Many feel that emphasis should be placed on recruiting a substantially lower age group and many CAMI research reports support this position.

Initial Assignment of Personnel

In present practice, employees tend to be recruited for a particular facility and to remain there. This policy introduces situations in which one facility is overstaffed while others are experiencing shortages. For example, as of September 1969, some centers had more than 100% of the authorized journeymen controllers on board whereas others (e.g., Chicago) had as few as 65% of the authorized journeyman force. On the other hand, many centers tend to be overstaffed with developmental controllers. For example, Indianapolis had 119% of authorized positions filled, and Fort Worth had 364% of authorized positions filled (Corson et al., 1970). The general situation of being understaffed with journeymen and overstaffed with developmentals results in a severe strain on operations, and places a heavy burden of training developmentals on those journeymen who are available. More centrally controlled assignment procedures could make for a better distribution of new recruits to facilities. Assignments would be based on the current and projected needs of the system and the capabilities of the various facilities for providing training to the new influx of personnel.

Training

The National Air Traffic Training Program as developed by the Air Traffic Service and the FAA Office of Training includes specific instructional plans and standard lesson guides for training in the three options. Instructional phases for the various programs are indicated below.

En Route Program

Phase 1: Flight Data/Interphone

Phase 2: Nonradar Control

Phase 3: Radar Control

Terminal Program

Phase 1: Flight Data

Phase 2: Ground Control

Phase 3: Local Control

Phase 4: Nonradar Control

Phase 5: Radar Control

Flight Service Program

Phase 1: Weather Observation

Phase 2: Teletypewriter

Phase 3: Broadcast

Phase 4: Flight Data

Phase 5: Preflight

Phase 6: Inflight

Preliminary training for terminal and flight service program trainees takes place at the FAA Academy in Oklahoma City, Oklahoma. On the other hand, beginning in April 1970, recruits for the en route training program were assigned to a field activity for six to eight months training prior to attending the Academy. (A similar procedure, i.e., field training initiated prior to Academy training, will be installed for terminal option trainees during the early part of 1971.)

Following a period of indoctrination and on-the-job training at a facility, the en route trainee reports to the FAA Academy for what is termed qualification training--approximately nine weeks in duration. Thus, when trainees arrive at the Academy, they have already established a certain degree of familiarity with respect to the equipment and procedures and are better able to take advantage of the academic and laboratory training provided. It is anticipated this training cycle will have the additional advantage of enabling the Academy personnel to concentrate entirely on training, and relieve them of screening responsibilities. This procedure should also, of course, result in a markedly reduced attrition rate at the Academy.

As mentioned above, comparable procedures for the terminal option candidates will be initiated as an operational procedure beginning in 1971. Thus, terminal trainees will spend six to eight months at a field terminal facility before reporting to the Academy for approximately nine weeks qualification and training activities. As with the en route program, it is anticipated that this will make the period of time spent at the Academy more productive, and will also eliminate the screening function at the Academy.

Preliminary training in the various options and phases has normally taken place at the FAA Academy. Entry level training for terminal and flight service station trainees provides general instruction in each option to the point of enabling a trainee to become certified as an air traffic control specialist. Following this training, he is assigned to a facility where he receives a variety of additional training segments which enable him to qualify as a journeyman controller. At the facilities, formal classroom training is given in addition to on-the-job training and, where possible, training with simulation facilities is provided. Each facility normally has a supervisor in charge of training. The supervisor's responsibility is to insure that the guidelines set forth by the National Air Traffic Training Program are followed and that developmental controllers are given as much opportunity as possible to become qualified for more advanced positions. The description of training problems in this report employs a simpler categorization of formal training programs than that used by the FAA. This was done to permit a somewhat more straightforward discussion of human factors problems related to training.

Initial training at the FAA Academy is normally required for new recruits. Training is given in each of the three options with the amount of training time varying from option to option. The content of these initial training programs varies, but in general includes all material which has general applicability across all types of facilities. For example, the initial training course for the terminal option as now constituted consists of nine weeks of classroom and laboratory sessions. During these nine weeks, all of the so-called "knowing units" are covered at a general level in the classroom, while the associated "doing units" are covered to the extent possible in an elementary laboratory environment. Thus, at the end of this nine-weeks training program, the trainee has enough general familiarity with air traffic control to take his place as a developmental controller in a facility.

On-the-job training at each facility, while coordinated by the National Air Traffic Training Program, is conducted primarily by local personnel. Thus, the quality and quantity vary as a function of time and personnel available to conduct such training. Some advanced training, of course, is available through specialized courses given at the Air Academy and NAFEC.

Entry Level Training

Initial training was suspended and the Academy was closed from 1963 to 1968. The failure to recruit and train controllers for such an extended period has now placed severe demands on the Academy to handle an enrollment much larger than its normal capacity. To meet the demand, additional shifts and marginally qualified instructors are being used. The Academy's normal annual capacity for training is: En Route Option--1520; Terminal Option--1360; Flight Service Station Option--600.

The Academy program includes two to three weeks of training in basic subjects (e.g., weather and navigation) required to prepare the trainees for the "Airmen's Certification Test." This material is intermixed with other instruction of three to four weeks in length relating to specific flight data handling activities and tasks anticipated for the trainees after assignment to facilities. The last portion of training consists of control procedures.

Much research and development effort is required to make certain that the curriculum and course content at the Academy is optimally designed from the standpoint of effectiveness, efficiency, and relevance to the activities which the trainee will be called upon to perform in the early stages of employment at a facility. For example, one of the principal problems appears to be that much of the material taught at the Academy is not used for a year or more after the trainee is assigned to a facility. Thus, this material must be relearned before practical applications of it can be made on-site. Substantial research, and particularly development, should be applied to method as well as content. Due to the extreme pressures, there has been little opportunity for Academy personnel to develop new and improved teaching methods although substantial use is made of multi-media and student response techniques. With much of the material taught at the Academy, programmed instruction and particularly computer-assisted instruction techniques should prove valuable and should justify substantial expenditures of research and development funds.

Qualification Training

As the term is used in the FAA, qualification training means that training required to be qualified for the applicable rating at the facility concerned. Qualification training, as used in this report, has a wider meaning which includes all on-the-job training conducted at the various facilities. Approximately 60% of the training required to qualify as a journeyman controller is given at the facility either in the classroom or on the job.

Facilities vary widely with respect to the formality with which controllers are assigned to serve as instructors and with respect to the quality of the instruction given, the degree of supervision provided for instructors, and the amount of training instructors have had in teaching techniques. Physical facilities for training are typically quite inadequate. Some facilities have no classroom or laboratory space at all. Training to the journeyman level normally requires approximately 36 months, and in many instances, controllers take even longer to reach journeyman proficiency.

There is room for substantial improvement in both content and technique of on-the-job training programs at all types of facilities. Research and development activities in support of these efforts should include (1) examination of curriculum and course content for its relevance to job requirements, (2) development of an improved sequence of instructional material, e.g., to prevent long gaps between learning and use, and (3) application of improved instructional techniques such as programmed instruction and computer-assisted instruction. The latter recommendation is particularly important since the demand for qualified instructors cannot be met in the foreseeable future. Thus, expenditures for the development of programmed instruction and computer-assisted instruction materials could have significant cost benefits.

Simulation Training

As part of qualification training and for proficiency maintenance, there is a substantial need for the increased use of simulation, particularly for training in radar control functions. Most facilities do not have radar simulation capability but there are plans to install such simulators as rapidly as possible.

The value of simulation in large command and control systems has been demonstrated dramatically by NASA Mission Control at the Manned Space Flight Center, Houston, Texas. The success of the manned orbital and lunar missions is unquestionably due in large part to the extensive rehearsal, using dynamic simulation, of all predictable emergencies. While the extensive simulation and emergency rehearsal employed by NASA Mission Control will probably never be feasible in the ATC environment, there is undoubtedly much to be learned from such experience. It is suggested that NASA Mission Control operations and the training that supports these operations be studied with a view to adapting the techniques and procedures which are appropriate to the ATC system.

Human factors efforts are needed in the planning and implementation support of simulation facilities. Since there will be a great increase in the use of simulators for training in the next several years, high priority should be placed on the application of human factors efforts in this area. This would involve (1) conducting detailed analyses of controller activities and tasks to identify those which can be simulated successfully and efficiently, (2) specification of the requirements for fidelity of simulation, and (3) providing specific assistance in the construction of training scenarios.

In addition, special emphasis should be placed upon developing techniques for using simulation to obtain measures of proficiency. Personnel who are responsible for developing training programs using simulators are not often skilled in the techniques of measuring proficiency. Consequently, special attention should be given to insuring that adequate criterion measures are provided. This can be accomplished only by early participation in the software development phases of the simulation planning.

Human factors support should also be obtained to establish requirements for training to maintain proficiency. This would involve conducting studies of skill maintenance and detailed analyses of the degradations of specific skills which occur over time. Skills which are found to degrade most rapidly can be programmed for frequent reinforcement training with the simulator.

General Education Development

Air traffic controllers work under pressure for long hours at jobs calling for high technical skill. The continuing requirements for job-related training and proficiency maintenance make it quite difficult for controllers to devote time and attention to broadening their knowledge and skills in areas not directly related to their immediate employment. As a result, controllers are so highly specialized that when opportunities arise to advance to positions requiring more general knowledge or to retire (which may be at a relatively early age), they lack the qualifications for other employment. It is, therefore, important to provide controllers with the opportunity for education in jobs not directly related to their current assignment. Special emphasis should be given to training in research and analysis activities since many of the more senior positions in FAA require such capabilities.

Supervisory and Management Training

Controllers who are successful and remain employees for a sufficient period of time can expect to advance to positions as crew chiefs, watch supervisors, facility chiefs, or other supervisors at the facility, regional, or headquarters levels. Almost no opportunities exist for formal training in supervisory and management functions. (Formal programs in these areas have been unavailable since 1968 but are planned for reinstatement in the near future.) Human factors inputs to such training can have a beneficial effect on the supervisors' role in work space layout, systems and procedures planning, proficiency measurement and evaluation, and generally in providing potential supervisors with an appreciation of the importance of the human factors problem in the air traffic control facility.

Cross Position/Option Training

There has been a consistent tendency in the past to recruit, train, and employ controllers within a single option at one facility. More recently, the trend has been toward development of a more mobile work force. Thus, substantial movement can be expected among options and between facilities as capabilities of personnel are developed to warrant such transfers. The implementation of such plans will require sizable new human factors efforts to specify the requirements for cross training among various options. These requirements should, of course, be based upon well documented equipment task analyses and knowledge and skill requirements by position and level. It is also anticipated that an increased simulation capability will provide the facilities with far greater capacity for cross training. Again, detailed human factors inputs to the instructional materials used in cross training can add significantly to the value of these programs.

Operations

Air traffic controllers are employed in three different types of facilities: En Route Centers, Terminals, and Flight Service Stations. Although only limited quantitative data exist concerning the detailed nature of these jobs, it is clear that controllers' activities are often near the upper extreme of several continua, e.g., difficulty, stressfulness, and responsibility. Some controllers are called upon almost daily to perform near their psychological and physiological limits in situations requiring the utmost efficiency.

The participation of human factors specialists in the study of air traffic control problems has varied from substantial during the late 1940's and through the 1950's to grossly inadequate throughout the 1960's. The small number of dedicated medical, psychological, and engineering personnel assigned to human factors activities in the past decade have, of necessity, directed their efforts almost entirely to "putting out fires." Inadequate funding for in-house and contract efforts has precluded the implementation of research and development programs consistent with the major technological advances required to support the vastly expanded air traffic burden. Consequently, there is a substantial backlog of requirements for human factors research and development activities, many of which appear to be quite rudimentary in nature. Comparable military command and control systems developed during this period have received human factors support which was larger by several orders of magnitude. Consequently, there is much catching up to do. It is necessary to go back and apply the well tested and documented methods of activity and task analysis, proficiency measurement, information and communications theory, man-computer interaction, and in many cases straightforward "knobs and dials" techniques to provide a body of human factors data specifically oriented to air traffic control problems. This report suggests many areas where such attention is sorely needed.

During the time this study was conducted, there was a considerable amount of labor unrest among ATC personnel, including a period of slowdown and "sick in." Consequently, it was difficult to obtain detailed information on controller activities through visits to ATC facilities. Thus, the following description of the working environment is directly quoted from the Air Traffic Controller Career Committee Report (Corson et al., 1970).

Working Conditions

For a work force which is expected to perform tasks that at times are extremely stressful, the conditions under which its members work are of special consequence. Hence, this Committee observed in the centers, terminals, and flight service stations it visited and through the analysis of much additional data, the following factors:

- The environment - the buildings and structures within which the controller works, the quality of lighting, levels of noise and other physical and psychological factors.
- The control equipment used - the kinds and qualities of radar and communications equipment upon which the controller relies in controlling air traffic.
- The practices prevailing as to the design and scheduling of work shifts, days off, rest breaks and meal periods, scheduling of vacations and other leave, and medical examinations, that affect the physical demands made upon the controller.

Psychological Environment

The impact of working conditions on controllers in the en route traffic control centers - unlike terminals and stations - is more psychological than physical. Most centers are housed in modern air conditioned buildings built within the last decade, but the center controller, unlike his counterpart in the terminal or flight service station, does not see an airplane while on duty. He works in a large windowless room filled with radar scopes and associated communications equipment. His only contact with pilots is by radio and their conversation is of necessity limited to the actual control situation. He seldom sees the chief or assistant chief of the center except by specific appointment, and few of these officials come to know the relatively large number of controllers they supervise. Controllers on different crews frequently are not acquainted with each other. The center controller is expected to focus his attention throughout his hours on the job or the tasks he is assigned. Few pilots or other aviation representatives have occasion to visit these remotely located centers.

The terminal controllers and station specialists, on the other hand, work in a much different environment. The terminal controller, with few exceptions, will spend part of his shift in the tower cab where he can observe the movement of aircraft and other activities on the field. His job may enable him to come to know pilots and other persons associated with the operation of the airport. The station specialist deals directly with pilots and other persons at the airport. The relatively small number of controllers employed in each terminal and station enables each to come to know and develop social relationships with his fellow workers and with supervisors.

In short, terminal and station specialists work in an environment which tends to satisfy in fuller measure the psychological needs of some individuals. Conversely, the center controllers operate in a "dehumanized" environment which tends to aggravate other causes of discontent. This contrast is reflected in the frequency with which center controllers seek to transfer to other facilities and the lesser frequency with which terminal or station controllers voice a desire to transfer to centers.

Physical Environment

Several newer terminals and stations provide controllers an attractive and efficient physical environment. Most older towers and stations, however, offer poor surroundings in which to work. The lighting, ventilation, noise levels, and crowding in radar approach control rooms in the older facilities are a source of constant irritation. Because available financial resources have been concentrated on the development of the forthcoming automated air traffic control system, many badly needed improvements have been deferred. For example, there has been no new authorization of funds for the construction of towers since FY 1967. The prospect is, however, that limited new obligational authority will be available within FY 1970 for these purposes.

FAA has attempted to improve the environment in these field facilities by painting, installation of new lighting, introduction of noise suppressant ceilings, carpeting, and other items through what is called "Operation Bootstrap." Unfortunately limited funds, limited personnel, and other project delays have meant that many facilities have yet to experience significant improvement.

Control Equipment

The kinds and qualities of radar and communications equipment on which controllers must rely are additional factors which aggravate working conditions. The critical tool upon which many controllers depend - the radar - is at the best an imperfect instrument for air traffic control, and in some facilities provides the controller an incomplete or confusing view of the air space he must control. The radar maintained by military installations that is jointly used by FAA field facilities is unsatisfactory for the control of civilian air traffic in numerous instances. Radio frequencies are also often without reliable backup except perhaps through other sectors.

Much equipment now in place has been installed with little effort to design it to meet the particular needs of the controller. Switches and other devices, as well as the consoles used by the controller, reflect in their design and location little apparent consideration of the function to be performed by the individual. And within the centers, sectors controlling adjoining air space are often physically separated, thereby causing problems of coordination.

The limitation of funds has made it possible to improve the equipment available to controllers in only a limited number of facilities within the past fiscal year. For example, in selected terminals and centers the following items of equipment were added:

9 VOR systems (navigation aids)
4 instrument landing systems at airports
4 towers relocated and 4 new towers constructed
4 flight service stations relocated
75 Brite I radar displays in tower cabs
1 airport surveillance radar system (ASR)
2 ASR systems relocated

FAA hopes to replace the military radar facilities now being used by facilities with new solid-state radars at a rate of 12 each year commencing in FY 1972.

From a human factors point of view, these operational problems can be grouped in the following categories:

1. Optimizing man-machine interface functions

2. Evaluating performance

3. Optimizing shift schedules and work-rest cycles.

The following is a discussion of each of these problem areas in some detail.

Optimizing Man-Machine Interface Functions

To examine the nature of the man-machine interface in air traffic control, it is helpful to describe the operator's tasks in terms of capabilities required to perform them. Table 7, which is based on an analysis of the human factors literature, provides a list of the human capabilities required in air traffic control. The list encompasses essentially all of those skills an air traffic controller must possess (in every case refined by training) in order to perform successfully the various activities and tasks required for air traffic control. The categories shown in Table 7, in addition to being used to structure the discussion which follows, were also used to obtain judgments from controllers in another phase of the project reported in Chapter 4.

Visual Monitoring--Display. En route and terminal controllers monitor a variety of cathode ray tube (CRT) displays. These may be small alphanumeric CRT presentations of computer readouts, weather information, and the like. There are also large plan position indicator (PPI) displays (see Figure 7, for example) and large bright tube displays containing alphanumeric lags and a variety of automated information aids for establishing and maintaining aircraft identification, altitude, and range. These displays present all of the standard human factors problems which are encountered in similar displays in other systems such as:

Specification of Information to be Displayed. Careful analyses are needed to identify the specific information required for the performance of each activity within the various positions at each type of facility. Detailed analyses of information requirements can insure the parsimonious allocation of information elements to displays at various positions within the system. Without such detailed information, there is always a tendency, in the interest of safety, to include more information in each display than is absolutely

Table 7

Descriptions and Examples of Human Capabilities

(a) Visual Monitoring-Display: to attend to a continuously changing visual information source and report system status on request.

Examples: observation of CRT, meters, and counters.

(b) Visual Monitoring-Nondisplay: to attend to a continuously changing visual information source and report system status on request.

Examples: observing aircraft patterns, signal lights, and runways.

(c) Auditory Monitoring: to attend to a continuously changing auditory information source and report system status on request.

Examples: listening for radio, telephone, and intercom messages or warning signals.

(d) Reading: the rapid and accurate extraction of relevant information from written or printed material, on the basis of limited exposure.

Examples: reading flight progress strips, twx messages, weather sequences, frequency changes, tables, maps, and charts.

(e) Recording: the preparation of written messages, information and reports.

Examples: preparing flight progress strips and weather sequences; encoding flight data.

(f) Reporting: transmitting oral messages, information, and reports.

Examples: transmitting oral flight path instructions, altitude instructions and weather reports.

(g) Control Operations: applying manual force to equipment or controls once a response has been selected and a decision to act has been made.

Examples: manipulating tuning controls, cursors, or shrimp boats; teletyping.

Table 7--Cont'd.

(h) Information Organization: the evaluation, synthesis, and integration of information from varied visual or auditory sources.

Examples: simultaneous consideration of type of aircraft, relative speed, maneuverability, and cockpit visibility; integrating weather information from a variety of sources.

(i) Selecting Among Alternatives: predicting, on the basis of all available information, which of a number of alternatives optimizes system function.

Examples: path selection, conflict detection, and delay prevention.

(j) Information Storage: the short-term retention of recently acquired material--information subject to immediate recall.

Examples: carrying in one's mind such information as radio frequencies, aircraft identification information, wind conditions, and flight paths.

necessary. This extraneous information contributes to the work load of each controller since he must sort through it to select the information he requires.

Pictorial versus Symbolic Displays. Most situation displays now contain a mixture of pictorial (e.g., maps) and symbolic (e.g., alpha-numeric) information. Systematic analyses are required to specify the most effective manner of presentation for each required item of information.

Coding Information. A variety of coding dimensions (position, shape, size, orientation, blinking, etc.) can be employed. Careful experimentation is required to determine the optimum coding for each type of information. In addition, it is important to evaluate coding configurations in the total display context. Often a coding technique which appears promising when evaluated in isolation becomes confusing or unusable when combined on a display containing other information codes.

Single versus Multiple Displays. In the early stages of equipment development, there is usually a basic decision to be made regarding the size and complexity of displays. It may be possible to use an array of single-purpose displays, each containing one or two items of information. Alternatively, it may be possible to combine several information items in one large, multiple-purpose display. Careful human factors analyses of the tradeoffs in terms of operational effectiveness, maintainability, and reliability should be undertaken before a decision is made.

Three-Dimensional Displays. The use of three-dimensional displays has been proposed for many years, but like the weather, no one has done very much about it. Clearly, research and development activities relating to three-dimensional displays should be fostered, and human factors personnel should be active in these efforts.

Visibility Problems. With the development of bright tube and computer generated displays, most of the earlier problems of visibility (certainly those of threshold detection) have been eliminated. There still remain, however, problems with regard to the shape and size of symbols, line width and contrast. All of these influence in one way or another the speed and accuracy with which information can be obtained from the displays, and they probably relate as well to personal variables such as training level, fatigue, and the subjective acceptability of display design. Each of these problem areas calls for research and for devising a method of transmitting research information on a timely basis to equipment and system designers.

Visual Monitoring--Nondisplay. This is an important task for controllers working in tower cabs. There has been little human factors attention given to the design of tower cabs since the early 1950's. Present and future airport design will place new requirements on controllers for observing both ground and air activity in multiple approach patterns, on parallel runways, and under increasingly difficult atmospheric conditions.

Auditory Monitoring. Many of the controllers' information inputs come through radio, telephone, intercom, and direct voice. Artificial signals such as beeps and bells provide additional information. Human factors data should be provided to the designers of all such circuits and signals to insure that the controller is sufficiently insulated from extraneous information or noise, that the information reaching a given controller is required by him, and that it is presented clearly with a high signal-to-noise ratio. The solution to these problems lies mainly in improved equipment. However, significant additional improvement can be obtained through detailed attention to human factors aspects of the problem. Detailed analytical attention should be given to analyses of message content (see, for example, Busch, 1970), development of more efficient and concise message formats, elimination of unnecessary redundancies, reallocation of communication responsibilities across a wider base, substitution of computer-controlled audio response, and the substitution of data link and visual display for verbal communication where possible.

Reading. In the performance of their duties, controllers are required to obtain information from written or printed material. Often this entails rapid extraction of relevant information from flight progress strips, twx messages, weather sequences, frequency changes, tables, maps, or charts. These tasks can be facilitated through studies and experimental analyses of the format of the various documents and forms from which information must be extracted. Techniques such as color coding, underlining, selective capitalization, use of bold-face type for important data, and analyses of nomenclature for reducing ambiguities all offer significant possibilities for improvement in this area.

Recording. Controllers often generate written messages to be transmitted to other controllers and supervisors for information or action. Again, attention should be given to standardizing the format of such messages and to improving techniques of encoding so as to increase the usefulness of these messages to their recipients.

Reporting. This category includes transmission of flight path information, altitude instructions, weather reports, and the entire range of data required by pilots in the performance of their duties. Since one of the primary constraints on system capacity is the availability of voice communication channels, much attention should be directed toward improving the quality of verbal reports. The pilot, of course, has essentially the same problems in auditory monitoring as the controller. Consequently, the areas of concern listed under that topic above apply here. Controlled experimental investigations are required of the information format, encoding techniques, elements of redundancy, optimum rates of speaking, and transmission sequence of various information items. Experimental parameters might well be extrapolated from methodologies described in Busch (1970).

Control Operations. Manipulation of the various controls involved in tuning, adjusting, inputing data, and operating the various functional components in the ATC system covers almost the entire range of human factors problems relating to control. Figure 4, for example, provides one of many possible illustrations of the fact that a wide variety of controls still exist in the most modern NAS Stage A data entry and display subsystem for the radar controller position in the en route center. Operation of this console requires using several kinds of controls, e.g., push buttons, switches, a track ball, alphanumeric input and keys.

The console provided for data entry into the computer, shown in Figure 8, is particularly troublesome for the radar controller. The data entry keyboard appears to offer several advantages. It is compact. It requires only 14 alphanumeric keys to provide for the input of all digits and letters, for which the standard typewriter keyboard requires 36 keys. It is electronically compatible with standard data transmission codes, thus eliminating the need for additional decoding logic for communication with computers. It can be operated with one hand unlike the conventional technique for using a typewriter type keyboard.

In practice, however, inserting messages which require the operation of the left or right alpha keys prior to inserting an alpha character requires a substantial learning period and results in considerably slower operation than would be possible with a conventional keyboard. Thus, user acceptance has been low and it is felt that this keyboard was at least partially responsible

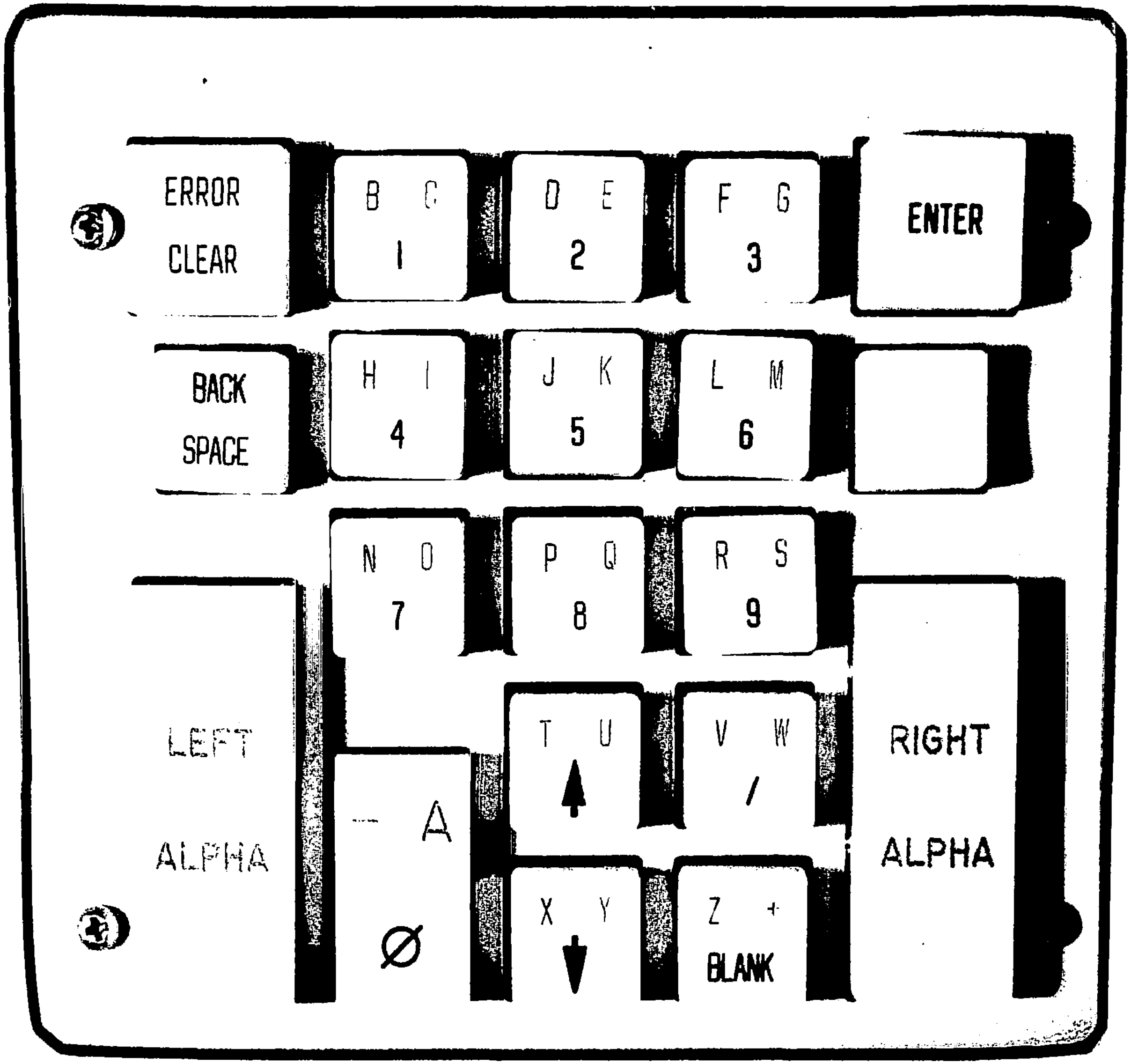


Fig. 8. Alphanumeric data entry keyboard.

for the estimates of increased operator work load in the NAS Stage A, as reported later in Chapter 4. This problem has been recognized by FAA personnel, and the more conventional typewriter type keyboard will be utilized in later increments of NAS Stage A and ARTS III.

Analyses are required to generate, for system designers, data relating to all of the standard control and control-display relationship problems involved in this very complex system. Personnel at NAFEC are presently conducting such analyses. Limitations in personnel and funds have prevented, however, the breadth and depth of effort required in this very important area.

Information Organization. One of the major functions of the air traffic controller is the synthesis and evaluation of a great mass of detailed data obtained through visual and auditory sources. Fragmentary studies have been conducted of the capability of controllers to receive and process specific categories of information in certain areas. There has been little attention given, however, to multivariate analyses of the capabilities for synthesis and integration of the whole range of inputs which are continually received by air traffic controllers. This is an especially difficult area and one requiring intensive and very sophisticated analysis. Studies are required to investigate the interaction effects of various techniques for encoding and displaying information through visual and auditory channels and to develop sensitive measures of throughput for the evaluation of such effects.

Selecting Among Alternatives. As used here, this category is essentially synonymous with what is normally considered decision making. An excellent statement of the decision making problem in the air traffic control situation is described in Buckley and Green (1962).

The [air traffic control] system is not unlike an animal which collects information about objects in its environment, refines this information, makes decisions about how to accomplish its purpose, executes them, and again watches the environment. He does all this, as the system does, in order to accomplish his purpose or mission.

Notice also that, just as in the case of the animal, there are specialized subfunctions. There is an information collection element, an information processing element, and a decision making element. In each case, new information is generated, i.e., there are informational products which result from the various processes carried on by the elements of the organic system.

The central function of the controller is and will remain, in one form or another, the making of control decisions. As the system evolves, he may get various degrees of help from machines in this process. In systems with extreme degrees of automation, machines may make decisions and then display them to the controller, and the controller may only have to make decisions for the sake of checking on the machine decisions. On the other end of the continuum, in today's system he is the decision maker, but in addition he must prepare and process and even display information to be used in his own decision making. He is presented with relatively "raw" information which he must further refine for use in decision making.

The information the controller might be given can vary in two ways: the items of information can vary and their qualities can vary. By qualities is meant just that; i.e., the qualities with which they are presented. For example, aircraft position or altitude can be presented in varying amount of detail, with various accuracy, with various delays. In addition to these essential qualities of the information as such, there are other qualities which may vary. These are less essentially related to the information, but concern more the method of portrayal, the display characteristics. Among these display characteristics, variations are such things as geographical presentation versus tabular or graphic presentation, display size, display brightness, letter size, alternate symbologies, type of lettering, etc. To sum up, we may distinguish three ways in which information presented to the controller may vary: in the items of information presented, in the informational qualities of the information presented, and in the display characteristics or manner of presentation.

Decision making is, of course, the crux of the air traffic controller's job. Perhaps because of the difficulty of studying this area, little systematic effort has been applied to assisting the controller with this most important activity. A most promising area for such research is the detailed analysis of decision requirements in various man-machine configurations. In each position within each type of facility, different configurations of equipment exist. As automated systems evolve, these configurations will change. Hopefully, in each stage of evolutionary development, more and better information will be provided to the controller to enable him to make his decision with respect to such items as flight path selection, conflict detection, and delay prevention. Each such man-machine configuration should be analyzed for the information available to the controller and with clearly identified parameters of the decisions he is called upon to make. Such specification of decision parameters can provide the basis for redefining functional allocations between men and machines and among the various controllers in the facility so as to distribute the decision making work load more effectively and to optimize the probability that "good" decisions result.

Man-Computer Interaction. Extensive analyses are required of techniques for improving decision making capability through real time interaction between the controllers and the computer capabilities that are becoming available. Specific areas include the development of optimized query languages, balancing the load between human operator and computer, and heuristic systems for the development of improved decision strategies.

Information Storage. This category includes the short-term retention and recall of recently acquired material. Often there is not time to make a written note of information obtained in verbal communication with pilots and other controllers. Consequently. the controller must retain a substantial amount of information for short periods of time. Analyses are required of the capabilities of controllers to remember the variety of types of information in this setting. Data of this type can be used in designing visual and auditory displays as well as in allocating function among the various controllers in such a way as to prevent overloading a controller and to achieve a more equitable distribution of the work load.

Evaluation of Performance

An analysis of the technical literature in air traffic control and discussions with cognizant personnel in the FAA facilities have indicated that efforts to improve system and subsystem function have invariably been stymied by the lack of adequate criteria for evaluating human performance. Attempts to arrive at rational decisions with respect to such matters as optimum staffing levels, work-rest cycles, shift scheduling, compensation, early retirement, equipment allocation and design, motivation, and communication system design are all hampered by the lack of valid and reliable measures of system and individual operator performance.

Human factors personnel at NAFEC have done extensive work on the development of system and individual performance measures utilizing the large systems simulation facilities available there. This work has demonstrated that reliable measures of performance can be developed and applied. The significance and validity of these measures have been demonstrated by setting them against independent criteria such as confidential supervisor and peer ratings. These measures offer great promise for research and development activities such as those normally carried out at NAFEC. Their use is, however, limited by the requirement for the availability of large scale simulation facilities which exist only at NAFEC. (A similar facility is planned for Oklahoma City.)

Buckley et al. (1970) recently completed one of the most extensive proficiency measurement analyses in the field of air traffic control. Data were obtained on a sample of 36 controllers using such measures as:

1. Proficiency at handling traffic in a simulated en route sector at each of three densities of air traffic,

2. Ratings of proficiency made by other observer-controllers monitoring the simulation,

3. Supervisor and peer ratings of controller proficiency (both special field survey ratings and current official ratings),

4. Part-task simulation measures (strip film representations of radar presentation to simulate air traffic displays).

In the full scale simulation runs, measurements were made of the following variables: (1) number of conflictions, (2) number of delays, (3) delayed time, (4) number of aircraft delayed, (5) aircraft time in system, (6) aircraft time in system for completed flights, (7) flight time deviation for completed flights, (8) number of completed flights, (9) number of control instructions, (10) number of contacts, (11) communication time, and (12) number of aircraft handled. After statistical analysis, six of the measures appeared to be least duplicative and most central to the matter of air traffic control system performance. These were: (1) number of conflictions, (2) amount of delay time, (3) aircraft time in system for completed flights, (4) number of completed flights, (5) number of control instructions, and (6) number of aircraft handled. The six measures were combined as a series of ratios (e.g., number of conflictions/number of aircraft handled) to arrive at final composite scores.

Findings in this important study were generally encouraging with respect to the use of full scale system simulation and part-task simulation devices as techniques for evaluating proficiency. The reliability of the objective simulator measures was quite acceptable. (Correlations between .60 and .70 were typical.) Reliability of observer ratings of simulation performance were lower but at acceptable levels. The distribution of simulation performance measures showed a sizable range of individual differences. (Some controllers did as well at the highest density as others did at the lowest density.) The evaluation of controllers by peers generally correlated better with simulation performance than did evaluations by supervisors.

Correlations of .50 and higher were found between part-task simulation scores and both field and simulation criterion. This is important since it indicates that part-task simulation (which is much simpler, less expensive, and more feasible to implement) can be used effectively until such time as full dynamic simulation capability is available at the various facilities.

The first step in undertaking the development of a comprehensive system of performance measures would be an analysis of the ATC system and its constituent subsystems to identify the desired or ideal output for which each is designed. It is important to identify ideal or model operational performances in order to have a standard against which to compare performance actually obtained in practice.

Following the identification of desired system and subsystem output performances, it is necessary to specify those portions of the outputs which are expected to result from human operator activity as distinct from those which result from equipment operation. When such a distinction is not made explicitly, there is often difficulty pinpointing the trouble spots in man-machine systems.

Once the role of the human operator at each subsystem and component level of the system has been identified, it is necessary to identify in measurable terms the behavioral characteristics which operators must demonstrate in order to meet acceptable standards of operation. These will, of course, vary from position to position within the system, and detailed analyses of all positions must be made to insure complete coverage of all behavior which, when taken collectively, will result in desired system performance. Wherever possible, system measures should be specified in quantitative terms. Among the variables which should be used are separation maintenance, time delays for critical events, runway utilization, error rates over specific time periods and measures of consistency and variability.

In a system as complex as the ATC system, it is often difficult to derive measures which have direct utility as total system performance measures. Consequently, it is important to identify those intermediate or proximate criteria which have proved to be (or are judged by experts to be) variables which contribute importantly to the ultimate performance output of the system as a whole. These intermediate criteria, used for the evaluation of any segment of the system, can be designed to reflect the function which that subsystem performs in the total air traffic and air navigation control system.

Several techniques may be used for developing performance requirements. These include detailed analyses of equipment and system specifications, system and activity analyses, and the use of critical incident techniques in identifying specific problem areas where criterion development is especially important. Statistical techniques, such as regression analysis, may also be employed where data can be obtained to conduct them.

One of the major steps in criterion development is establishing a detailed list of performance specifications for all important positions within the system and all activities associated with these positions. The criterion performance specifications should be reviewed by experts in each of the areas concerned. Agreement should be obtained before proceeding to develop specific performance measures of these parameters.

It is probably best to take an eclectic approach in developing criterion measures for the various parameters of system performance. Where possible, work sample measures should be taken of system outputs generated by the operator in routine use of the system. Measures derived from actual system operation have the advantage of realism and can reflect a variety of stressful operations in a way that cannot be simulated. In addition, measures which can be derived in normal system operation do not require diversion of controllers from their normal activities and thus involve only minimum requirements for special organizational and operational arrangements. Where operationally derived measurements of the variables under consideration are not possible or cannot be used, special measures must be constructed. Typically, these will be in the form of special problems to be worked out either in paper and pencil exercises or through the construction of simple part-task simulation devices. (Human factors personnel at NAFEC have performed preliminary work in the development of such part-task devices.) The goal, of course, is to develop a set of performance measures for the positions within the system which, when taken together, will account for the maximum obtainable variance in the total system performance. It is recognized that it is impossible to account for all system variance by means of operator performance measures. It is, however, important to account for as much of the total system output as possible on the basis of operator performance measures, since it is only through such techniques that the effect of variations in equipment and/or operator training, selection, and other variables can be evaluated.

Optimizing Shift Schedules and Work-Rest Cycles

There is a considerable body of published information concerning the stressful nature of the air traffic controller's job. There seems little doubt that the demanding responsibilities, intense activity, requirement for sustained concentration, and the catastrophic consequences of error do in fact produce stresses of a very high order. Controllers themselves are convinced that this is a young man's job and that the combined stresses and strains result in a deterioration of performance leading to burnout when controllers reach age 40 or so. There is, however, a surprisingly small amount of definitive research information in this important problem area.

In a comparison of the self-reported symptoms of controllers and FAA personnel in other (noncontroller) activities, Dougherty et al. (1965) found that controller personnel reported significantly more headaches, indigestion, chest pain and ulcers than did noncontroller personnel. This differential was reported to become more significant over time (in fact the difference did not appear until after three years' service as a controller). The authors concluded that, "...as an Air Traffic Control Specialist progresses through his career, the sicker he thinks himself to be in comparison with non-Air Traffic Control Specialists having similar years of experience, occupational status, and location." In a "Review of Medical Information Regarding Occupational Stress Among FAA Air Traffic Controllers," Catterson (1970), summarized medical evidence on whether job-related stress has a significant effect on the psychophysiological condition of FAA air traffic controllers. His sources included (1) anecdotal reports of individual air traffic controllers, (2) medical statistics, and (3) data from a special FAA stress study. Catterson points out the lack of controlled experimentation and the difficulties of interpreting the modest amount of biomedical data which is available. However, the material presented does strongly support the conclusion that there may be a significant amount of occupational stress in the air traffic controller's day-to-day activities, particularly in high density centers.

As the first step in a comprehensive series of studies relating to stress and fatigue, the Civil Aeromedical Institute conducted a study at Chicago's O'Hare airport tower during the summer of 1968.

The study was designed (1) to permit a comparison of physiological responses of controllers on different shifts and at different tower positions, (2) to determine the relationships between the stress attendant on air traffic control tasks as compared to those experienced by other populations of workers, and (3) to permit comparisons among the physiological responses of controllers at several terminals where qualitative differences in the work situations were known to exist. Physiological measures taken on the controllers included heart rate, galvanic skin response, blood pressure, and oral temperature. Biochemical measures included the pattern and quantity of phospholipids as well as fibrinogen in blood plasma. Urine samples were analyzed for epinephrine, norepinephrine, 17-OH corticosteroids, sodium, potassium, phosphate, urea, and creatinine.

Data were collected from each of 22 controllers at regular intervals during five, eight-hour work periods on the evening shift (1600-2400) when the density of traffic was heavy, and five days on the morning shift (0000-0800) when the traffic was light.

Results indicated that significantly higher heart rates occurred on the busy evening shift than on the morning shift. On the evening shift, converging, approaching traffic was more arousing than departing, diverging traffic. There was no differential response on the morning shift. Galvanic skin response results indicated that adaptation to the morning shift was incomplete in five days. Blood fibrinogen levels were not significantly elevated above the level expected for controllers within the age group of the sample. On the other hand, controllers had a higher total plasma phospholipid level than populations of normals, schizophrenics, and combat pilots. Phosphatidyl glycerol was significantly higher in controllers' plasma than in the normal population but less than that in combat pilot and schizophrenic populations.

Data derived from biochemical studies of the urine of the controllers revealed significant differences in the direction of a decrease in the excretion of metabolic products on the morning shift for the first four-hour period and an increase in the last four-hour period. This finding seemed to reflect the fact that the first four-hour period of the evening shift was extremely busy, while the first four hours of the morning shift was relatively quiet. Conversely, the last four hours of the evening shift was relatively quiet while the last four hours of the morning shift was rather busy. In general, ATC work at O'Hare was characterized by a general elevation of the end products of metabolism.

When data from the controller group were compared with data from other groups upon whom similar urinary variables were measured, comparisons showed that O'Hare tower work was significantly more stressful than long or difficult flying operations, prolonged decompression in an altitude chamber, or a ten-hour period in a flight simulator by inexperienced subjects. Taken as a whole, the measurements indicated that controllers were generally in a state of excitation, particularly on the evening shift. This state of arousal was interpreted as probably deriving from the controllers' intense concern for the separation of aircraft.

These research findings as well as others cited in this chapter make it clear that an effort should be undertaken to apply human factors techniques wherever possible to make the controller's job less demanding. This is important, not in order to "pamper" the incumbents, but to reduce the probability of error induced by overload, to prolong the useful working life of controllers, and to make it possible to fill the job with personnel of less than exceptional psychological and physiological stamina.

The entire spectrum of human factors activities recommended in this report have as one of their goals alleviation of stress. Two areas of investigation which are especially promising are optimization of shift scheduling, and optimization of work-rest cycles.

At present the scheduling of the controllers' work shifts varies from facility to facility. In most cases, controllers work on a rotating schedule alternating between day and night shifts. Assignment to the day and evening watches is usually rotated on a weekly basis, with a midnight shift scheduled once every five or six weeks. Some facilities employ a system where controllers work two weeks on the 0800-1600 shift, two weeks on the 1600-2400 shift, and one week on the 2400-0800 shift. Very few facilities schedule controllers on the same shift for long periods.

Shift rotations have the advantage of giving all controllers an opportunity to gain experience in peak density time periods with a chance for relief from such heavy loads on the evening and midnight shifts. In addition, there is premium pay associated with night and Sunday work. There are, however, potential disadvantages to such a rotation. These include the disruption of diurnal cycles, frequent psychological adjustments to changes in family living patterns, and inability to settle into well established routines associated with more or less standard pacing of activity. Often there are periods where adequate rest is impossible, such as when changing from the day to the midnight shift, where the controller has only eight hours in which to eat, sleep, and travel to and from work. A compounding factor is the heavy requirement for overtime work placed on controllers in many facilities.

To investigate the impact of various shift schedule arrangements, it is recommended that a program of research be undertaken to collect (1) proficiency data on a large sample at various times throughout the shift under all shift scheduling conditions, (2) non system-specific measures such as psycho-motor performance data, (3) physiological data, e.g., heart rate, urine samples for hormone analysis and galvanic skin response, and (4) subjective measures, e.g., self-estimates of fatigue, stress, and performance level and self-reported symptoms such as headaches, indigestion, chest pain, and ulcers.

The systematic compilation of data on a wide sample of controllers under various shift scheduling conditions should provide a body of information amenable to multivariate analysis. This would provide a rational basis for formulating shift schedule policies aimed at stabilizing the work load and improving the overall performance capability of the controller force.

Within any given shift, controllers may be called upon to work periods of several consecutive hours, sometimes with only a few minutes relief. This occurs most often under conditions of high stress, i.e., when traffic is unusually heavy. It is recommended that studies be conducted to determine the value of providing work breaks with planned rest and relaxation activities on a scheduled basis. This will be difficult to implement in most facilities, however, the impact on overall performance effectiveness should be substantial. Measurements such as those recommended for shift schedule research should be employed in evaluating work-rest cycle configurations.

CHAPTER 4

SYSTEMS ACTIVITY ANALYSIS

This chapter presents information concerning the activities of the three air traffic controller options: En Route, Terminal, and Flight Service Station. The various options and operational positions within each option are described in terms of the activities and tasks which the controller is required to perform. Table 8 lists the basic options and operational positions which were considered.

The occupational descriptions in this section were compiled from analyses conducted by the Training Division of the Office of Personnel and Training and by field personnel of the FAA Air Traffic Service. This material is contained in the three instructional manuals used in the en route, terminal, and flight service station training programs at the FAA Academy in Oklahoma City.

The occupational analyses relevant to en route and terminal options were presented to a sample of 29 experienced air traffic controllers (15 en route and 14 terminal controllers) who were asked to make estimates of the human capabilities called upon for performance of each activity or task and to rate each in terms of difficulty, restrictiveness, and stressfulness. The results of these two types of ratings are summarized in this chapter.

En Route Operations

The en route controller operating in today's air traffic control system must either memorize the identity of radar aircraft targets or transcribe an identifying code on clear plastic markers ("shrimp boats") which are moved manually across the horizontal radar display. Proximity of the marker and the moving aircraft target displayed on the scope assist the controller in

Table 8

Structure of the Air Traffic Control Training Program

EN ROUTE	TERMINAL	FLIGHT SERVICE
Positions:	Positions:	Positions:
Flight Data/ Interphone	Flight Data	Weather Observer
Non-Radar Control	Ground Control	Teletypewriter
Radar Control	Local Control	Broadcast
	Approach Control (Non-radar)	Flight Data
	Approach Control (Radar)	Preflight
		Inflight

remembering the identity of the individual targets. Supplementary information on any given flight, such as altitude and time estimates, are handwritten on paper flight progress strips. With the present system, the controller's radar scope shows only the range and bearing of the aircraft. Altitude is most commonly transmitted by voice radio from the pilot at the request of the ground-based controller.

Details of each operational position in a conventional en route traffic control center are described below in terms of the activities required for effective job performance.

Flight Data/Interphone

In the flight data/interphone position the en route controller's activities include (1) copying, interpreting, and distributing flight plan information, (2) preparing the required fix postings, (3) operating the interphone system, (4) encoding, decoding, interpreting, and disseminating teletype flight plan messages, (5) interpreting and posting weather information and notices to airmen (NOTAMS), (6) coordinating traffic by transmitting flight plans, estimates, control data, and revisions to the adjacent sector/facility, and (7) issuing clearances and advisories to aircraft.

Nonradar Control

The nonradar control position requires the controller to (1) operate radio equipment, (2) review the accuracy of flight progress strips, weather information, and NOTAMS for traffic control purposes, (3) receive and post flight progress reports, (4) analyze the traffic picture for potential conflicts, (5) initiate, issue, revise, and forward clearances, advisories and other control information to departing, en route, and arriving aircraft, as well as relaying appropriate information to the adjacent sector/facility, and (6) prepare required reports and maintain sector logs.

Radar Control

In the radar control position, the en route controller is required to (1) align and adjust radar equipment as well as read and interpret the radar scope display, (2) provide, upon request, traffic advisories to aircraft operating under visual flight rules, (3) operate the coordinator position, and (4) prepare required reports and maintain sector logs.

Terminal Operations

The terminal controller's general function is to control air traffic on or near an airport by direct vision or radar. The concept of air traffic control employed to maintain safe and efficient utilization of air space includes providing a ground-based separation service which is either (a) procedural in nature, or (b) dynamic, i.e., based on continuous ground-derived information about aircraft positions. Airport surveillance radar (ASR) provides the controller with a visual presentation of traffic operating in the general vicinity of an airport (generally within a 60-mile radius) and permits him to maintain the minimum separations necessary to expedite the safe flow of terminal area traffic. Aircraft range and azimuth as detected by the ASR is displayed on plan position indicators (PPI) located at a terminal radar approach control (TRACON) room and/or in a control tower cab. An electronic map of the area covered by the ASR is displayed on the PPI in such a manner that radar signals received are correlated with locations above the surface of the earth. ASR also includes secondary surveillance radar (radar beacon) which supplements basic ASR by transmitting interrogating signals to transponder-equipped aircraft to facilitate radar identification.

In the immediate future, there is a need to augment the capacity of the terminal radar system in order to satisfy the forecast growth of air traffic. It is anticipated that this requirement can be met through automation which will open up new alternatives in communications efficiency and air traffic procedures. The terminal automation system envisioned will be flexible enough to provide for additional modular expansion of capacity in response to the growth of air traffic. The specific components of this system, ARTS II and ARTS III, have been described in Chapter 3.

The details of each operational position in a conventional terminal facility are described below in terms of the activities required for effective job performance.

Flight Data

In the flight data position, the terminal controller is required to (1) operate the interphone system, flight data entry, and printout equipment, (2) copy, interpret, and relay flight data, (3) prepare and distribute flight progress strips, (4) receive and relay weather information and NOTAMS, (5) set up frequencies on standby radio equipment, (6) alert emergency equipment, (7) make visibility reports, and (8) collect, tabulate, and store daily records.

Ground Control

In the ground control position, the controller is required to (1) monitor and analyze ground traffic, (2) operate the radio equipment and guard assigned radio frequencies, (3) issue taxi clearances, (4) collect, analyze, and distribute pilot reports (PIREPS) as well as reports concerning hazards, or the operational status of facilities, (5) relay, initiate or coordinate advisories, information, and IFR clearances, and (6) initiate and direct emergency action.

Local Control

The local control position requires the controller to (1) determine and issue instructions relative to the aircraft's flight path, landing and takeoff sequences, clearances, and traffic information, (2) assign runways, (3) issue control instructions and advisories to departing aircraft, (4) instruct pilots to change radio frequencies or radar beacon codes, (5) operate the airport visual aid system, (6) observe and report weather changes, and (7) monitor navigational aids.

Approach Control (Nonradar)

In the approach control (nonradar) position the controller is responsible for (1) sequencing fix posting, (2) reviewing the accuracy of flight data, (3) updating weather information and NOTAMS, (4) receiving and posting flight progress reports, (5) revising estimates, (6) analyzing traffic for potential conflicts, (7) monitoring the approaches of aircraft on instrument clearances, (8) initiating, issuing, and revising clearances, advisories, and other control information, (9) analyzing and expediting total traffic movement by coordination with other positions within the facility, as well as outside facilities, (10) providing flight assistance service, (11) receiving, interpreting, and disseminating pilot weather reports, and (12) operating direction-finding equipment.

Approach Control (Radar)

The approach control (radar) position requires the controller to (1) provide radar arrival control, departure control, and emergency service, (2) align and operate radar equipment, (3) read and interpret the radar scope display, (4) provide, upon request, traffic advisories to aircraft operating under visual flight rules, and (5) provide Stage I, II, or III service.

Flight Service Station Operations

The flight service station is an operational facility which performs functions related to the acquisition, distribution, and dissemination of meteorological and other aeronautical information bearing on flight safety. Flight service stations provide briefings to pilots at local airports and, through an extensive system of telephone lines, briefings to pilots at more than 1,000 airports in nearly as many communities. These facilities provide inflight weather briefings, warnings, and advisories through a system of strategically located radio communications outlets. The communication system is used to relay approach and departure clearances at non-tower airports, to monitor en route navigation aids, and to provide emergency assistance to lost or disoriented aircraft. Despite the importance of those services provided by the flight service stations, few problems presently associated with the air traffic control picture occur in this area. Therefore, occupational evaluations were not sought from flight service station controllers as was done for en route and terminal controllers. An occupational analysis of the activities performed by flight service station controllers is presented below.

The details of each functional position in a conventional flight service station are described below in terms of the activities required for effective job performance.

Weather Observer

In the weather observer position, the controller is required to (1) maintain continuous observation of weather and atmospheric conditions, (2) evaluate sky cover, and (3) determine ceilings, visibility, altimeter settings, and station pressure.

Teletypewriter

In the teletypewriter position, the controller is required to (1) teletypewrite, (2) read Baudot tape, and (3) operate the automatic send/receive unit, teletypewriter line switching unit, and the relay reperforator unit.

Broadcast

In the broadcast position, the controller is required to (1) maintain a cumulative collection of all incoming broadcast material, (2) analyze material for proper action, and prepare and edit material prior to broadcast, (3) observe schedules and time restrictions in making broadcasts, and (4) operate the pilots' automatic telephone weather answering service.

Flight Data

In the flight data position, the controller is required to (1) typewrite flight data materials, (2) operate the interphone and telephone system, (3) receive, analyze, and distribute flight data and NOTAMS in accordance with operating procedures, (4) estimate progress of aircraft, and (5) maintain current flight data displays and NOTAM displays.

Preflight

In the preflight position, the controller is required to (1) continuously reassess and update weather guidance materials, (2) prepare and maintain pictorial weather chart displays, (3) maintain current displays of sectional planning charts and the airmen's information manual, (4) provide preflight briefings, (5) operate and maintain weather bureau facsimile equipment, and (6) file records and reports.

Inflight

In the inflight position, the controller is required to (1) operate air-to-ground equipment, (2) monitor navigational aids and communication equipment, (3) continuously analyze and update weather information, (4) collect, interpret and distribute PIREPS, (5) provide VFR flight plan service, en route service, and airport advisory service, and (6) provide emergency service to aircraft and take appropriate action regarding overdue, missing, or unreported aircraft.

Controller Ratings of Activities and Tasks

Air Traffic Controller Sample

A sample comprised of 15 en route and 14 terminal air traffic controllers stationed at the National Aviation Facilities Experimental Center (NAFEC) rated the materials described in the following pages. Controllers ranged in experience from four to 32 years. Median experience for en route controllers was 17 years, and for terminal controllers, 16 years. Experience throughout the entire spectrum of air traffic control facilities in terms of traffic density was represented in the sample, although the greatest number of controllers had their most recent experience at high density facilities.

Procedures

Ratings were made with respect to the human requirements listed in Table 7 (page 45). The controllers were given a breakdown of the series of tasks associated with each activity in the occupational analysis. (Appendix A provides a sample of one such task analysis, the Approach Control (Nonradar) position which is one of five training phases within the terminal controller option.) A total of eight such position analyses were actually used, one for each of the five terminal positions and three en route positions.

Controllers were asked to examine each of the tasks which make up an activity and to determine the two human factors requirements most critical to performance of the task. Where a task involved more than two requirements, controllers were asked to indicate only the two most significant. Controllers prepared a rating for every task in the occupational analysis of the positions within their option. These ratings were then summed to the activity level.

Results

The summary ratings for terminal and en route controllers are presented in Figure 9, which shows the pooled activities for all positions of terminal and en route controller options as they were rated by the sample.

Figure 9 indicates that the capability most often called upon in the terminal option is control operations, while information organization is the most required capability in the en route option. This figure can be examined to throw light on the relative demands for each capability in each option in a like manner. For example, the en route option demands more capability in reading (as defined here) than the terminal option; conversely, the terminal option is more demanding than the en route with respect to all forms of monitoring.

Both groups of controllers indicated approximately equal demands for reporting (transmitting oral flight path instructions, altitude instructions, weather, etc.) and performing control operations (applying manual force to controls once the response has been selected and the decision to act has been made).

En route controllers reported a higher requirement than terminal controllers with respect to information organization, which involves the evaluation, synthesis, and integration of information from varied visual or

EN ROUTE AND TERMINAL : ALL POSITIONS

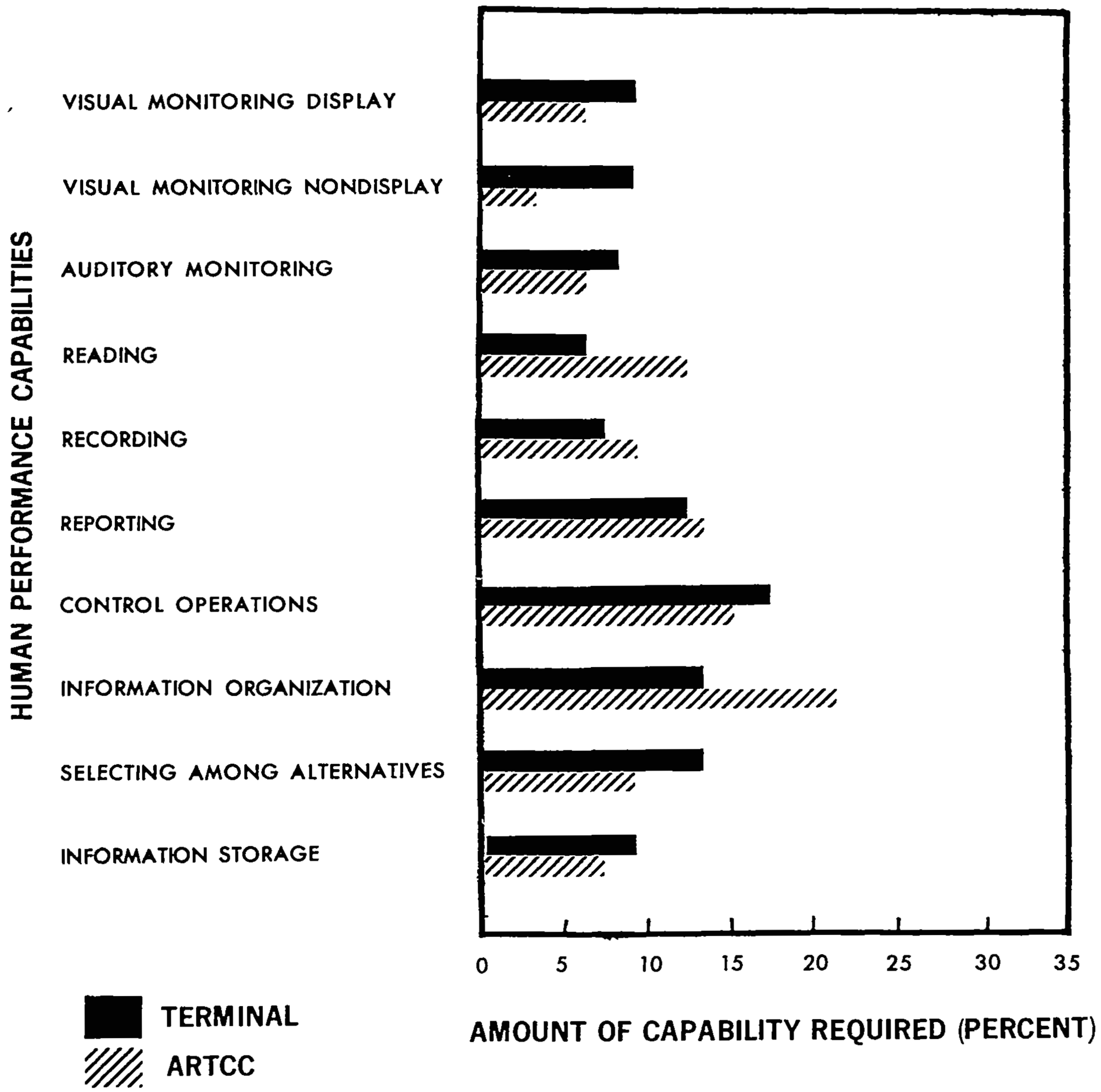


Fig. 9. Occupational analysis of activities of terminal and en route air traffic controllers in terms of human capabilities.

auditory sources. In a practical sense, this includes such activities as the simultaneous consideration of type of aircraft, relative speed, and maneuverability or integrating weather information from a variety of sources.

Slight differences between the two groups existed in regard to selecting among alternatives. Terminal controllers reported more required activity in predicting from available information which alternative optimizes system function.

There was little difference between en route and terminal controller groups in regard to their ratings of information storage, i.e., the short-term retention of recently acquired material which is subject to immediate recall. Examples of this capability include retaining and recalling such information as radio frequencies, flight numbers, vectors and routings for particular aircraft.

En Route Controllers. Figures 10 through 12 present profiles of the ways in which en route controllers viewed the human performance requirements of their jobs. The figures represent each of the three en route controller positions listed in the FAA training manual. The activities and tasks of each position were rated in terms of the human performance requirements which comprise them.

The profile for the flight data/interphone position (Figure 10) shows that reading, control operations, and information organization capabilities are rated as heavily required. Visual and auditory monitoring, recording, reporting, selecting among alternatives, and information storage each received less emphasis in the ratings.

In the nonradar control position (Figure 11) the capabilities rated as most heavily required were reporting and organizing information. The two capabilities accounted for more than 40% of the controller's indicated requirements.

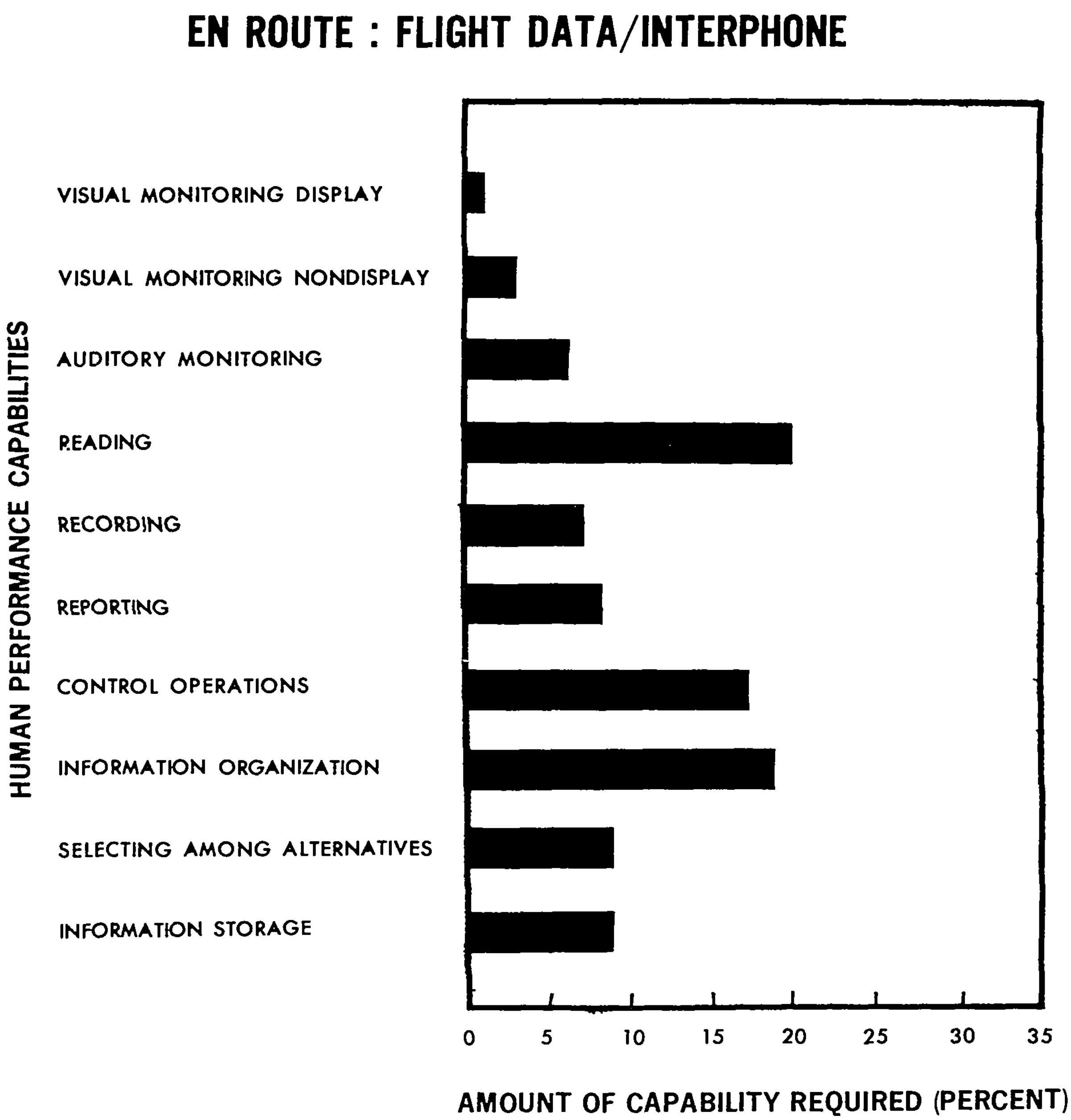


Fig. 10. Occupational analysis of activities in terms of human capabilities for the flight data/interphone position for en route controllers.

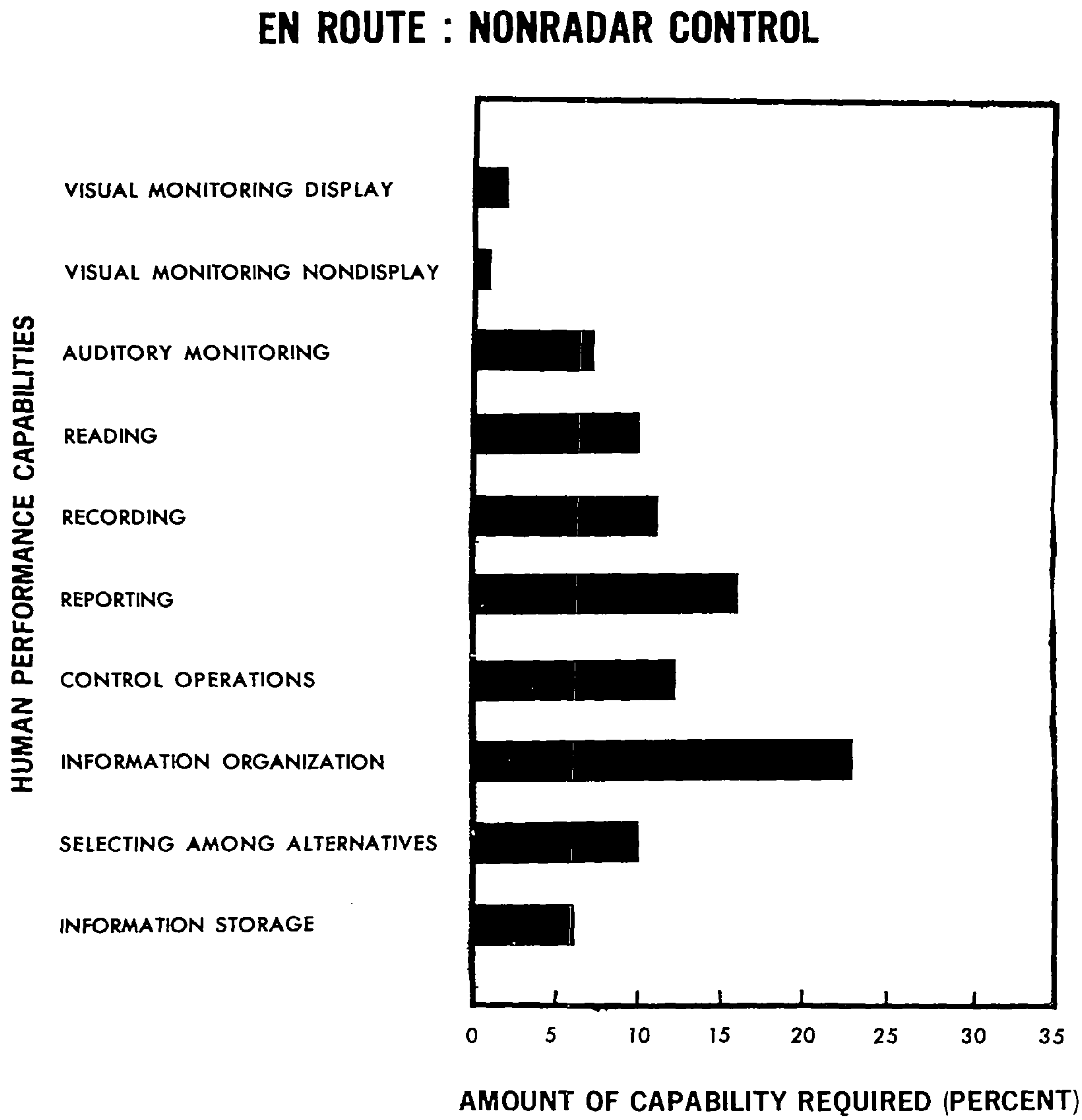


Fig. 11. Occupational analysis of activities in terms of human capabilities for the nonradar control position for en route controllers.

At the radar control position (Figure 12), the activities rated as being most heavily required were visual monitoring of displays, recording, and organizing information.

In general, it is the information organization requirement which cuts across all three positions. If one were to attempt to reduce the en route traffic controller's job to one single overriding skill requirement, it would be the ability to integrate information from varied visual and auditory sources.

Terminal Controllers. Figures 13 through 17 show the five positions within the terminal option as rated by the sample of terminal controllers. In the flight data position (Figure 13), control operations were indicated as an important requirement substantially more often than any other capability.

The ground control position (Figure 14) shows an unusually nondifferentiated profile. No capability stands out as being required significantly more than many others.

The local control profile (Figure 15) shows that the visual monitoring of nondisplays, reporting, information organization, and selecting among alternatives constituted the more important requirements. Taken as a whole, the four activities received 61% of the total number of ratings.

In the approach control (nonradar) position (Figure 16), two activities--information organization and selecting amont alternatives--were indicated substantially more often than others. The two activities comprised more than 37% of the total number of ratings.

In the approach control (radar) position (Figure 17), as might be expected, the visual monitoring of displays is the capability most required. The second requirement which emerges distinctly in this position is control operations.

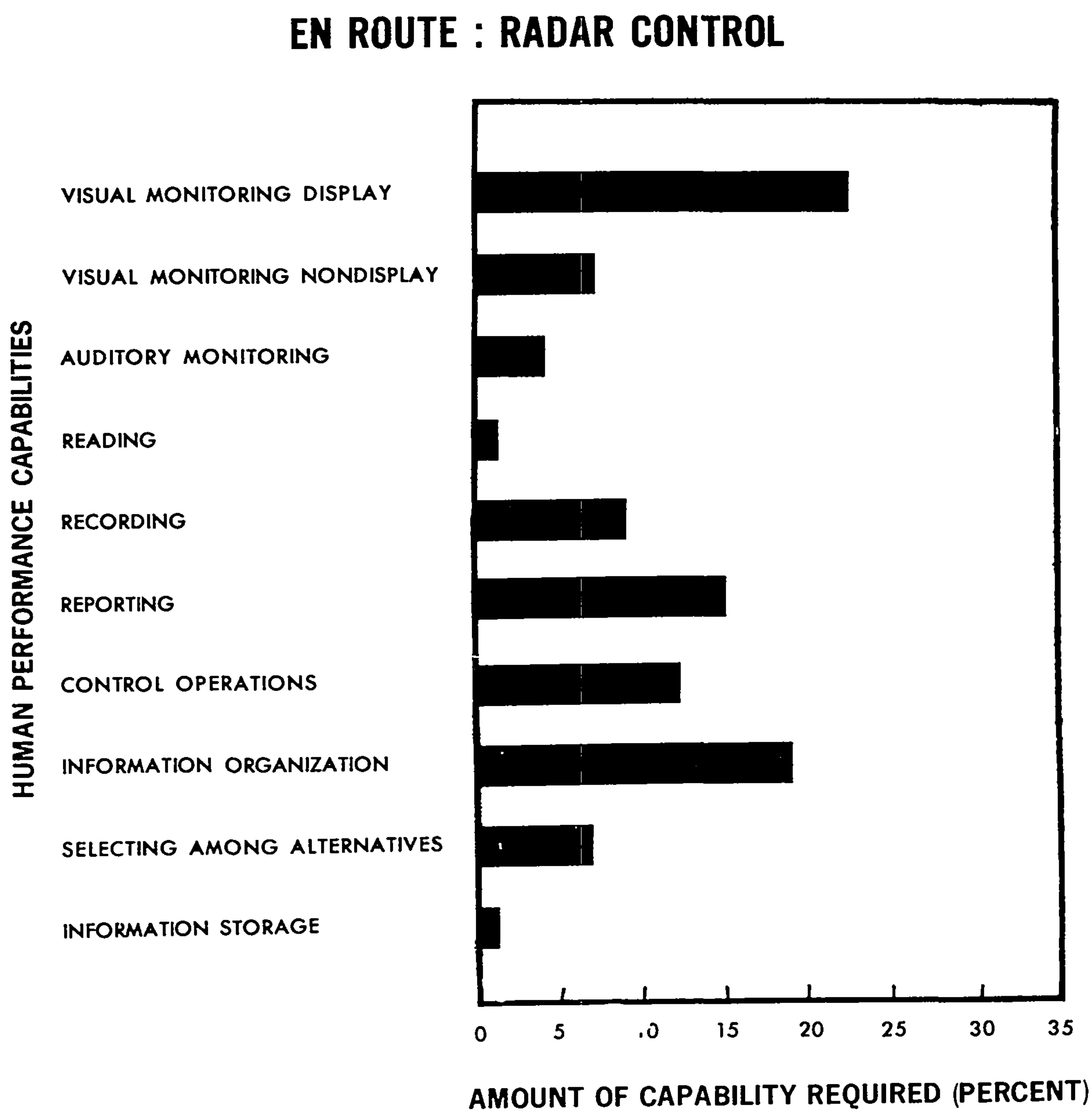


Fig. 12. Occupational analysis of activities in terms of human capabilities for the radar control position for en route controllers.

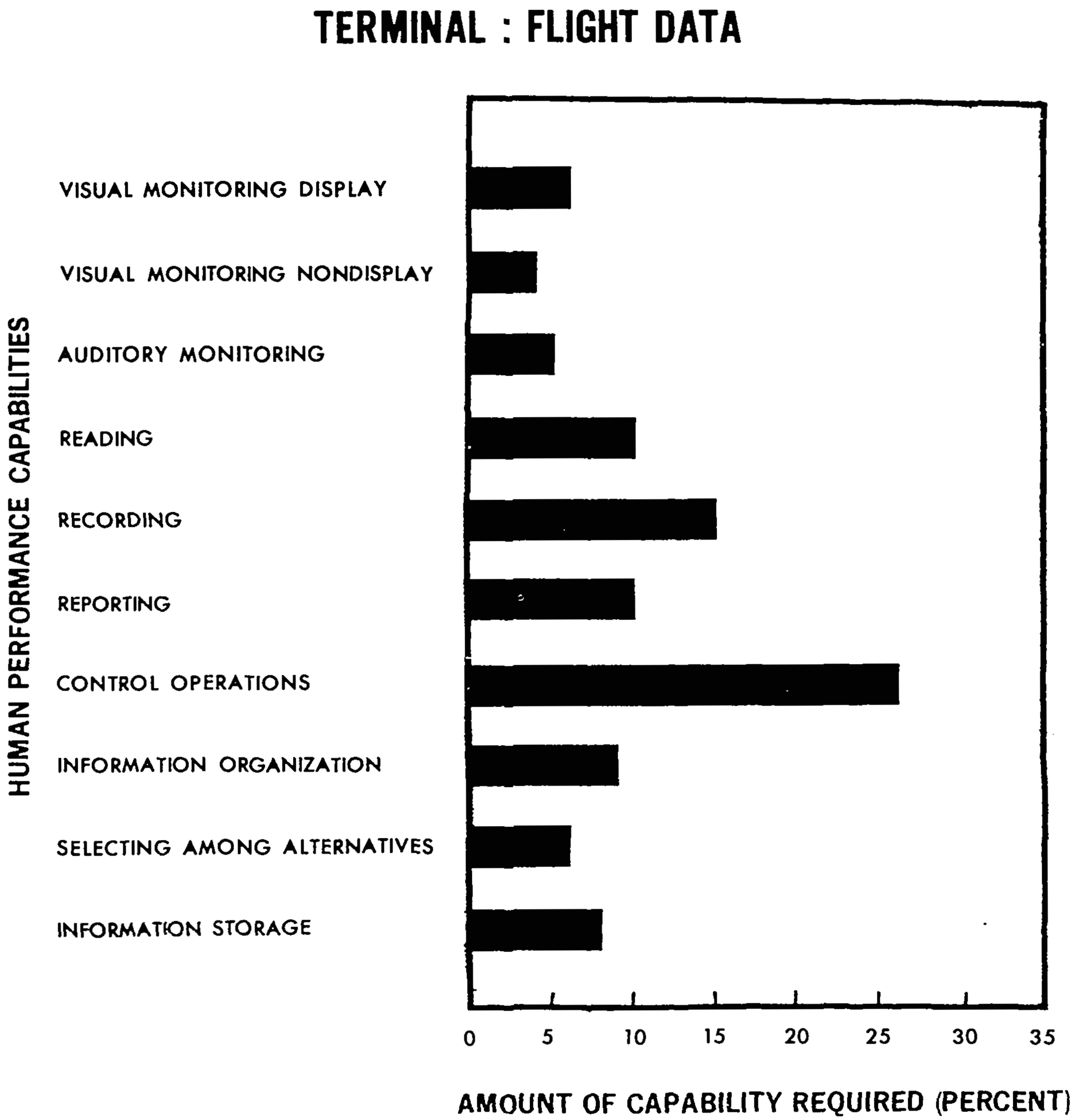


Fig. 13. Occupational analysis of activities in terms of human capabilities for the flight data position for the terminal controller.

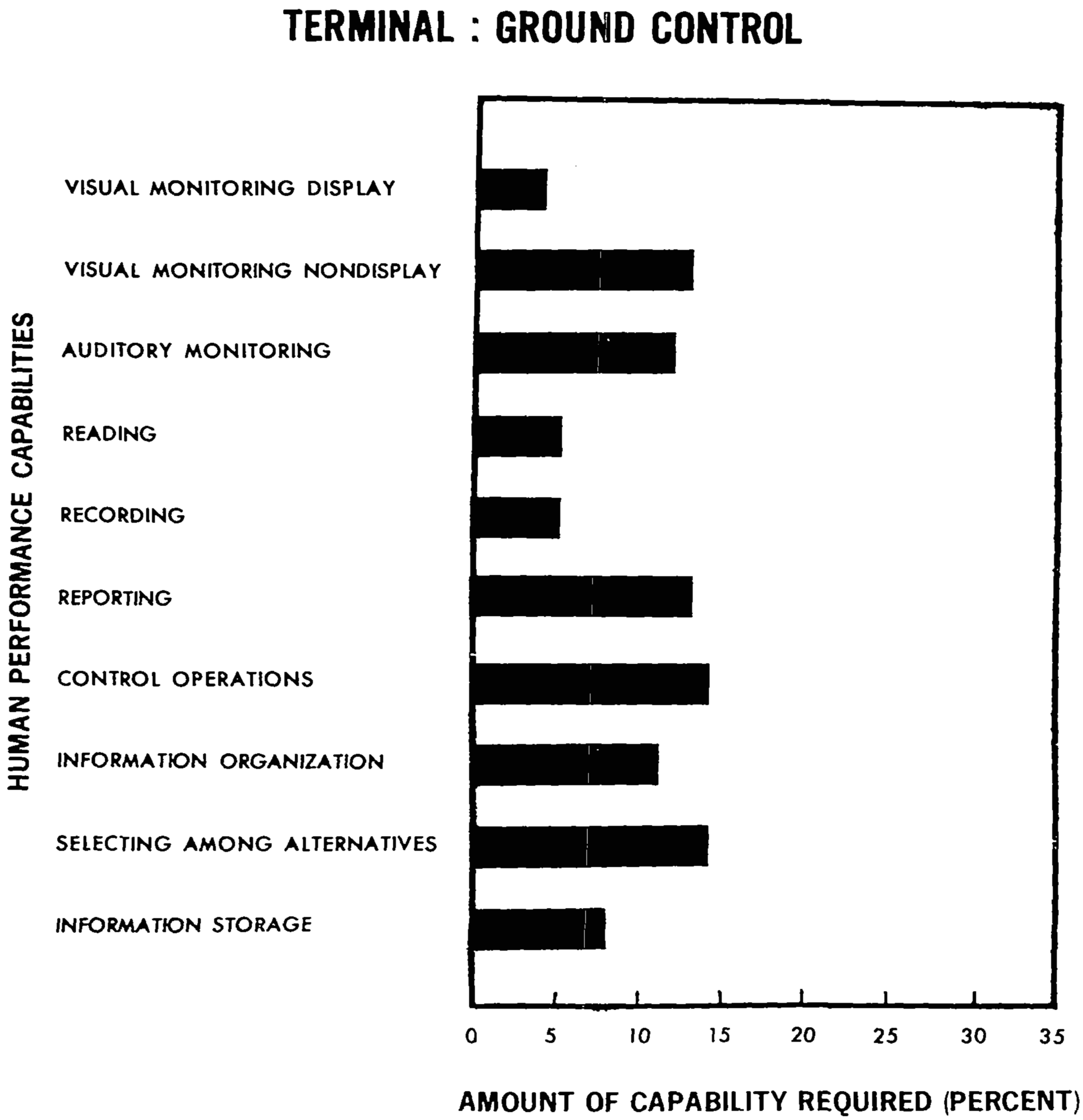


Fig. 14. Occupational analysis of activities in terms of human capabilities for the ground control position for the terminal controller.

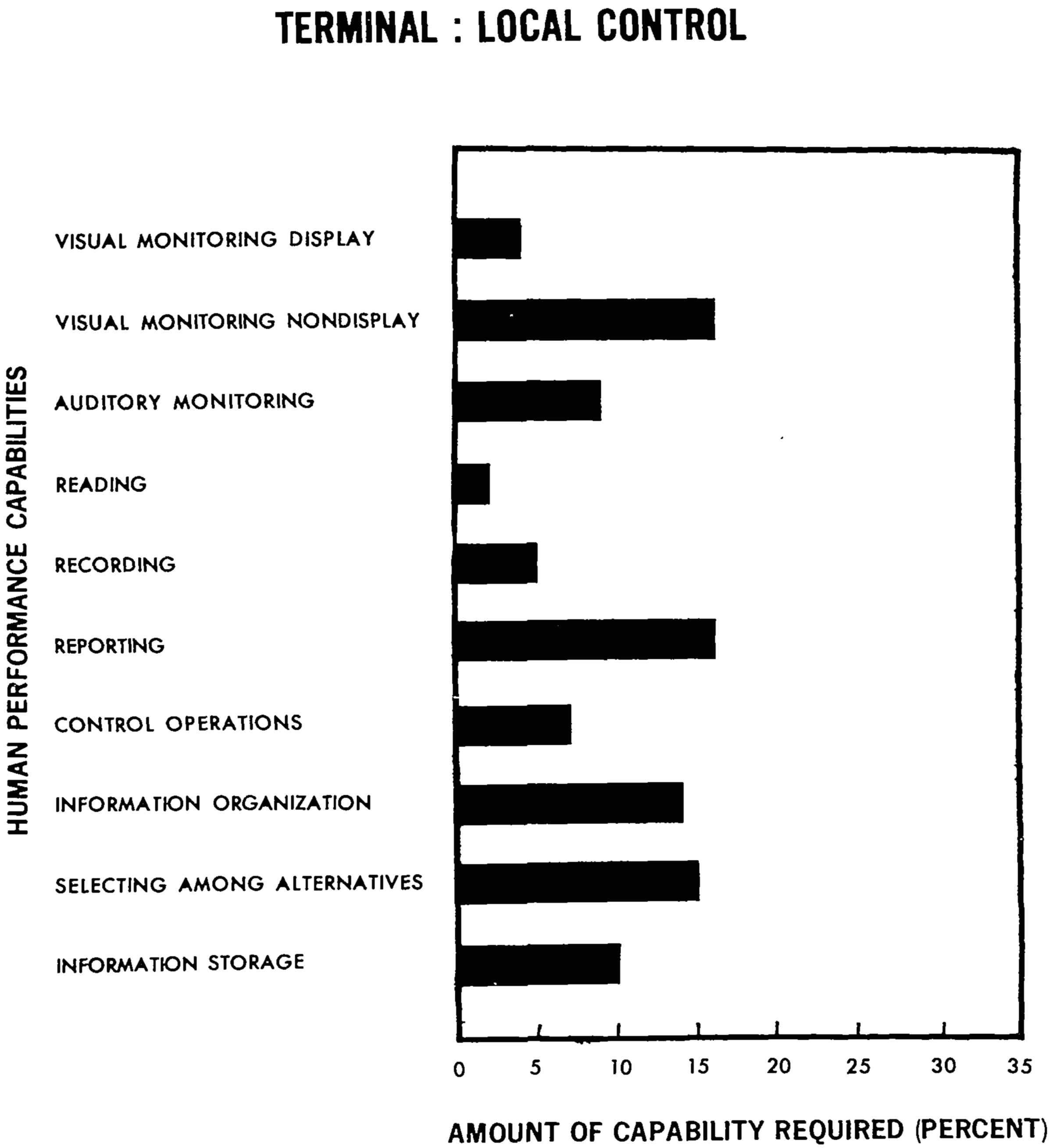


Fig. 15. Occupational analysis of activities in terms of human capabilities for the local control position for the terminal controller.

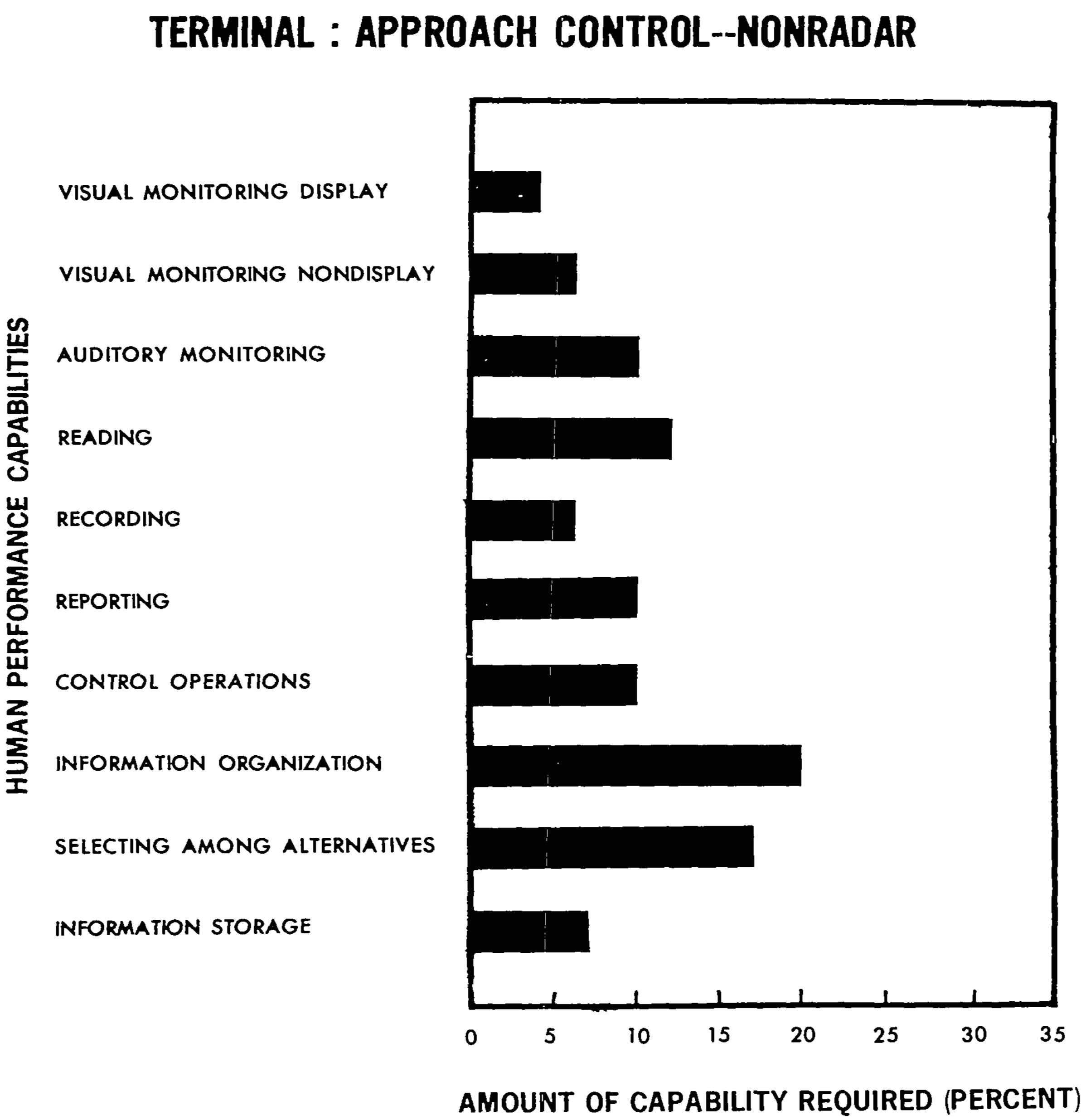


Fig. 16. Occupational analysis of activities in terms of human capabilities for the approach control-nonradar position for terminal controllers.

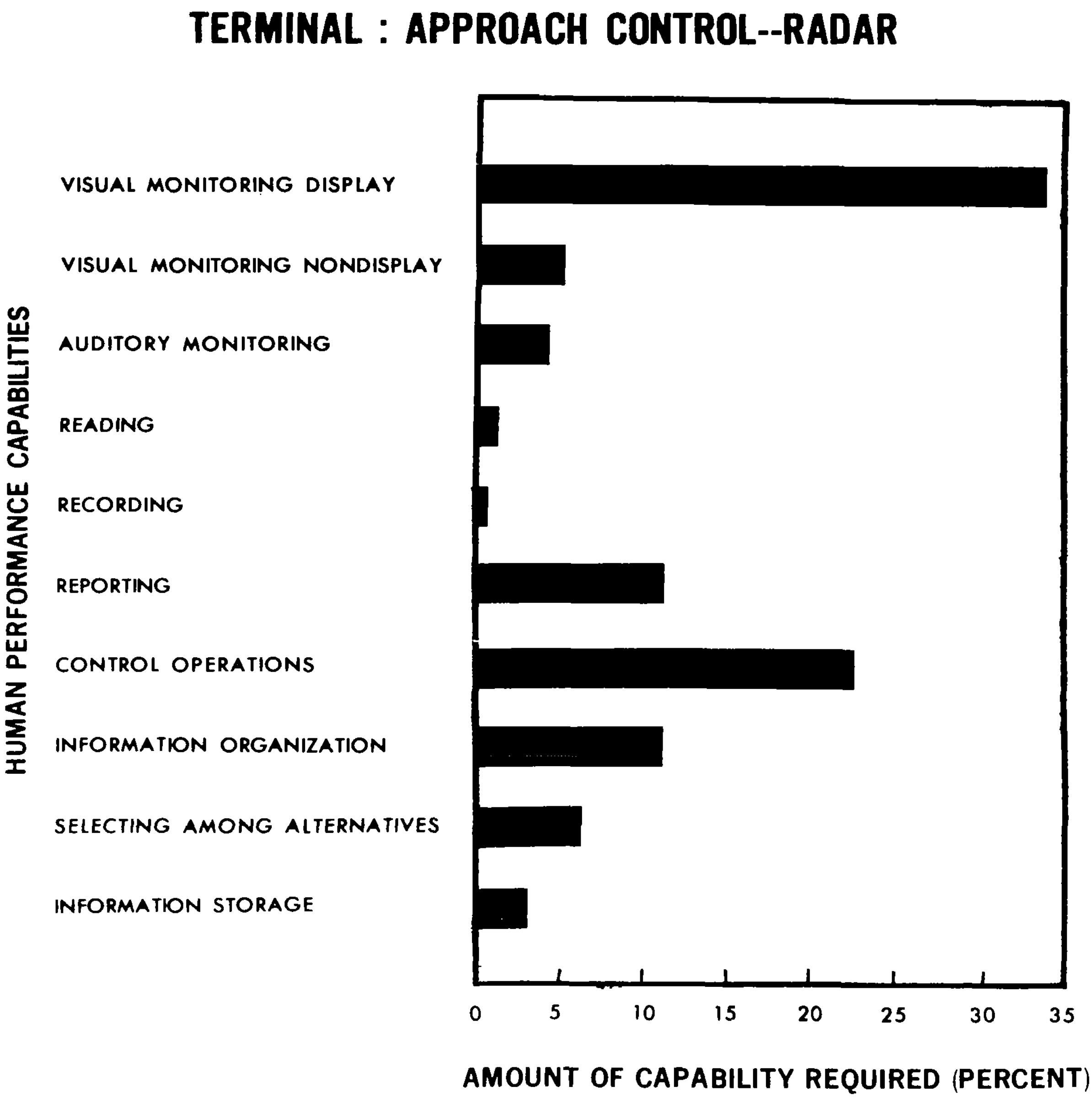


Fig. 17. Occupational analysis of activities in terms of human capabilities for the approach control-radar position for terminal controllers.

Unlike the total profile which emerged in regard to en route controllers where information organization appeared to be a requirement which cut across all the various positions, the five terminal controller positions, looked at as a group, have no single overriding requirement. The tasks and activities of this group span the entire spectrum of capabilities required of controllers.

Figure 18 shows the human capabilities profile which results from a combination of the en route and terminal task analyses. It can be seen that information organization and control operations are the largest components of the air traffic controller's occupation. Selecting among alternatives and reporting are also heavily required capabilities. These are followed by reading, recording, and information storage--at an approximately equal level. Monitoring activities as a group represent the least required activities as rated by this group of controllers.

Task Dimensions

In another portion of the study, each en route and terminal controller examined lists of activities for each position within his option. En route controllers examined activity lists for the flight data/interphone, nonradar control, and radar control positions. Terminal controllers inspected activity lists for flight data, ground control, local control, approach control (nonradar), and approach control (radar) positions. Within the activity list for each position, controllers were asked to indicate those activities which were most and least (1) difficult, (2) restrictive, and (3) stressful. These terms were defined as follows:

1. Difficulty - the extent to which the activity requires technical training and experience for adequate performance.

EN ROUTE AND TERMINAL : ALL POSITIONS COMBINED

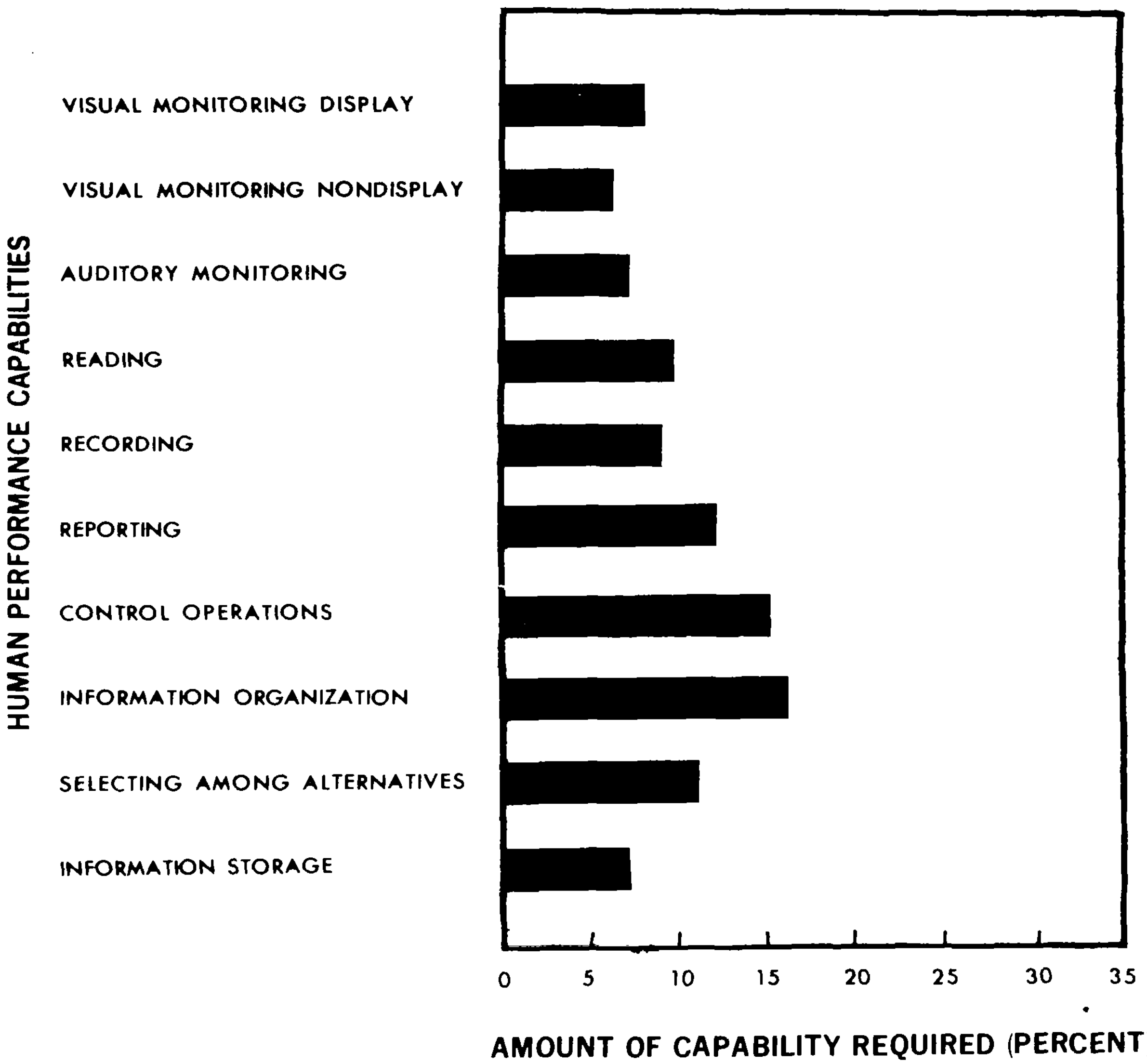


Fig. 18. Occupational analysis of activities in terms of human capabilities for all en route and terminal controller positions combined.

2. Restrictiveness - the amount of attention the activity requires of an air traffic controller, thereby restricting his ability to perform other activities at the same time.

3. Stressfulness - the extent to which an activity induces a sense of subjective strain, e.g., sweaty palms, pounding heart, "inner sweats."

Ratings for each of the three dimensions were made independently, i.e., a controller rated activities first for difficulty, then for restrictiveness, and finally for stress. These ratings were then combined to produce what might be referred to as a measure of task "demandingness." The rank ordering of activities for each position in both en route and terminal controller options is presented in Tables 9 through 16. (Ratings of the tasks on the individual dimensions of difficulty, restrictiveness, and stress are presented in Appendix B.)

Automation Effects

In another portion of this study, en route and terminal controllers were asked their opinions regarding the extent to which implementation of NAS Stage A or ARTS III would result in a change in the controller's capacity to handle air traffic, and in the controller's work load.

Figure 19 shows controller estimates of the change which NAS Stage A and ARTS III will produce in capacity to handle air traffic. The inference which can be drawn is clear. This group of air traffic controllers was quite pessimistic regarding the extent to which the new equipment would increase the capacity of the system to handle air traffic. Only one-third of the sample (34%) felt that traffic handling capacity would increase. Of the remainder, 21% felt that it would result in no change, while 46% felt that the amount of traffic handled would decrease. Independent estimates of the increase in system capacity which is to result from the implementation of the NAS Stage A and ARTS III systems have ranged as high as 40% (Alexander et al., 1969).

Table 9

Ranking of En Route Air Traffic Controller Activities for the Flight Data/Interphone Position in Terms of Task Demandingness

1. Issue Clearances and Advisories to Aircraft
2. Coordinate Traffic with Adjacent Sectors or Facilities
3. Conduct On-the-Job Training for Entrance Grade Personnel
4. Relay Estimates and Control Data to Adjacent Sectors or Facilities
5. Evaluate Performance of Entrance Grade Personnel
6. Transmit Flight Plans and Estimates
7. Relay Revisions to Adjacent Sectors or Facilities
8. Receive and Post Flight Progress Reports
9. Interpret and Disseminate Teletype Flight Plan Messages
10. Prepare Required Fix Postings (Manually)
11. Copy and Interpret Flight Plan Information
12. Interpret and Post Weather Information and NOTAMS
13. Revise Estimates
14. Encode and Decode Teletype Messages
15. Review Flight Data Prepared by the "F" man
16. Prepare Required Fix Postings (Automation)
17. Sequence Flight Progress Strips
18. Operate Interphone System
19. Distribute Flight Progress Strips
20. Mechanical Operation of the Headset
21. Load Strip Holders

Table 10

Ranking of En Route Air Traffic Controller Activities for the Nonradar Control Position in Terms of Task Demandingness

1. Initiate and Issue Clearances, Advisories, and Other Control Information to Departing En Route and Arriving Aircraft in Accordance with 7110.9 Manual
2. Analyze Traffic Picture for Potential Confliction
3. Initiate Emergency Procedures and/or Search and Rescue Action
4. Administer On-the-Job Training for Developmental Controller
5. Revise Clearances
6. Forward Control Information
7. Implementation of SCATANA Procedures
8. Relay Revision to Adjacent Sector or Facility
9. Initiate or Provide Flight Assistance Service
10. Operate the AMIS Position (Where Staffed)
11. Review Weather Information and NOTAMs for Traffic Control Purposes
12. Review Flight Progress Strips for Accuracy
13. Assign and Supervise Duties of the A-Position
14. Receive and Post Flight Progress Reports
15. Prepare Required Reports and Maintain Sector Logs
16. Operate Radio Equipment

Table 11

Ranking of En Route Air Traffic Controller Activities for the Radar Control Position in Terms of Task Demandingness

1. Operate Radar Position
2. Operate Radar Handoff Position
3. Administer On-the-Job Training for Developmental Control Personnel
4. Operate Coordinator Position
5. Provide Traffic Advisories to VFR Aircraft upon Request
6. Read and Interpret Radar Scope Display
7. Align and Adjust Radar Equipment
8. Prepare Required Reports and Maintain Sector Logs

Table 12

Ranking of Terminal Air Traffic Controller Activities for the Flight Data Position in Terms of Task Demandingness

1. Copy, Interpret and Relay Flight Data
2. Make and Report Visibility Observations
3. Operate Flight Data Entry and Printout Equipment
4. Alert Emergency Equipment
5. Set Up Frequencies on Standby Radio Equipment
6. Prepare and Distribute Flight Progress Strips
7. Change Tape Reels and/or Recorder Belts
8. Receive, Relay and Post NOTAM Information
9. Operate Interphone Systems
10. Receive and Relay Weather Information
11. Operate Telautograph/Electrowriter
12. Collect, Tabulate and Store Daily Records

Table 13

Ranking of Terminal Air Traffic Controller Activities for the Ground Control Position in Terms of Task Demandingness

1. Issue Taxi Clearances--Aircraft and Vehicles
2. Monitor and Analyze Ground Traffic
3. Initiate and Direct Emergency Action
4. Relay or Initiate Advisories, Information or IFR Clearances to Aircraft
5. Relay, Initiate or Coordinate Advisories and Information to Other than Aircraft
6. Observe, Collect, Analyze and Disseminate Reports Regarding Hazards or Operational Status of Facilities
7. Collect, Analyze and Disseminate PIREP's
8. Operate Portable Traffic Control Light (Light Gun)
9. Read and Interpret Console Instruments
10. Operate Radio Equipment
11. Guard Assigned Radio Frequencies

Table 14

Ranking of Terminal Air Traffic Controller Activities for the Local Control Position in Terms of Task Demandingness

1. Determine and Issue Landing Sequence and Traffic Information
2. Determine and Issue Instructions Relative to the Flight Path of an Aircraft
3. OJT
4. Issue Clearances or Approval for Special Operations (Low Approaches, Contact Approaches, Visual Approaches, Simulated Instrument Approaches, etc.)
5. Issue Landing Clearances and Related Information
6. Issue Takeoff Clearances
7. Issue Control Instructions and/or Advisories to Departing Aircraft
8. Assign Runways
9. Instruct Pilots to Change Radio Frequencies/Radar Beacon Codes
10. Observe and Report Weather Changes
11. Operate Airport Light Systems and Visual Aids
12. Monitor Navigation Aids and Operate Monitor Control Panels

Table 15

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Nonradar Position in Terms of Task Demandingness

1. Analyze Traffic for Potential Conflictions
2. Initiate and Issue Clearances, Advisories and other Control Information
3. Analyze and Expedite Total Traffic Movement
4. Coordinate with Outside Facilities
5. Monitor Approaches of Aircraft on Instrument Clearances
6. Operate DF Equipment
7. Provide Flight Assistance Service
8. Review Flight Data for Accuracy and Preferential Routing
9. Revise Clearances
10. Coordinate Within the Facility
11. Revise Estimates
12. Receive, Interpret and Disseminate Pilot Weather Reports
13. Review Weather and NOTAMS
14. Receive and Post Flight Progress Reports
15. Sequence Fix Posting

Table 16

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Radar Position in Terms of Task Demandingness

1. Provide Radar Arrival Control Service
2. Provide Radar Emergency Service
3. Provide Radar Departure Control Service
4. Provide Stage I, II, or III Service
5. Read and Interpret Radar Scope Display
6. Provide Traffic Advisories to VFR Aircraft Upon Request
7. Align Radar Equipment
8. Operate Radar Equipment

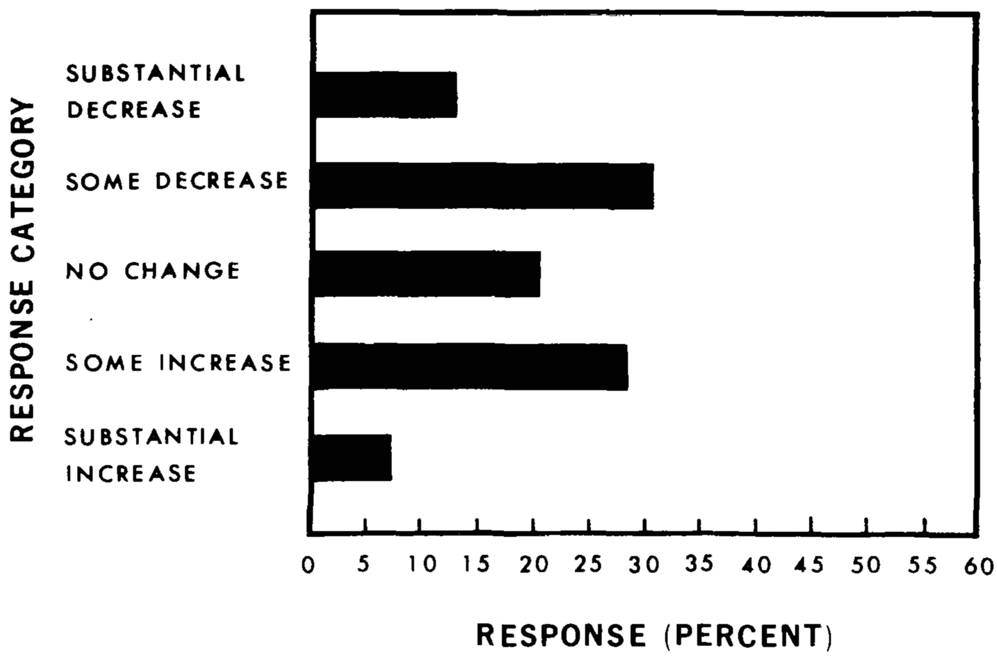


Fig. 19. Air traffic controller responses to the statement: Implementation of NAS Stage A or ARTS III will result in the following change in the controllers' capacity to handle air traffic (N = 29).

Controllers' estimates of the change which new equipment would make in the work load are shown in Figure 20. Nearly all of the controller sample (86%) believed that implementation of NAS Stage A or ARTS III would result in an increase in their work load. One of the most compelling reasons underlying the change to a more automated system was the desire to alleviate the work load of controllers, who are already overburdened in many high traffic density locations. Of the controllers sampled, all of whom had had considerable exposure to the new automated equipment, only three percent felt that it would result in any decrease in the present work load. Examples of controllers' comments on why they felt as they did about the capacity of the equipment to increase traffic handling and to decrease work load are provided in Table 17.

Uses of Human Requirements and Demandingness Data

The information contained in this chapter can serve a number of purposes, since it has implications for all of the major system functions--staffing, training, and operations. It is hoped that the data can be added to the body of information concerning those controller positions involved in the terminal and en route options and used as background data in research and development activities. Examples of how such data can be utilized are discussed below under appropriate headings taken from the system functions analysis presented on page 45 of this report.

1. Analyzing task/skill requirements. In conducting activity and task analyses of controller positions, reference to the figures and tables in this chapter can provide useful background information with respect to the underlying human performance requirements and the relative demands placed on en route and terminal controllers in performing the activities and tasks involved. The methodology employed herein was well received by the controllers who served as subjects and a similar methodology is recommended in future refinements of the activity and task structure of these positions.

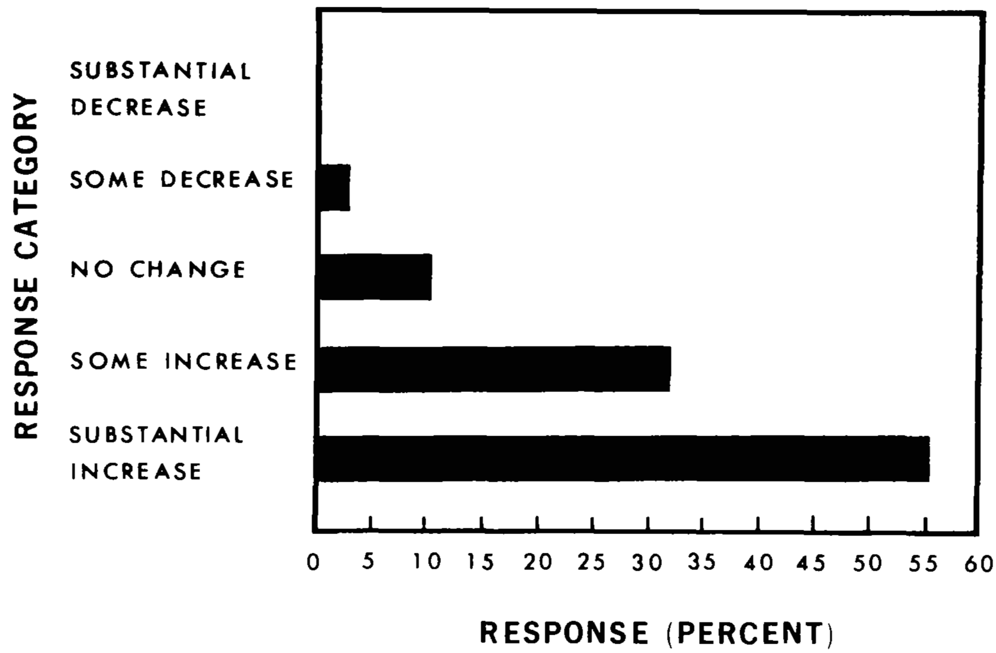


Fig. 20. Air traffic controller responses to the statement: Implementation of NAS Stage A or ARTS III will result in the following change in the controllers' work load (N = 29).

Table 17

Sample Comments on NAS and ARTS System by Controllers

"Alphanumeric key pack limitations will increase the work load, e.g., restriction on multiple entry (ID's) for similar functions (intersector actions)."
"Work load increase due to the radar controller assuming additional duties of handoff man. Many additional operations are required to perform a control function."
"Because we now have more functions, starting, moving, and shaping tracks. Entering track reroutes in order to maintain a flat track when vectoring, a/c."
"Increase in work load due to additional duties placed on radar controller through use of cat/funct panel and alphanumeric key pack and difficulty using alphanumeric key pack."
"Too many buttons to push; the equipment is unreliable."
"Handoff function is too slow; can only handoff one aircraft at a time and then you must use interphone if the aircraft was on a heading; you must make too many entries to update computer."
"More mechanical work to control fewer aircraft; more button pushing; more waiting for responses from computer."
"Problems associated and cat/funct panel and alphanumeric key pack."
"Trying to control traffic and push buttons are just too much to do."
"Man-machine interface is poor; the equipment is too complicated; the computer response is slow to input."
"Cannot work buttons involved with that left alpha, and right alpha."

2. Selecting personnel. Data concerning human capability requirements and the various types of demands placed on controllers in performing at each position should be taken into account in structuring selection and classification instruments for screening personnel to be assigned to these positions. For example, selection devices designed to measure monitoring capability might be weighted more heavily in selecting personnel for the terminal option than for the en route options, whereas selection devices aimed at measuring information organization and reading (the rapid and accurate extraction of relevant information from written or printed material, on the basis of limited exposure) might be more heavily weighted for selecting personnel to be assigned to an en route center position.

3. Training. In all types of training it is important to review the data presented in this chapter so as to pinpoint the training for specific options, and positions within options, in such a way as to emphasize those capabilities most called for and to provide for more practice in those tasks and activities felt to be the most demanding (difficult, restrictive, and stress producing).

4. Man-machine interface. These data provide the beginnings of a basis for establishing more effective liaison between personnel requirements and hardware design activities. The early identification of human performance dimensions can result in more efficient man-machine interface configurations. If equipment designers are made aware of those capabilities called upon heavily by each task and of the activities and tasks which prove to be most demanding in the operational situation, they are in a position to evaluate equipment designs for the possibility of reducing the capabilities required and/or modifying the design in such a way as to reduce the demandingness of the job.

5. Evaluation of performance. These estimates of the capabilities required in each position and the difficulty, restrictiveness, and stress-inducing aspects of the various positions can serve as guidelines to those

responsible for the development of proficiency measures. As with selection instruments, proficiency measures should be designed to reflect the most important characteristics of the jobs being measured. Reference to the figures and tables in this chapter can serve as relevant background information for the conduct of analyses leading to the improvement of such criterion measures.

These examples of possible applications of the data reported herein should not be thought of as exhaustive. In addition, it should be remembered that these data are based on a small number of controllers and that the occupational analyses utilized for this study were relatively unsophisticated, having been developed only for the structuring of training programs. Within these limitations, however, it is felt that the data reported can prove to be effective and useful background material for a variety of such applications.

CHAPTER 5

RESEARCH AND DEVELOPMENT REQUIREMENTS

This report has identified a number of problem areas in air traffic control which are susceptible to analysis and solution through the use of human factors techniques. Recommendations relevant to these problems appear at various points throughout the preceding chapters. These recommendations are presented again below in consolidated form.

Reports of this kind are often criticized on the grounds that they make isolated, general recommendations without identifying the specific steps necessary for implementation and without integrating these recommendations into a unified program of research. Consequently, the second section of this chapter presents a detailed outline of important human factors research and development projects to support the overall effort to solve air traffic control problems.

Summary of Recommended Research

The following section of this report recapitulates, in summary form, human factors studies and support activities which have been recommended in this report. Although each topic is discussed more fully in the body of the report, the material provided here is presented in a form suitable for determining the dimensions of a research and/or development program in each of eight important areas.

Also provided in this section are individual outlines for ten research projects. Although it is intended that these projects form a unified and integrated research program, it is possible to view each work statement as a self contained unit.

General Human Factors Studies

System Analysis. Analysis of the ATC system and its constituent subsystems is required as a first step leading to the development of a comprehensive set of human performance measures. The goal of such an analysis would be the identification of the desired or model output for each subsystem in order to provide a standard against which to compare operational performance. The following series of studies is appropriate.

- Analyze the present air traffic control system to identify system and subsystem outputs and to establish an operational performance model.
- Identify system functions and allocate appropriate functions to man or equipment subsystems.
- Develop quantitative human performance criteria relevant to system output including intermediate or proximate criteria in cases where it is not possible to obtain direct performance measures.
- Based on the above, specify standards of proficiency for human performance.

Activity and Task Analysis. As in other complex technical occupations, air traffic control requires that specific information be available concerning tasks and activities involved in the job. This information is not available on a scale and with the degree of precision required to describe accurately the most important characteristics of the air traffic controller's job. The following steps should be implemented.

- Perform a detailed task analysis for all positions and options in the present system and for NAS Stage A and ARTS III equipment as this is phased in.

- Based on the above task analyses, perform analyses of the skills and abilities required for effective operational performance for each controller position and option.

- Adapt qualitative and quantitative personnel requirements techniques such as those developed by the Department of Defense to establish manpower and training requirements for the air traffic control system.

Analysis of Information Flow and Processing. A primary function of the air traffic controller is the synthesis and evaluation of a great mass of information obtained from visual and auditory sources. Data gathered from these sources must be organized by the human in a manner suitable for decision-making. Specifying the decision parameters can provide a basis for meaningful distribution of the information components of the controller's work load in order to optimize the decision strategies. The following studies are required.

- Determine the information requirements for each controller position and option.

- Conduct analyses of information flow and usage.

- Based on the above, perform special analyses of:
  - (a) man-computer interactions
  - (b) information storage (short-term retention of information by controllers)
  - (c) decision making

Specific Human Factors Applications

Personnel Subsystem. The problem of projecting staffing requirements is compounded by the absence of specific design information concerning what equipment and procedures will be in use within the period of time required to recruit and train the air traffic controllers who must man the system. A basic step in predicting these requirements involves the specification of skill and ability components required for the various positions and options open to controllers. The following tasks should be undertaken.

- Develop recruiting and staffing requirements and personnel assignment plan.

- Determine the differential requirements for various terminal and en route facilities in task-specific terms to provide a systematic basis for assignment and reassignment of controllers.

- Establish centrally controlled assignment procedures to assure the appropriate distribution of manpower among facilities.

Training. Much research and development effort is required to insure that the curriculum at the FAA academy is optimally designed from the standpoint of effectiveness, efficiency, and relevance to the activities which a trainee will be required to perform on the job. In addition, a much greater degree of standardization is required in both the content and technique of on-the-job training programs conducted at the various facilities. In regard to training, the following activities should be initiated.

- Develop detailed curriculum and course content requirements based on analysis of controller activities.

- Evaluate, and ultimately modify the present training program in light of the above requirements.

- Evaluate the applicability to the controller training program of advanced instructional methods such as programmed instruction, self-tutoring, and computer assisted instruction.

- Develop improved instructional programs in the areas of:
    - (a) proficiency maintenance
    - (b) cross-training
    - (c) supervisor training
    - (d) advancement
    - (e) job-training in areas not related to current assignment

Simulation. The value of simulation in large command and control systems has been demonstrated by the NASA manned orbital and lunar missions whose success was due in large part to an extensive use of dynamic simulation. High priority should be placed on conducting analyses of controller activities and tasks with the objective of identifying those which can be simulated with a high degree of fidelity. Basic research and development efforts in this area should include the following.

- Evaluate NASA Mission Control simulation methods to determine their applicability to air traffic control.

- Develop simulators for use in operational analyses and in training.

- Conduct simulator studies for the purposes of:
  - (a) developing proficiency measures
  - (b) evaluating developmental systems or subsystem configurations
  - (c) training (initial and proficiency maintenance)
  - (d) performance evaluation

Equipment Design. Since the major part of the controller's information input comes directly from the equipment which he operates, this equipment exerts a direct influence on the adequacy of his decisions. Human factors data should be provided to the designers of such equipment. Data should bear on the kind of input devices that produce minimal strain on the controller with maximum data input. Steps in such a program should include the following:

- Evaluate human factors aspects of equipment now in use to develop guidelines for future designs.

- Enlist the participation of human factors specialists in the design, development, testing, and evaluation of new equipment.

- Conduct special studies relating to the design of air traffic controllers' displays. Study areas should include:
  - (a) information coding and symbology
  - (b) display format and information content
  - (c) visual qualities (luminance, contrast, size, resolution, up-date rate, etc.)
  - (d) single versus multiple displays
  - (e) three-dimensional displays

- Conduct special studies relating to other forms of information presentation, for example:
  - (a) form and content of aural messages
  - (b) visual monitoring from tower cabs
  - (c) format, wording, and coding of information in written materials

- Formulate design guidelines for controls and control-display relationships.

<u>Controller Work Load</u>. Efforts should be undertaken to make the controller's job less demanding. Objectives would include reducing the probability of error induced by information overload, prolonging the useful working life of controllers, and making it possible to employ as controllers personnel of less than exceptional psychological and physiological stamina. Studies in this area should include the following:

- Conduct studies of controller performance and work load (under simulated and actual conditions) for the purpose of collecting data on:
  - (a) task proficiency
  - (b) psychomotor performance
  - (c) physiological responses
  - (d) subjective estimates of performance decrement

- Based on the results of the above studies, evaluate potential methods of alleviating controller work load and stress, such as:
  - (a) modification of shift schedules
  - (b) reallocation of duties
  - (c) planned rest and relaxation
  - (d) equipment modification
  - (e) revision of procedures

Human Factors Research Program

Presented below is an outline of the program and individual work steps necessary to provide human factors inputs on most of the more important air traffic control problems discussed in the body of this report. Each is presented as a research task with (a) a specification of the steps necessary for that task's accomplishment, (b) the approximate number of calendar months required to accomplish the total task as well as the individual steps, and (c) the relative proportions of effort involved in allocating available resources. The projects are sufficiently detailed to serve as the point of departure for developing a statement of work for an in-house or contracted research and development effort.

The order in which these research tasks are presented is not meant to suggest the priority with which they should be undertaken. It should be noted, however, that Tasks 001 and 002 which relate to detailed task and skill analyses and the development of improved proficiency of measurement techniques, are fundamental to essentially all the other research and development tasks proposed, and to many other areas of staffing, training, and operations. Consequently, it is recommended that research and development programs in these two areas receive the highest priority. It should also be noted that, although many of the tasks are interrelated and require the cross feeding of information, the initiation of any of these tasks does not require the completion of any of the others.

Given adequate funding and staffing, this program of concurrent investigation could produce substantial improvement in the quality of human factors support provided to the air traffic control development program within a relatively short period of time.

Research Task 001

Title: Analysis of differential ability requirements for terminal, center, and flight service station controllers

WORK STEPS	1	2	3	4	5	6	7	8	9	10	11	12	PERCENT EFFORT
1. Review occupational analysis (FAA AC 70-1247, 2342, etc.) for completeness, accuracy, and logical consistency.	X	X											12
2. Prepare revised list of performance units.		X	X										12
3. Review tasks within performance units for completeness, accuracy, and logical consistency.		X	X										12
4. Submit revised list to sample of controllers, supervisors for ratings (See Appendix A).				X	X	X	X						12
5. Submit revised list to sample of controllers, supervisors for judgments of operator functions required for task performance (See Appendix B).				X	X	X	X	X					15
6. Prepare revised statement of performance units and tasks for each position/option.					X	X	X	X	X				15
7. Prepare statement of ability requirements for each of three options.							X	X	X	X	X		9
8. Design system for continuous updating of task and ability requirements.								X	X	X	X	X	12
9. Deliver reports, documentation, and recommendations.												X	1

CALENDAR MONTHS

Research Task 002

Title: Develop means for better evaluation of proficiency

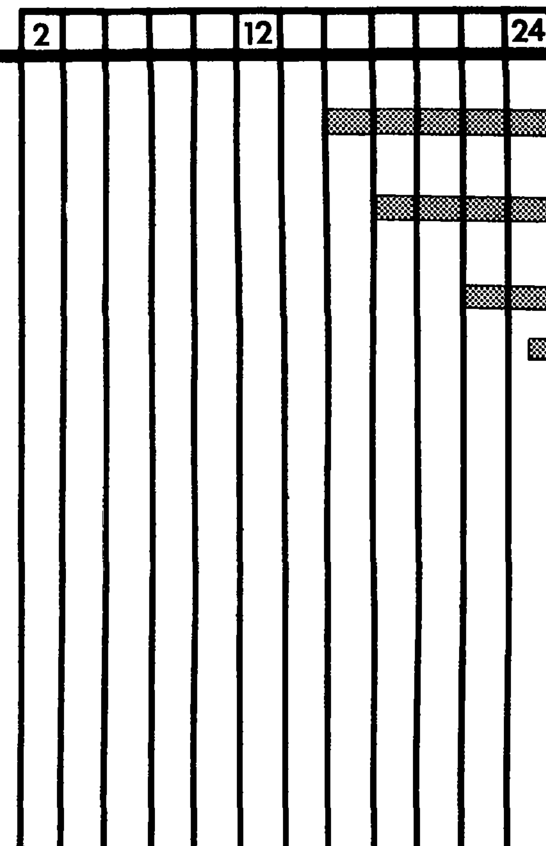
WORK STEPS	CALENDAR MONTHS (2 … 12 … 24)	PERCENT EFFORT
1. Review current status of performance evaluation in FAA - (NAFEC, CAMI, etc.) and related agencies.		7
2. Obtain performance requirements data on continuing basis.		5
3. Establish priority schedule for positions/options for initial inclusion in project.		3
4. Design techniques for normalizing distribution oı supervisors ratings.		4
5. Promulgate procedures from (4) with instructions and procedure for monitoring.		2
6. Develop experimental measures (paper and pencil and part-task) for priority positions/options.		24
7. Pretest and validate experimental measures on samples of controllers.		15
8. Refine and streamline procedures for field use of most useful measures.		8
9. Install measuring instruments and techniques in all facilities.		17

(Continued)

Research Task 002 (Continued)

Title: Develop means for better evaluation of proficiency

CALENDAR MONTHS

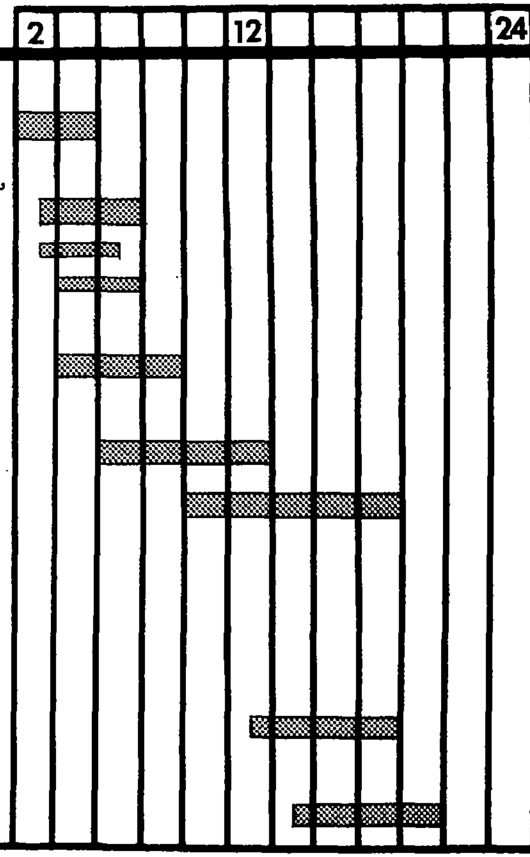


WORK STEPS	PERCENT EFFORT
10. Establish system for continual updating and improvement of measures and techniques.	5
11. Design and document methodology for development of measures for remaining positions.	5
12. Develop recommendations for improving state of the art in performance measurement in FAA setting.	4
13. Deliver reports, materials and documentation.	1

Research Task 003

Title: Studies of skill retention and degradation

CALENDAR MONTHS

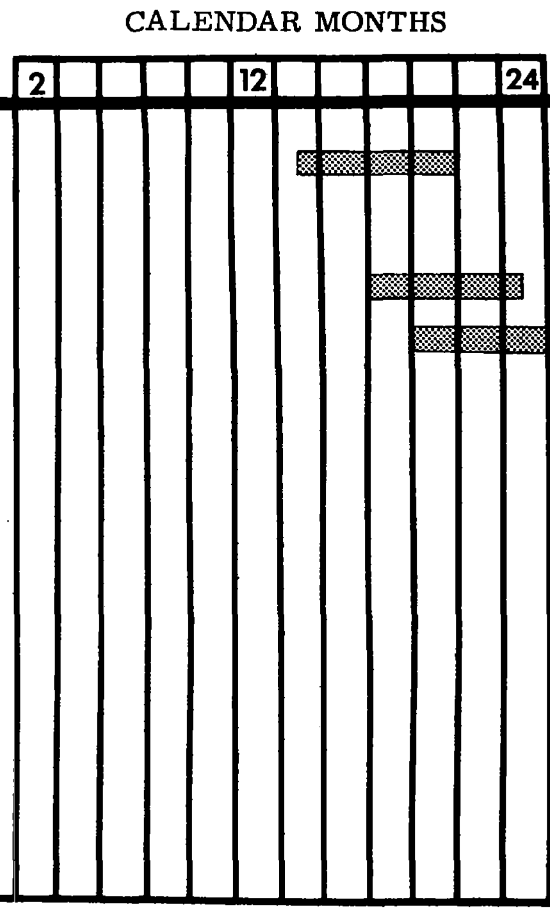


WORK STEPS	PERCENT EFFORT
1. Determine skill requirements (coordinate with Task 001).	14
2. Analyze requirements for criticality, frequency of use, and probability of decay through lack of practice. a. Review literature b. Obtain controller judgments	8
3. Select list of skills which are critical, subject to long periods of nonuse, and subject to decay.	4
4. Develop precise measures of performance on these skills.	14
5. Measure skill level of controllers at: a. Time of qualification as controllers b. Three months c. Six months d. Twelve months	16
6. Analyze data to identify those skills which degrade over time.	8
7. Develop proficiency maintenance training program to apply to these skills.	8

(Continued)

Research Task 003 (Continued)

Title: Studies of skill retention and degradation

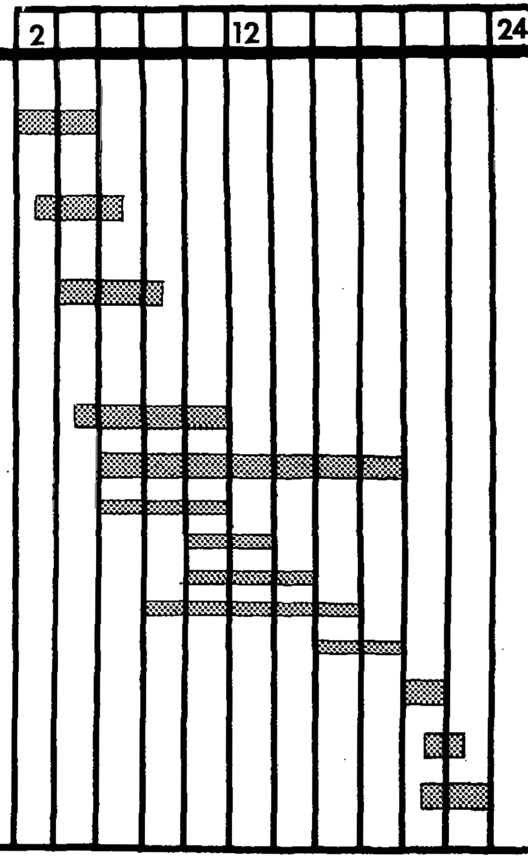


WORK STEPS	PERCENT EFFORT
8. Develop specific exercises for simulator or part task trainers to exercise these skills.	14
9. Develop recommendations for improved simulator and part-task training for such proficiency maintenance.	8
10. Prepare and submit reports.	6

Research Task 004

Title: *Development of techniques for projecting manpower requirements*

CALENDAR MONTHS



WORK STEPS	PERCENT EFFORT
1. Establish formal means for obtaining system design information.	5
2. Determine knowledge and skill requirements for projected systems (coordinate with Task 001).	8
3. Establish differential knowledge/skill requirements for various positions in system.	2
4. Determine critical parameters, e.g., selection ratio, attrition in training and over time on the job, long term effects of high stress, etc.	2
5. Construct model of manpower system.	57
a. System specifications	(5)
b. Program specifications	(8)
c. Assignment of exponent values to parameters	(5)
d. Complete programming	(31)
e. Debug and test programs	(8)
6. Operate model using 1955 - 1970 data as system test.	8
7. Review outcomes of system test for required changes.	2
8. Revise model based on review.	5

(Continued)

Research Task 004 (Continued)

Title: Development of techniques for projecting manpower requirements

WORK STEPS	CALENDAR MONTHS 2					12						24	PERCENT EFFORT
9. Construct procedure for iterative update and refinement of model based on feedback.									▒	▒	▒	▒	10
10. Begin using model for establishing recruiting quotas, etc.												▒	1

Research Task 005

Title: Development of procedures for cross training, between positions/options

WORK STEPS	CALENDAR MONTHS (1 – 6 – 12)	PERCENT EFFORT
1. Determine in detail the knowledge and skill requirements of each position in each option (coordinate with Task 001).		4
2. Establish hierarchy of requirements across positions/options.		3
3. Analyze all positions for common elements regarding knowledge/skill requirements. a. Obtain judgments from controllers b. Consult literature on transfer of training		10
4. Select a few positions for which shortages are projected, skill requirements are similar, and cross training appears feasible.		4
5. Establish experimental cross training facility.		12
6. Develop precise performance measures of knowledge and skills for selected positions (coordinate with Task 002).		20
7. Develop paradigms for cross training in common elements.		6

(Continued)

Research Task 005 (Continued)

Title: Development of procedures for cross training, between positions/options

WORK STEPS	CALENDAR MONTHS 1	2	3	4	5	6	7	8	9	10	11	12	PERCENT EFFORT
8. Conduct cross training in selected positions.						X	X	X	X	X	X		25
9. Obtain very detailed data concerning changes in performance as a result of training.								X	X	X	X		6
10. Employ cross trained personnel in new positions in facilities on experimental basis.											X	X	1
11. Follow experimental trainees with measures of job performance.											X	X	1
12. Feed back data to experimental facility.									X	X	X	X	1
13. Refine procedures into practical techniques for onsite cross training.										X	X	X	1
14. Prepare reports for future use.									X	X	X	X	6

Research Task 006

Title: Studies of man-computer interaction

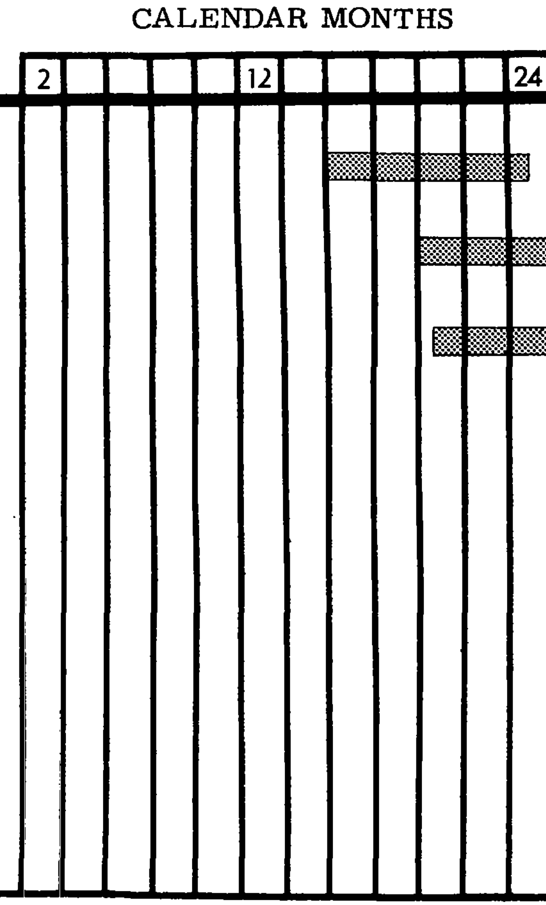
WORK STEPS	CALENDAR MONTHS (2 ... 12 ... 24)	PERCENT EFFORT
1. Establish facility for continuing studies of optimization of humans and computers: a. General purpose digital computer b. Capability for simulation of ATC environment c. Sophisticated technical staff d. Experienced controllers		16
2. Define characteristics of future ATC systems to serve as models for studies.		10
3. Specify decision roles of operators in future systems.		10
4. Construct models of man-computer interaction for testing limits of allocation of function.		6
5. Obtain empirical data using controllers in simulated ATC environment.		16
6. Play empirical data in fast time against changes in parameters, e. g., density, message format, data-link, etc.		10
7. Analyze data for conflictions, delays, aircraft handled, a/c flight time deviations, control instructions required, communications time, etc.		10

(Continued)

Research Task 006 (Continued)

Title: Studies of man-computer interaction

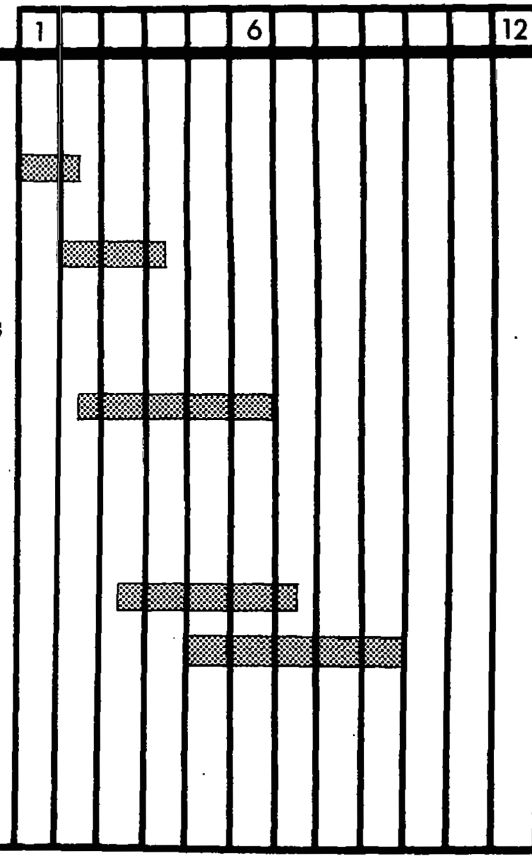
WORK STEPS	PERCENT EFFORT
8. Replay models based on varying allocations of function to man and computer.	10
9. Feed data from analyses to equipment and software designers for optimization of new designs.	6
10. Replicate analyses with new design parameters and projections as they become available.	6



Research Task 007

Title: Studies of operator load in information processing tasks

CALENDAR MONTHS



WORK STEPS	PERCENT EFFORT
1. Determine requirements of ATC positions for information processing by controllers (coordinate with Task 001).	8
2. Develop simulations of information processing tasks which are: a. Representative of variety of control systems b. Controllable and variable re: load on controllers c. Measurable by objective means	16
3. Develop measures (coordinate with Task 002). a. Sensitive to work load changes b. Measurable in quantitative terms c. Related to "status" of controller	16
4. Construct part-task simulation of information processing tasks.	16
5. Conduct experiments using above tasks varying: a. Message density b. Length of work session	24

(Continued)

Research Task 007 (Continued)

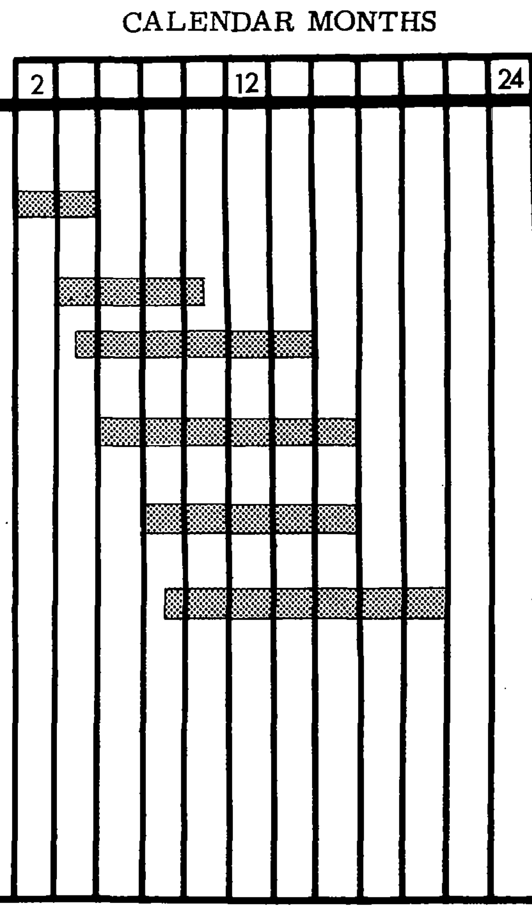
Title: Studies of operator load in information processing tasks

WORK STEPS	1					6						12	PERCENT EFFORT
6. Analyze data for effects of work load on: a. Task-specific measures, e.g., transmissions handled, error rates, decision quality, time to respond, etc. b. Perceptual-motor measures, e.g., reaction time, arm-hand steadiness, spatial orientation, perceptual speed, etc. c. Subjective measures, e.g., self estimates of stress and fatigue, performance level, symptoms, etc.							X	X	X	X	X		12
7. Prepare recommendations for evaluation of equipment design, work load distribution, situational variables, etc.											X	X	8

Research Task 008

Title: Studies of improved techniques for simulation training

WORK STEPS	PERCENT EFFORT
1. Analyze skill requirements (coordinate with Task 001) to identify those appropriate for training by simulation.	8
2. Select those skills which are critical and for which simulation training is highly relevant.	3
3. Develop scenarios for training.	13
4. Construct software packages for generation of simulation to replicate scenarios.	31
5. Develop highly specific performance measures of critical variables.	13
6. Conduct series of experiments using controllers as subject to study: a. Degree of fidelity of simulation required b. Effects of massed versus distributed practice c. Sequencing of training d. Retention factors for differential skills (coordinate with Task 003)	16



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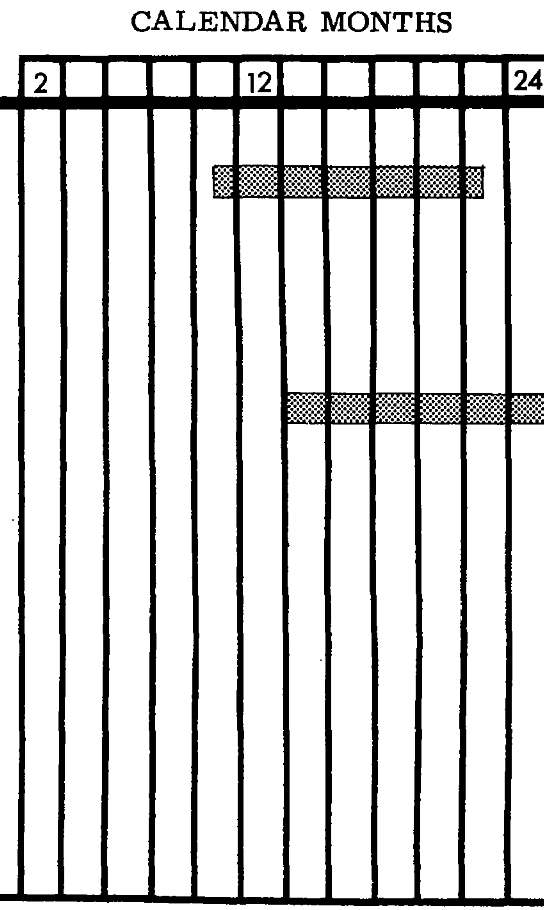
Research Task 008 (Continued)

Title: Studies of improved techniques for simulation training



WORK STEPS	PERCENT EFFORT
7. Develop techniques for data analysis which will pro-feedback to: a. Simulator design b. Software development c. Training, planning and scheduling d. Systems and procedures design	8
8. Prepare series of reports and develop dissemination system for distribution of such reports and data.	8

Research Task 009

Title: Development of improved training techniques

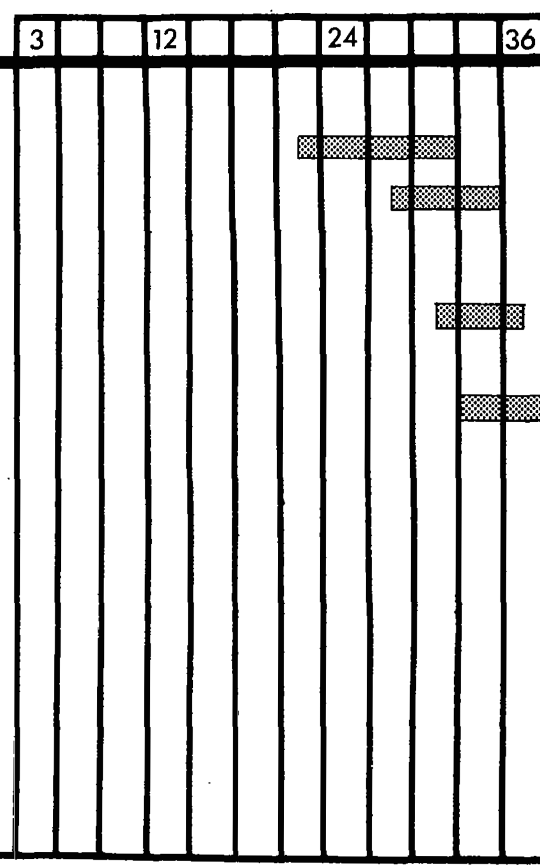
WORK STEPS	CALENDAR MONTHS (3 … 12 … 24 … 36)	PERCENT EFFORT
1. Establish experimental training facility (off-line from normal activities at FAA Academy and operating facilities)		17
2. Review knowledge and skill requirements for all positions/options.		7
3. Select a small number of critical requirements for intensive study.		4
4. Evaluate relative effectiveness of: a. Conventional techniques b. Self-paced programmed instruction c. Computer managed self-instruction d. Computer administered instruction		4
5. Develop sensitive measures of outcomes of training.		8
6. Conduct preliminary runs on small samples to pre-test and refine curriculum and training techniques.		7
7. Analyze and redesign all courses to optimum configuration based on results of preliminary runs.		13

(Continued)

Research Task 009 (Continued)

Title: Development of improved training techniques

WORK STEPS	CALENDAR MONTHS	PERCENT EFFORT
8. Administer standard content to random samples of trainees (new and advanced) using each method.		17
9. Analyze outcomes of training in all methods.		7
10. Prepare recommendations for training based on data, detailing the preferred method for each type of content.		7
11. Prepare detailed procedures manuals for conduct of training by each method.		9



Research Task 010

Title: Studies of shift scheduling and work-rest cycles

WORK STEPS	CALENDAR MONTHS 1	2	3	4	5	6	7	8	9	10	11	12	PERCENT EFFORT
1. Evaluate and select series of critical performance tasks.	■	■											6
2. Identify and select representative sample of high and low traffic density facilities.	■	■											4
3. Identify battery of measures for assessing performance decrement.		■	■	■									6
4. Pretest measures in one set of high and low density facilities.				■	■								12
5. Determine optimal battery of measures for assessing performance decrement on basis of pretest data.						■	■	■					6
6. Collect proficiency data from controller sample operating in selected facilities under representative shift scheduling and work-rest cycle parameters: a. Task proficiency b. Psychomotor performance c. Physiological data d. Subjective measures of fatigue and stress								■	■	■			30

(Continued)

D1—SEQUENCE FIX POSTING

a b c d e f g h i j A. Determine the altitude and time presented on the strip.

a b c d e f g h i j B. Insert the strip in a holder and sequence on the flight progress board according to altitude levels, in the following manner:
1. Lowest altitude on the bottom.
2. Chronologically if two aircraft are at the same altitude level.
3. Sequence as to destination when more than one airport is involved.

D2—REVIEW FLIGHT DATA FOR ACCURACY AND PREFERENTIAL ROUTING

a b c d e f g h i j A. Check the flight progress strip for:
1. Correct format.
2. Accuracy.
3. Completness.

a b c d e f g h i j B. Check routings for:
1. Preferential.
2. Standard inbound.
3. Standard outbound.
4. Correct clearance limits.
5. Correct altitudes.
6. Compatibility with the aircraft navigational equipment.

a b c d e f g h i j C. Check for release point time.

D3—REVIEW WEATHER AND NOTAMS

a b c d e f g h i j A. Keep current on weather information and NOTAMS concerning the terminal area.

a b c d e f g h i j B. Determine what effect weather/NOTAMS will have on the control of air traffic.

D3—REVIEW WEATHER AND NOTAMS--Cont'd.

a b c d e f g h i j C. Anticipate possible alternate courses of action by pilots

D4—RECEIVE AND POST FLIGHT PROGRESS REPORTS

a b c d e f g h i j A. Receive flight progress information
1. Via radio
2. Via radar
3. From center
4. From FSS
5. From other towers

a b c d e f g h i j B. Determine on which strip the report should be recorded.

a b c d e f g h i j C. Post and correct the strip.

a b c d e f g h i j D. Evaluate the new information.

D5—REVISE ESTIMATES

a b c d e f g h i j A. Determine that an estimate needs revision.

a b c d e f g h i j B. Determine the new estimate time by adding or subtracting the difference.

a b c d e f g h i j C. Enter the revised estimate on the flight progress strip.

a b c d e f g h i j D. When the revised estimate indicates a variation of ten minutes or more from the Center estimate, the Center shall be notified.

D6—ANALYZE TRAFFIC FOR POTENTIAL CONFLICTIONS

a b c d e f g h i j A. Determine, from the flight progress strip, the altitude/time routing of each aircraft.

a b c d e f g h i j B. Compare the altitudes/times routing with other strips, keeping in mind standard separations.

D6—ANALYZE TRAFFIC FOR POTENTIAL CONFLICTIONS--Cont'd.

a b c d e f g h i j | C. | Determine, after comparison, that standard separations exist.

a b c d e f g h i j | D. | Project the proposed aircraft movements and determine that standard separation will be maintained.

a b c d e f g h i j | E. | Develop alternate plans for aircraft movement, when applicable.

D7—MONITOR APPROACHES OF AIRCRAFT ON INSTRUMENT CLEARANCES

a b c d e f g h i j | A. | Receive reports from aircraft on approach.

a b c d e f g h i j | B. | Post information as required.

a b c d e f g h i j | C. | Evaluate the reports.

a b c d e f g h i j | D. | Determine that reports indicate the approach is normal.

a b c d e f g h i j | E. | Initiate corrective action to assure conformance with above.

D8—INITIATE AND ISSUE CLEARANCES, ADVISORIES AND OTHER CONTROL INFORMATION

a b c d e f g h i j | A. | Determine clearance/advisory pertinent to the operation.

a b c d e f g h i j | B. | Formulate the clearance/advisory/post as required.

a b c d e f g h i j | C. | Evaluate application of the clearance/advisory to the operation.

a b c d e f g h i j | D. | Determine method/time of delivery.

a b c d e f g h i j | E. | Issue clearance/advisory.

a b c d e f g h i j | F. | Receive acknowledgment as necessary.

D9—REVISE CLEARANCES

a b c d e f g h i j — A. Determine if a clearance revision is necessary.

a b c d e f g h i j — B. Formulate the clearance revision/post as required.

a b c d e f g h i j — C. Evaluate application of the clearance revision to the operation.

a b c d e f g h i j — D. Determine proper time of delivery.

a b c d e f g h i j — E. Issue clearance revision.

a b c d e f g h i j — F. Receive acknowledgment as necessary.

D10—ANALYZE AND EXPEDITE TOTAL TRAFFIC MOVEMENT

a b c d e f g h i j — A. Analyze the traffic situation.

a b c d e f g h i j — B. Assure that procedures are being followed.

a b c d e f g h i j — C. Project the traffic situation and foresee potential conflictions.

a b c d e f g h i j — D. Evaluate the control being exercised for:
1. Safety
2. Expeditious movement
3. Maximum use of airspace

a b c d e f g h i j — E. Determine a plan to be followed where potential conflictions or delays are noted.

a b c d e f g h i j — F. Coordinate traffic movement with positions of operation within the facility or other facilities, if necessary.

D11—COORDINATION WITHIN THE FACILITY

a b c d e f g h i j — A. Determine when coordination is required

D11—COORDINATION WITHIN THE FACILITY--
Cont'd.

a b c d e f g h i j B. Determine with whom coordination is required.
1. Arrival control coordinates with and relays information (as appropriate) to:
   a. Departure control
   b. Local control
2. Departure control coordinates with and relays information (as appropriate) to:
   a. Arrival control
   b. Local control
   c. Ground control
   d. Flight data
   e. Clearance delivery
3. Local control coordinates with and relays information (as appropriate) to:
   a. Arrival control
   b. Departure control
   c. Ground control
   d. Flight data
4. Ground control coordinates with and relays information (as appropriate) to:
   a. Flight data
   b. Local control
   c. Departure control
   d. Clearance delivery
5. Crew chief coordinates intra-facility control functions

a b c d e f g h i j C. Perform the coordination:
1. Inform other positions what is needed or what is being done.
2. Arrive at an agreement on a course of action or obtain an acknowledgment.

D12—COORDINATE WITH OUTSIDE FACILITIES

a b c d e f g h i j A. Determine when coordination is required.

a b c d e f g h i j B. Determine with whom coordination should be affected.

D 12—COORDINATE WITH OUTSIDE FACILITIES--Cont'd.

a b c d e f g h i j C. Coordinate:
1. IFR arrivals
2. IFR departures
3. Other operations in the area that are traffic factors for adjacent airports
4. Revise estimates
5. EAC's
6. Flow control times or procedures
7. Altitude vacated or altitude requested
8. Field conditions
9. Others

D13—PROVIDE FLIGHT ASSISTANCE SERVICE

a b c d e f g h i j A. Determine when flight assistance service is needed.

a b c d e f g h i j B. Determine the service pertinent to the operation.

a b c d e f g h i j C. Acquire the necessary information.

a b c d e f g h i j D. Formulate the information/advice suggestion.

a b c d e f g h i j E. Evaluate application of the service to the operation.

a b c d e f g h i j F. Issue the information/advice suggestion.

a b c d e f g h i j G. Receive acknowledgment as necessary.

D14—RECEIVE, INTERPRET AND DISSEMINATE PILOT WEATHER REPORTS

a b c d e f g h i j A. Receive in-flight weather reports from aircraft.

a b c d e f g h i j B. Acknowledge and record the information.

a b c d e f g h i j C. Analyze the reports.

a b c d e f g h i j D. Disseminate the report.

a b c d e f g h i j E. Determine what flight advisories should be issued as a result of this information.

D15—OPERATE DF EQUIPMENT

a b c d e f g h i j	A.	Turn on the equipment.
a b c d e f g h i j	B.	Determine the frequency to be used.
a b c d e f g h i j	C.	Select the frequency.
a b c d e f g h i j	D.	Adjust the equipment controls.
a b c d e f g h i j	E.	Test the equipment: 1. By receiving a transmitted signal from a known source. 2. By comparing the bearing indicated witn a predetermined known bearing.
a b c d e f g h i j	F.	Re-adjust equipment as necessary.

APPENDIX B

Rankings of Controller Activities in Terms of Difficulty, Restrictiveness, and Stressfulness

Ranking of En Route Air Traffic Controller Activities for the Flight Data/Interphone Position in Terms of Difficulty

	Activities	Rank
1.	Issue Clearances and Advisories to Aircraft	19.0
2.	Coordinate Traffic with Adjacent Sectors or Facilities	21.0
3.	Conduct On-the-Job Training for Entrance Grade Personnel	7.5
4.	Relay Estimates and Control Data to Adjacent Sectors or Facilities	5.5
5.	Evaluate Performance of Entrance Grade Personnel	17.0
6.	Transmit Flight Plans and Estimates	20.0
7.	Relay Revisions to Adjacent Sectors or Facilities	18.0
8.	Receive and Post Flight Progress Reports	7.5
9.	Interpret and Disseminate Teletype Flight Plan Messages	13.0
10.	Prepare Required Fix Postings (Manually)	13.0
11.	Copy and Interpret Flight Plan Information	13.0
12.	Interpret and Post Weather Information and NOTAMS	9.0
13.	Revise Estimates	13.0
14.	Encode and Decode Teletype Messages	13.0
15.	Review Flight Data Prepared by the "F" man	5.5
16.	Prepare Required Fix Postings (Automation)	13.0
17.	Sequence Flight Progress Strips	2.0
18.	Operate Interphone System	1.0
19.	Distribute Flight Progress Strips	3.0
20.	Mechanical Operation of the Headset	13.0
21.	Load Strip Holders	4.0

Ranking of En Route Air Traffic Controller Activities for the Flight Data/Interphone Position in Terms of Restrictiveness

	Activities	Rank
1.	Issue Clearances and Advisories to Aircraft	17.0
2.	Coordinate Traffic with Adjacent Sectors or Facilities	19.5
3.	Conduct On-the-Job Training for Entrance Grade Personnel	9.0
4.	Relay Estimates and Control Data to Adjacent Sectors or Facilities	12.5
5.	Evaluate Performance of Entrance Grade Personnel	16.0
6.	Transmit Flight Plans and Estimates	21.0
7.	Relay Revisions to Adjacent Sectors or Facilities	18.0
8.	Receive and Post Flight Progress Reports	12.5
9.	Interpret and Disseminate Teletype Flight Plan Messages	15.0
10.	Prepare Required Fix Postings (Manually)	9.0
11.	Copy and Interpret Flight Plan Information	19.5
12.	Interpret and Post Weather Information and NOTAMS	6.0
13.	Revise Estimates	12.5
14.	Encode and Decode Teletype Messages	5.0
15.	Review Flight Data Prepared by the "F" man	3.0
16.	Prepare Required Fix Postings (Automation)	9.0
17.	Sequence Flight Progress Strips	1.5
18.	Operate Interphone System	1.5
19.	Distribute Flight Progress Strips	4.0
20.	Mechanical Operation of the Headset	12.5
21.	Load Strip Holders	7.0

Ranking of En Route Air Traffic Controller Activities for the Flight Data/Interphone Position in Terms of Stressfulness

	Activities	Rank
1.	Issue Clearances and Advisories to Aircraft	19.0
2.	Coordinate Traffic with Adjacent Sectors or Facilities	21.0
3.	Conduct On-the-Job Training for Entrance Grade Personnel	15.0
4.	Relay Estimates and Control Data to Adjacent Sectors or Facilities	13.0
5.	Evaluate Performance of Entrance Grade Personnel	13.0
6.	Transmit Flight Plans and Estimates	20.0
7.	Relay Revisions to Adjacent Sectors or Facilities	18.0
8.	Receive and Post Flight Progress Reports	10.5
9.	Interpret and Disseminate Teletype Flight Plan Messages	13.5
10.	Prepare Required Fix Postings (Manually)	10.5
11.	Copy and Interpret Flight Plan Information	17.0
12.	Interpret and Post Weather Information and NOTAMS	7.5
13.	Revise Estimates	7.5
14.	Encode and Decode Teletype Messages	5.0
15.	Review Flight Data Prepared by the "F" man	3.0
16.	Prepare Required Fix Postings (Automation)	7.5
17.	Sequence Flight Progress Strips	2.0
18.	Operate Interphone System	1.0
19.	Distribute Flight Progress Strips	4.0
20.	Mechanical Operation of the Headset	16.0
21.	Load Strip Holders	7.5

Ranking of En Route Air Traffic Controller Activities for the Nonradar Control Position in Terms of Difficulty

	Activities	Rank
1.	Initiate and Issue Clearances, Advisories, and Other Control Information to Departing En Route and Arriving Aircraft in Accordance with 7110.9 Manual	10.0
2.	Analyze Traffic Picture for Potential Confliction	2.0
3.	Initiate Emergency Procedures and/or Search and Rescue Action	1.0
4.	Administer On-the-Job Training for Developmental Controller	6.5
5.	Revise Clearances	6.5
6.	Forward Control Information	10.0
7.	Implementation of SCATANA Procedures	15.0
8.	Relay Revision to Adjacent Sector or Facility	16.0
9.	Initiate or Provide Flight Assistance Service	10.0
10.	Operate the AMIS Position (Where Staffed)	4.0
11.	Review Weather Information and NOTAMs for Traffic Control Purposes	10.0
12.	Review Flight Progress Strips for Accuracy	14.0
13.	Assign and Supervise Duties of the A-Position	10.0
14.	Receive and Post Flight Progress Reports	13.0
15.	Prepare Required Reports and Maintain Sector Logs	5.0
16.	Operate Radio Equipment	3.0

Ranking of En Route Air Traffic Controller Activities for the Nonradar Control Position in Terms of Restrictiveness

	Activities	Rank
1.	Initiate and Issue Clearances, Advisories, and Other Control Information to Departing En Route and Arriving Aircraft in Accordance with 7110.9 Manual	15.0
2.	Analyze Traffic Picture for Potential Confliction	2.0
3.	Initiate Emergency Procedures and/or Search and Rescue Action	1.0
4.	Administer On-the-Job Training for Developmental Controller	5.5
5.	Revise Clearances	5.5
6.	Forward Control Information	9.0
7.	Implementation of SCATANA Procedures	14.0
8.	Relay Revision to Adjacent Sector or Facility	16.0
9.	Initiate or Provide Flight Assistance Service	11.5
10.	Operate the AMIS Position (Where Staffed)	3.0
11.	Review Weather Information and NOTAMs for Traffic Control Purposes	9.0
12.	Review Flight Progress Strips for Accuracy	13.0
13.	Assign and Supervise Duties of the A-Position	9.0
14.	Receive and Post Flight Progress Reports	11.5
15.	Prepare Required Reports and Maintain Sector Logs	7.0
16.	Operate Radio Equipment	4.0

Ranking of En Route Air Traffic Controller Activities for the Nonradar Control Position in Terms of Stressfulness

	Activities	Rank
1.	Initiate and Issue Clearances, Advisories, and Other Control Information to Departing En Route and Arriving Aircraft in Accordance with 7110.9 Manual	11.5
2.	Analyze Traffic Picture for Potential Confliction	4.0
3.	Initiate Emergency Procedures and/or Search and Rescue Action	1.0
4.	Administer On-the-Job Training for Developmental Controller	5.0
5.	Revise Clearances	6.5
6.	Forward Control Information	8.0
7.	Implementation of SCATANA Procedures	11.5
8.	Relay Revision to Adjacent Sector of Facility	16.0
9.	Initiate or Provide Flight Assistance Service	13.5
10.	Operate the AMIS Position (Where Staffed)	2.0
11.	Review Weather Information and NOTAMs for Traffic Control Purposes	9.5
12.	Review Flight Progress Strips for Accuracy	13.5
13.	Assign and Supervise Duties of the A-Position	9.5
14.	Receive and Post Flight Progress Reports	15.0
15.	Prepare Required Reports and Maintain Sector Logs	6.5
16.	Operate Radio Equipment	3.0

Ranking of En Route Air Traffic Controller Activities for the Radar Control Position in Terms of Difficulty

	Activities	Rank
1.	Operate Radar Position	5.0
2.	Operate Radar Handoff Position	3.0
3.	Administer On-the-Job Training for Developmental Control Personnel	1.0
4.	Operate Coordinator Position	2.0
5.	Provide Traffic Advisories to VFR Aircraft upon Requests	4.0
6.	Read and Interpret Radar Scope Display	8.0
7.	Align and Adjust Radar Equipment	6.5
8.	Prepare Required Reports and Maintain Sector Logs	6.5

Ranking of En Route Air Traffic Controller Activities for the Radar Control Position in Terms of Restrictiveness

	Activities	Rank
1.	Operate Radar Position	7.0
2.	Operate Radar Handoff Position	6.0
3.	Administer On-the-Job Training for Development Control Personnel	1.0
4.	Operate Coordinator Position	2.5
5.	Provide Traffic Advisories to VFR Aircraft upon Requests	5.0
6.	Read and Interpret Radar Scope Display	8.0
7.	Align and Adjust Radar Equipment	4.0
8.	Prepare Required Reports and Maintain Sector Logs	2.5

Ranking of En Route Air Traffic Controller Activities for the Radar Control Position in Terms of Stressfulness

	Activities	Rank
1.	Operate Radar Position	8.0
2.	Operate Radar Handoff Position	6.5
3.	Administer On-the-Job Training for Developmental Control Personnel	1.0
4.	Operate Coordinator Position	3.0
5.	Provide Traffic Advisories to VFR Aircraft upon Requests	5.0
6.	Read and Interpret Radar Scope Display	6.5
7.	Align and Adjust Radar Equipment	3.0
8.	Prepare Required Reports and Maintain Sector Logs	3.0

Ranking of Terminal Air Traffic Controller Activities
for the Flight Data Position in Terms of Difficulty

	Activities	Rank
1.	Copy, Interpret and Relay Flight Data	10.5
2.	Make and Report Visibility Observations	1.0
3.	Operate Flight Data Entry and Printout Equipment	5.0
4.	Alert Emergency Equipment	2.0
5.	Set Up Frequencies on Standby Radio Equipment	9.0
6.	Prepare and Distribute Flight Progress Strips	12.0
7.	Change Tape Reels and/or Recorder Belts	5.0
8.	Receive, Relay and Post NOTAM Information	7.0
9.	Operate Interphone Systems	8.0
10.	Receive and Relay Weather Information	5.0
11.	Operate Telautograph/Electrowriter	10.5
12.	Collect, Tabulate and Store Daily Records	3.0

Ranking of Terminal Air Traffic Controller Activities
for the Flight Data Position in Terms of Restrictiveness

	Activities	Rank
1.	Copy, Interpret and Relay Flight Data	8.5
2.	Make and Report Visibility Observations	1.0
3.	Operate Flight Data Entry and Printout Equipment	11.0
4.	Alert Emergency Equipment	5.0
5.	Set Up Frequencies on Standby Radio Equipment	6.0
6.	Prepare and Distribute Flight Progress Strips	8.5
7.	Change Tape Reels and/or Recorder Belts	8.5
8.	Receive, Relay and Post NOTAM Information	3.5
9.	Operate Interphone Systems	8.5
10.	Receive and Relay Weather Information	3.5
11.	Operate Telautograph/Electrowriter	12.0
12.	Collect, Tabulate and Store Daily Records	2.0

Ranking of Terminal Air Traffic Controller Activities
for the Flight Data Position in Terms of Stressfulness

	Activities	Rank
1.	Copy, Interpret and Relay Flight Data	4.0
2.	Make and Report Visibility Observations	1.0
3.	Operate Flight Data Entry and Printout Equipment	3.0
4.	Alert Emergency Equipment	5.5
5.	Set Up Frequencies on Standby Radio Equipment	10.0
6.	Prepare and Distribute Flight Progress Strips	8.5
7.	Change Tape Reels and/or Recorder Belts	7.0
8.	Receive, Relay and Post NOTAM Information	8.5
9.	Operate Interphone Systems	2.0
10.	Receive and Relay Weather Information	11.0
11.	Operate Telautograph/Electrowriter	12.0
12.	Collect, Tabulate and Store Daily Records	5.5

Ranking of Terminal Air Traffic Controller Activities for the Local Control Position in Terms of Difficulty

	Activities	Rank
1.	Determine and Issue Landing Sequence and Traffic Information	2.0
2.	Determine and Issue Instructions Relative to the Flight Path of an Aircraft	1.0
3.	OJT	7.5
4.	Issue Clearances or Approval for Special Operations (Low Approaches, Contact Approaches, Visual Approaches, Simulated Instrument Approaches, etc.)	5.5
5.	Issue Landing Clearances and Related Information	5.5
6.	Issue Takeoff Clearances	7.5
7.	Issue Control Instructions and/or Advisories to Departing Aircraft	10.0
8.	Assign Runways	4.0
9.	Instruct Pilots to Change Radio Frequencies/Radar Beacon Codes	12.0
10.	Observe and Report Weather Changes	9.0
11.	Operate Airport Light Systems and Visual Aids	11.0
12.	Monitor Navigation Aids and Operate Monitor Control Panels	3.0

Ranking of Terminal Air Traffic Controller Activities for the Local Control Position in Terms of Restrictiveness

	Activities	Rank
1.	Determine and Issue Landing Sequence and Traffic Information	3.0
2.	Determine and Issue Instructions Relative to the Flight Path of an Aircraft	1.0
3.	OJT	8.5
4.	Issue Clearances or Approval for Special Operations (Low Approaches, Contact Approaches, Visual Approaches, Simulated Instrument Approaches, etc.)	5.5
5.	Issue Landing Clearances and Related Information	8.5
6.	Issue Takeoff Clearances	5.5
7.	Issue Control Instructions and/or Advisories to Departing Aircraft	7.0
8.	Assign Runways	4.0
9.	Instruct Pilots to Change Radio Frequencies/Radar Beacon Codes	11.0
10.	Observe and Report Weather Changes	10.0
11.	Operate Airport Light Systems and Visual Aids	12.0
12.	Monitor Navigation Aids and Operate Monitor Control Panels	2.0

Ranking of Terminal Air Traffic Controller Activities for the Local Control Position in Terms of Stressfulness

	Activities	Rank
1.	Determine and Issue Landing Sequence and Traffic Information	2.0
2.	Determine and Issue Instructions Relative to the Flight Path of an Aircraft	1.0
3.	OJT	7.5
4.	Issue Clearances or Approval for Special Operations (Low Approaches, Contact Approaches, Visual Approaches, Simulated Instrument Approaches, etc.)	6.0
5.	Issue Landing Clearances and Related Information	5.0
6.	Issue Takeoff Clearances	7.5
7.	Issue Control Instructions and/or Advisories to Departing Aircraft	9.0
8.	Assign Runways	4.0
9.	Instruct Pilots to Change Radio Frequencies/Radar Beacon Codes	11.5
10.	Observe and Report Weather Changes	10.0
11.	Operate Airport Light Systems and Visual Aids	11.5
12.	Monitor Navigation Aids and Operate Monitor Control Panels	3.0

Ranking of Terminal Air Traffic Controller Activities for the Ground Control Position in Terms of Difficulty

	Activities	Rank
1.	Issue Taxi Clearances--Aircraft and Vehicles	2.0
2.	Monitor and Analyze Ground Traffic	9.0
3.	Initiate and Direct Emergency Action	10.5
4.	Relay or Initiate Advisories, Information or IFR Clearances to Aircraft	10.5
5.	Relay, Initiate or Coordinate Advisories and Information to Other than Aircraft	1.0
6.	Observe, Collect, Analyze and Disseminate Reports Regarding Hazards or Operational Status of Facilities	8.0
7.	Collect, Analyze and Disseminate PIREP's	6.0
8.	Operate Portable Traffic Control Light (Light Gun)	6.0
9.	Read and Interpret Console Instruments	3.0
10.	Operate Radio Equipment	6.0
11.	Guard Assigned Radio Frequencies	4.0

Ranking of Terminal Air Traffic Controller Activities for the Ground Control Position in Terms of Restrictiveness

	Activities	Rank
1.	Issue Taxi Clearances--Aircraft and Vehicles	2.0
2.	Monitor and Analyze Ground Traffic	7.0
3.	Initiate and Direct Emergency Action	10.0
4.	Relay or Initiate Advisories, Information or IFR Clearances to Aircraft	11.0
5.	Relay, Initiate or Coordinate Advisories and Information to Other than Aircraft	1.0
6.	Observe, Collect, Analyze, and Disseminate Reports Regarding Hazards or Operational Status of Facilities	9.0
7.	Collect, Analyze and Disseminate PIREP's	8.0
8.	Operate Portable Traffic Control Light (Light Gun)	6.0
9.	Read and Interpret Console Instruments	4.0
10.	Operate Radio Equipment	5.0
11.	Guard Assigned Radio Frequencies	3.0

Ranking of Terminal Air Traffic Controller Activities for the Ground Control Position in Terms of Stressfulness

	Activities	Rank
1.	Issue Taxi Clearances--Aircraft and Vehicles	3.0
2.	Monitor and Analyze Ground Traffic	6.0
3.	Initiate and Direct Emergency Action	9.5
4.	Relay or Initiate Advisories, Information or IFR Clearances to Aircraft	11.0
5.	Relay, Initiate or Coordinate Advisories and Information to Other than Aircraft	1.0
6.	Observe, Collect, Analyze and Disseminate Reports Regarding Hazards or Operational Status of Facilities	9.5
7.	Collect, Analyze and Disseminate PIREP's	7.0
8.	Operate Portable Traffic Control Light (Light Gun)	8.0
9.	Read and Interpret Console Instruments	2.0
10.	Operate Radio Equipment	5.0
11.	Guard Assigned Radio Frequencies	4.0

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Nonradar Position in Terms of Difficulty

	Activities	Rank
1.	Analyze Traffic for Potential Conflictions	15.0
2.	Initiate and Issue Clearances, Advisories and other Control Information	9.5
3.	Analyze and Expedite Total Traffic Movement	13.0
4.	Coordinate with Outside Facilities	14.0
5.	Monitor Approaches of Aircraft on Instrument Clearances	11.0
6.	Operate DF Equipment	2.0
7.	Provide Flight Assistance Service	6.0
8.	Review Flight Data for Accuracy and Preferential Routing	3.0
9.	Revise Clearances	9.5
10.	Coordinate Within the Facility	1.0
11.	Revise Estimates	7.5
12.	Receive, Interpret and Disseminate Pilot Weather Reports	4.5
13.	Review Weather and NOTAMS	7.5
14.	Receive and Post Flight Progress Reports	12.0
15.	Sequence Fix Posting	4.5

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Nonradar Position in Terms of Restrictiveness

	Activities	Rank
1.	Analyze Traffic for Potential Conflictions	15.0
2.	Initiate and Issue Clearances, Advisories and Other Control Information	8.5
3.	Analyze and Expedite Total Traffic Movement	14.0
4.	Coordinate with Outside Facilities	13.0
5.	Monitor Approaches of Aircraft on Instrument Clearances	11.0
6.	Operate DF Equipment	2.0
7.	Provide Flight Assistance Service	5.5
8.	Review Flight Data for Accuracy and Preferential Routing	1.0
9.	Revise Clearances	8.5
10.	Coordinate Within the Facility	3.0
11.	Revise Estimates	10.0
12.	Receive, Interpret and Disseminate Pilot Weather Reports	5.5
13.	Review Weather and NOTAMS	5.5
14.	Receive and Post Flight Progress Reports	11.0
15.	Sequence Fix Posting	5.5

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Nonradar Position in Terms of Stressfulness

	Activities	Rank
1.	Analyze Traffic for Potential Conflictions	15.0
2.	Initiate and Issue Clearances, Advisories and other Control Information	8.0
3.	Analyze and Expedite Total Traffic Movement	13.0
4.	Coordinate with Outside Facilities	14.0
5.	Monitor Approaches of Aircraft on Instrument Clearances	11.0
6.	Operate DF Equipment	1.5
7.	Provide Flight Assistance Service	4.5
8.	Review Flight Data for Accuracy and Preferential Routing	1.5
9.	Revise Clearances	9.0
10.	Coordinate Within the Facility	3.0
11.	Revise Estimates	10.0
12.	Receive, Interpret and Disseminate Pilot Weather Reports	4.5
13.	Review Weather and NOTAMS	6.5
14.	Receive and Post Flight Progress Reports	12.0
15.	Sequence Fix Posting	6.5

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Radar Position in Terms of Difficulty

	Activities	Rank
1.	Provide Radar Arrival Control Service	8.0
2.	Provide Radar Emergency Service	6.0
3.	Provide Radar Departure Control Service	5.0
4.	Provide Stage I, II, or III Service	1.0
5.	Read and Interpret Radar Scope Display	3.0
6.	Provide Traffic Advisories to VFR Aircraft Upon Request	2.0
7.	Align Radar Equipment	7.0
8.	Operate Radar Equipment	4.0

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Radar Position in Terms of Restrictiveness

	Activities	Rank
1.	Provide Radar Arrival Control Service	7.5
2.	Provide Radar Emergency Service	7.5
3.	Provide Radar Departure Control Service	5.5
4.	Provide Stage I, II, or III Service	1.0
5.	Read and Interpret Radar Scope Display	3.0
6.	Provide Traffic Advisories to VFR Aircraft Upon Request	2.0
7.	Align Radar Equipment	5.5
8.	Operate Radar Equipment	4.0

Ranking of Terminal Air Traffic Controller Activities for the Approach Control/Radar Position in Terms of Stressfulness

	Activities	Rank
1.	Provide Radar Arrival Control Service	7.0
2.	Provide Radar Emergency Service	8.0
3.	Provide Radar Departure Control Service	5.0
4.	Provide Stage I, II, or III Service	1.0
5.	Read and Interpret Radar Scope Display	3.0
6.	Provide Traffic Advisories to VFR Aircraft Upon Request	2.0
7.	Align Radar Equipment	6.0
8.	Operate Radar Equipment	4.0

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