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Carroll E. Hopkins
Captain USAF

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The verification process resulted in acceptance of all variables. The tests of the hypotheses revealed that little differences exist in the importance of the scheduling factors as perceived by the groups tested. A schedule is proposed by the author that will provide the best mission support. This schedule was arrived at independently yet is similar to that schedule most desired by the flight controllers.

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ANALYSIS OF THE FACTORS GOVERNING
THE SCHEDULING OF FLIGHT CONTROLLERS
IN SUPPORT OF LONG DURATION
MANNED SPACEFLIGHT MISSIONS

THESIS

Carroll E. Hopkins
Captain USAF

GSM/SM/71-6

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ANALYSIS OF THE FACTORS GOVERNING THE SCHEDULING OF FLIGHT CONTROLLERS IN SUPPORT OF LONG DURATION MANNED SPACEFLIGHT MISSIONS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
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in Partial Fulfillment of the
Requirements for the Degree of

Master of Science

by

Carroll E. Hopkins, B.S.M.E.
Captain USAF

Graduate Systems Management
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Carroll E. Hopkins

Contents

Contents

Contents

List of Figures

List of Tables

Abstract

This study has two main purposes: to identify the factors, or variables, that govern the scheduling of flight controllers in support of long duration manned spaceflight; and to develop a scheduling system that best satisfies the needs of these personnel and the activity they support.

A review of related research yielded a tentative list of nine scheduling variables. They are: fatigue, flexibility of schedules, length of shift, morale, office work, overtime, personnel qualifications, shift cycle, and training. A questionnaire was developed to verify these variables, to measure the relative importance of them, and to determine which of five proposed schedules were perceived by the flight controllers as being the best. Hypotheses were tested to determine if the flight controllers and their supervisors perceive the importance of these scheduling variables differently. Other organizations performing similar tasks were studied to provide a data base of scheduling systems in use.

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ANALYSIS OF THE FACTORS GOVERNING THE SCHEDULING OF FLIGHT CONTROLLERS IN SUPPORT OF LONG DURATION MANNED SPACEFLIGHT MISSIONS

I. The Problem and Its Environment

Introduction

This is a study of the scheduling of ground support personnel in the manned spaceflight environment. This support is a critical link in the success of the manned spaceflight effort. The purpose of this research is to identify those scheduling systems and the variable factors that can and/or should be considered in the scheduling of ground support personnel. The specific task is to provide information to aid in the development of a scheduling system that will best incorporate these factors for support of long duration spaceflight missions.

Definitions

The following are definitions of certain terms, the meaning of which are not definitively stated elsewhere in this thesis:

Flight controller is an engineer, or technician, who monitors the condition of the spacecraft via telemetry data throughout the spaceflight. He is a planner, implementer, systems expert, decision maker and console operator. (Ref 50:83).

FAA is an acronym for Federal Aviation Agency and for the purpose of this paper is used to indicate the air traffic controllers employed by this organization.

SCF is an acronym for Satellite Control Facility. The Satellite Control Facility is operated by the Air Force in support of unmanned Air Force space operations.

MEOL is an acronym to be used to designate the Manned Earth Orbiting Laboratory type space programs for the purpose of this research.

RAPCON is an acronym used to designate the FAA's radar approach control facility.

PAR is an acronym for Precision Approach Radar.

Diurnal Rhythm (Circadian rhythm or day/night metabolic clock) is the physiological and psychological rhythm of the human body that closely approximates the daily sleep-wakefulness cycle. (Ref 2:265).

Renal Rhythm is the physiological rhythm that controls the body functions, in particular the waste elimination functions. (Ref 9:183).

Alert Duty is that duty that combat crews are assigned which requires them to be ready to go to war at any moment. This is usually 24 hours a day duty for one or more days.

Real Time is the time in which reporting on events or recording of events is simultaneous with the occurrence of events. (Ref 1:231).

Factors and Variables are used interchangably.

Statement of the Problem

The problem treated in this research is:

1. The identification of the factors that govern the scheduling of flight controller support for long duration manned spaceflight.

2. The identification and selection of a schedule that best satisfies the needs of flight controller scheduling.

Background

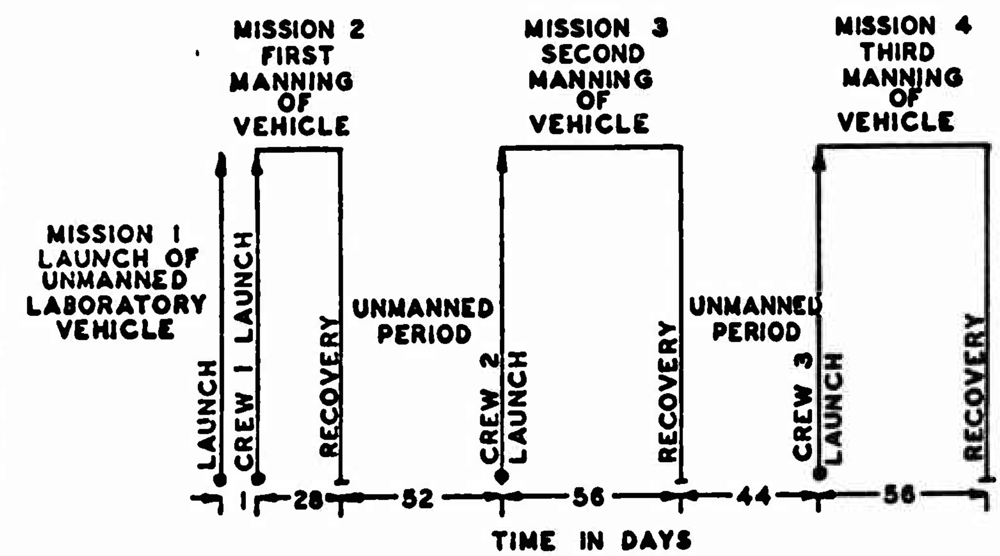
In the mid 1973 time period, the first of a series of long duration manned earth orbital laboratory (MEOL) space missions will be initiated. During each mission a multitude of highly complex systems and experiments must be monitored by ground support personnel. This support is supplied by functional areas within the National Aeronautics and Space Administration's Flight Operations Directorate (FOD). Each of the supporting areas is required to provide highly trained and skilled flight controllers in varing numbers to meet the demands of the mission.

As of this point in time, 1971, the scheduling of flight controller support is a manual effort. The personnel required to support a mission are drawn from nine basic areas or branches. These supporting areas for

Apollo missions are Flight Operations, Command Module Systems, Lunar Module Systems, Flight Dynamics, Communications, Aeromedical, Booster, Experiments, and Retrofire. (Ref 50:85). Of these areas all but Aeromedical and Communication personnel come from the Flight Control Division (FCD). For a more detailed discussion of mission support activities see Appendix A. The supervisor in each area is responsible for the scheduling of his personnel. The recommendations for mission manning are forwarded to a division level mission planner who integrates the branch recommendations into an over all total mission manning schedule. Due to manpower constraints it is not unusual that such a schedule will require all personnel from any single area for mission support. The requirements for total support by a branch brings the day to day functional activities to a halt. Due to the relatively short duration of the missions this is usually of little consequence. The Apollo missions to date have varied from approximately seven days for Apollo XIII to thirteen days for Apollo XV. The first lunar missions were approximately ten days in length. (Ref 51:6).

The entrance of the MEOL into spaceflight will bring missions of greater than four weeks in length. The MEOL missions are designed to expand the knowledge of manned earth orbital operations and to accomplish carefully selected scientific, technological, and medical investigations. (Ref 51:1). The Skylab Program (the first of the

MEOL type missions) will begin in late 1972, with four basic objectives: perform scientific investigations, accomplish scientific applications, determine the effects on men of long duration exposure to orbital conditions, and aid in the economical and effective development of future space programs. For a more detailed discussion see Appendix B. The current expected manned mission will be from 28 to 56 days in length, and future manned missions could be of much longer duration. Between each mission there will be periods, approximately 45 days in length, in which the orbiting laboratory vehicle will not be manned. Figure 1 is a graphic description of the typical MEOL mission profile.



TYPICAL MANNED EARTH ORBITING LABORATORY MISSION PROFILE

FIGURE 1

The periods of time that the laboratory is unmanned requires a minimum of ground support. During this period some experiments may be conducted via remote control and the status of the vehicle must be observed. Degredation of the vehicle or scientific equipment could preclude initiation of the follow-on manned mission.

The effort required by the flight controllers during the period in which the laboratory is manned will be maximum. All systems must be closely monitored for crew safety and operating condition. The activation of experiments will also require close co-ordination between the vehicle and ground. This will induce a very heavy work load on the flight controllers. Since the experiments are conducted at different times a variation in this work load will result. To support the activities of the missions will require each branch to carefully utilize its manpower resources.

The long duration of each MEOL mission complicates the utilization of qualified personnel. The mission must be supported, as a prime objective, and the functional administrative work must also be accomplished. During the time in which the current mission is being flown, future missions must be planned and normal day to day activities must be carried on.

The support of the activities of long duration manned spaceflight requires careful utilization of available manpower resources. To support the mission activity and administrative functions the flight controllers must be scheduled such that maximum support is available. This scheduling is constrained by many variables. These variables and their interrelationships must be identified and understood before maximum utilization of the flight controllers can be attained.

Specific Objectives

The specific objectives of this research are:

1. To assemble current information and facts concerning scheduling systems.

2. To study available related scheduling systems and identify and analyze the variable factors that govern the schedule.

3. To determine what the critical factors are that should be considered in scheduling a flight controller.

4. To determine subjectively what the best flight controller shift schedule should be.

Significance of the Problem

The flight controller performs a variety of functions when supporting a manned spaceflight mission. As Harold Miller, former Chief of Flight Control Division Simulations Branch, stated,

> "The flight controller is a planner, implementer, systems expert, operator, and decision maker. (He) in conjunction with the crew, must determine the flight plan that is to be followed, and it must account for items such as experiments, sleep cycles,...

> critical activities such as orbital manuvers and so forth. During the mission he must listen to information from different sources and react to these inputs instantaneously. Pressure is ever present with a flight controller while he is doing his job." (Ref 50:84).

In the performance of his many and varied tasks he is under continual stress and pressure. He must continually be alert and aware not only of what is happening at the present moment, but also what is to come, as well as what has gone on before. The success of the mission as well as crew safety is in the hands of the flight controller. To maximize the probability of mission success, steps must be taken to insure the maximum efficiency of the flight controller.

The efficiency of the individual is dependent on his work schedule. Length of shift, shift rotation and rest between shifts are variables related to the schedule and to the alertness and efficiency of the individual. These few factors, however, are not the only variables connected with development of a schedule. This research identifies and analyses the most important factors that should be considered when developing a schedule for flight controller mission support. The knowledge of these factors then allows the development of a scheduling system and shift rotation pattern which maximizes flight controller efficiency and consequently mission success.

Scope and Limitations

The nature of manned spaceflight is such that the applicability of this study is generally limited to the National Aeronautics and Space Administration, (NASA), Manned Spacecraft Center, (MSC). The findings of this research can, with slight modification, be useful for support of unmanned spaceflight efforts.

This effort is limited to the variables of scheduling of personnel from the MSC Flight Operations Directorate. Research is limited to the scheduling of only mission essential personnel. Pure functional support and administrative support personnel will not be considered. The research effort is restricted to manned spaceflight. Other projects were investigated for background information only.

Methodology

The data for this research is drawn from three sources: existing literature, interviews, and questionnaires. The literature search was conducted to identify various scheduling systems and variable factors. These factors were found to be discussed more completely in works concerning air crew scheduling, air traffic controller scheduling, and human factors. This information provided a broad base of knowledge and specific research data related to scheduling systems and factors.

The second and third sources rely on expert opinion to gain an insight into the various scheduling systems presently being used in each area investigated, FAA, air crews, etc. The interviews provided further information as to what the personnel actually do, the conditions under which they work, the variables that govern their work schedules, and information about actual scheduling systems in use.

From the literature and interviews a tentative list of factors and scheduling systems was developed. The factors appearing in three or more systems, or discussed by three or more authors, are considered as being of sufficient commonality to be judged as a tentative critical variable in the scheduling system. From this group of variables, five scheduling systems were identified that would provide adequate flight controller support. A questionnaire was developed to determine which tentative factors are critical factors and which schedule is best suited to the needs of the flight controller. The questionnaires were sent to a selected random sample of MSC flight controllers. They were asked to state which factors they considered important and to rank the schedules in order of importance. They were also asked to express their preference for the proposed schedules based on their estimate of each schedule's incorporation of the given variables and personal desires. The result was an indication of the importance of variables and an identification of a scheduling system that would best fit the needs of the flight controllers.

Assumptions

The assumptions made during the course of this research limited the scope and nature of the research. The assumptions are:

1. Those factors identified in areas outside of manned spaceflight are transferable to manned spaceflight scheduling.

2. The factors and schedules perceived by the flight controllers as being best are best for mission support and the flight control organization.

3. The number of flight controllers will not significantly increase or decrease during the course of any mission.

4. Each branch will maintain a sufficient level of qualified flight controllers to support any mission requirement regardless of the administrative work load in that branch.

Hypotheses

The following hypotheses are analyzed in this research.

1. There is no correlation between the rankings of the scheduling variables by the supervisors and flight controllers.

2. There is no correlation between the rankings of the scheduling variables by the supervisors and the civil service flight controllers.

3. There is no correlation between the rankings of the scheduling variables by the supervisors and the contractor flight controllers.

4. There is no correlation between the rankings of the scheduling variables by the civil service and the contractor flight controllers.

Plan of Presentation

Chapter II is a discussion of the data collection methodology. This chapter focuses on the formulation of the questionnaire and the manner in which data for this research was collected.

Chapter III is a review of scheduling systems and variables of schedules in use today. Its purpose is to identify the factors of scheduling personnel that other researchers have described.

Chapter IV contains the results of the data analysis process, identification of the scheduling variables, and selection of the most advantageous schedule.

Chapter V contains a summary, the conclusions, and the recommendations for further study.

II. Data Collection

This chapter reviews the manner in which data was collected for this research. The following sources will be discussed: literature, interviews, and questionnaires.

Literary Research Methods

At the initiation of this research effort, a DDC and NASA bibliography search was initiated to obtain references, completed research efforts and writings concerning the scheduling of personnel, employees, workers, etc. As a parallel effort a search of periodical literature, texts, and other writings on the subject was undertaken. This author concluded that very little has been written about employee scheduling per se. A great deal of material is available concerning the scheduling and planning of manufacturing processes. These schedules primarily involve machinery, materials, process flow, time and cost. Man is treated as being auxilary to the process and the only concern is that enough manpower, at the right skill level, will be available at the right time to achieve the desired output. This feeling is conveyed by Elwood Buffa in his discussion of scheduling systems when he states, "Therefore, while the aggregate plan has specified the quantitative change in workforce size, there still remains the implementation of this change in a way that makes the most sense." (Ref 4:575). There appears then to be a void of information about scheduling manpower.

This void is fortunately not a complete vacuum. One must look not at scheduling of employees, but at topics such as shift work, hours of work, etc. to discover information on the subject. Within such topic areas, there is a good deal of information regarding shift work, the schedules that evolve, variations in hours of work, and the effect of shift work on the employee and his environment. The majority of work done in this area has been accomplished by European researchers such as Murrell, Wayott, Merriott, de Jong, and others.

Continued pursuit of the subject matter reveals an insight into the many facets of scheduling people. The scheduling system must take into account many variable factors to achieve the desired level of productivity. Adequate knowledge and use of these factors in scheduling personnel greatly affects the efficiency, quantity, and quality of the produced product. It was in this area that the majority of literary research effort was concentrated. A detailed discussion of each factor is included in the next chapter.

Interviews

The relative lack of information available concerning the techniques of personnel scheduling led to the use of the interview to acquire knowledge of the subject. An interview, however, is simply someone's thoughts or opinions and little "fact" can be obtained in this manner. Tyrus Hillway points out that:

> "Opinion cannot have the weight of factual evidence in proving any case. On the other hand there are times when opinion may be the best evidence available. In such cases care is exercised to make sure that the opinion offered is qualified and authorative." (Ref 10:75).

Experience in scheduling of flight controllers in support of manned spaceflight is available at only one place in the United States - the Manned Spacecraft Center.

> "Often the simplest and most economical method of obtaining 'facts' is to go directly to the people who are in a position to know them and to ask for the desired information. It is reasonable to assume that people who have access to information, who are sufficiently intelligent to absorb it, and who are motivated to acquire and retain it are able, if they are willing, to provide the investigator with reports of many interesting and valuable 'facts'." (Ref 17:244).

The "facts" obtained must be evaluated in terms of credibility. Is the "fact" presented the respondent's direct observation, hearsay, or inference? The question of accurate memory is also a factor. "All of these things require caution in accepting as true the remembrance of things past." (Ref 17:245).

The relative lack of information available on the subject dictated the general form of the questions to be asked. To insure the information obtained would be comparable, a standardized interview format was used.

> "In the standardized interview or questionnaire, questions are presented with exactaly the same wording and in the same order to all respondents.

> The reason for standardization, of course, is to insure that all respondents are replying to the same question. Differences in question order can also influence the meaning and implications of a given question." (Ref 17:255).

The questions asked were open-ended. This was to enable the respondent to give a free, unlimited response so that the maximum amount of information could be obtained. The type of information desired from these interviews was:

1. What is the present scheduling system in use today? How does it work? Who has the primary responsibility for scheduling the employee? In short, learn as much about the scheduling system as possible.

2. What factors regulate the scheduling system today and what variables are perceived to be important in the future?

3. Gain an insight into the type of work the employee performs during operations support activities. Using these guidelines the interview format was developed. A copy of this format is enclosed in Appendix C.

The primary interviews were conducted at MSC on June 28, through July 3, 1971. The interviews were recorded for later analysis. The sequence of interviews included Chief of the Flight Control Division, either the branch chief or assistant branch chief in each of six branches within the division, selected branch section heads, and several division flight controllers. Time and their work load prohibited interviewing more than this number.

The information gathered at MSC was limited to the FCD organization. The experts interviewed were knowledgeable in their area of work and have had little exposure to methods of scheduling other than that presently in use in FCD. It was, therefore, advantageous to consider other organizations, who perform similar work, to obtain information on other scheduling systems in use. The criteria used to select an organization for study was as follows:

1. The workers must be required 24 hours a day, seven days a week for greater than one year.

2. The workers must perform a continuous monitoring function of dynamic data displayed on a (a) television screen, (b) radar scope, (c) event, status or caution and warning display.

3. The organization was readily accessable.

The organizations meeting such qualifications were Federal Aviation Agency (FAA) Air Traffic Control, Air Force Precision Approach Radar Control, Air Force combat crews (aircraft and missile), Air Force Satellite Control Facility, and the Air Force Air Defense Command Surveillance Group. Each of these groups was contacted and interviewed either in person or via telephone.

The FAA air traffic control group interviewed is located at Wright-Patterson Air Force Base, Ohio. This group was assumed to be typical of air traffic controller functions throughout the United States. This assumption is supported by the nature of the organization itself (federally controlled), the union rules and regulations, nature of work, and type of equipment used. The primary differences between organizations is in the personnel themselves and the size of each organization. The Deputy Chief of the RAPCON unit was interviewed using the same format that was used at MSC. The detailed results of this interview is contained in Chapter III.

Working side-by-side with the FAA air traffic controllers at Wright-Patterson AFB, are the Air Force Precision Approach Radar (PAR) controllers. These controllers perform a similar function to the FAA controllers - controlling aircraft landing at Wright-Patterson. The organization, however, is separate and distinct from the FAA organization. The PAR controllers are members of the Air Force Communications System, 2046th Communications Squadron, and are all military personnel. To maintain consistency, the same format was used in interviewing the Chief of Flight Facilities Division. The details of this organization's operations, scheduling factors, and scheduling system is contained in the following chapter.

Letters of Request for Data

A questionnaire was developed to obtain the desired information and sent to the SCF and ADC surveillance squadron. A copy of this communication is contained in Appendix D.

The questionnaire was developed based on (a) data from previous readings, (b) experience gained from previous personal interviews, and (c) a definite idea of what type of information was most usable. The questions asked were open-ended to allow the respondent to reply in depth.

> "The open ended questions are called for when the issue is complex, when the relevant dimensions are not known or when the interests of the research lies in the exploration of a process or of the individual's formulation of an issue." (Ref 17:262).

The returns, however, were not entirely satisfactory, as the respondent tended to answer in the shortest possible manner. This necessitated further telephone communications with each of the respondents to gain the desired information. The details of SCF and ADC scheduling systems are contained in the next chapter.

Questionnaire

The literature search and review of many documents, interviews and letters produced many ideas, opinions, experience, and facts. This information together with descriptions of scheduling systems and the variables affecting them was considered next. This effort resulted in a concise list of variables that generally affect the personnel being scheduled and consequently the schedule itself. A group of potential scheduling systems that fit the requirements of FCD was also identified. The next step was to determine if the identified variables actually effect the flight controller scheduling and which of the schedules was preferred.

Design of the Questionnaire. To determine the flight controller's reaction to proposed scheduling systems, a questionnaire was developed to determine which identified scheduling variables are valid to the flight controller, and which schedule he prefers. The questionnaire was selected as the best method to obtain such information. Direct answers to specific questions were desired, therefore, the closed, unstructured question form was used. "The closed questionnaire has the advantage of focusing the respondent's attention on the dimension of the problem in which the investigator is interested." (Ref 17:262).

The questionnaire devised consisted of three parts. The first was to obtain general information about the respondent. The second part was to determine which of the suggested variables are important to the schedule and what his preferred hours of work are. The last part was to determine which of the possible schedules best suited the flight controller.

To determine which of the suggested variables were valid, the flight controller was asked to state whether or not he felt each factor was important, and also to rank each variable on a scale of 0 to 10 according to its importance to him. The value allocated to each factor was then summed. The overall importance was based on total ranked value. A decision rule based on the percentage of affirmative responses was used to determine which of the factors would be validated. The end result was a list of verified scheduling factors and an indication of their relative importance.

The third portion of the questionnaire was to determine which of the proposed schedules is best suited to the flight controller's needs. The flight controllers as well as their supervisors were asked to make this choice. The reason for this is if the worker is allowed to express an opinion concerning his fate he will be somewhat better satisfied in his work. Therefore, the adopted schedule will produce better results in terms of employee morale, effeciency, effectiveness, and job satisfaction. (Ref 59: 324). This also allows for a comparison between supervisor and subordinate preferences.

Five scheduling systems were proposed to the flight controller. Each was briefly explained to insure that he understood how the schedule would work. He was then asked, in reference to the variable factors that he had chosen in Part II, to rank the schedules in order of preference.

<u>Validity and Pre-testing the Questionnaire</u>. Validity of the questionnaire was of prime importance in its design. Careful wording and definition of each question is important in obtaining valid results.

> "The validity of a measuring instrument may be defined as the extent to which differences in scores on the instrument reflect true differences among individuals, groups, or

> situations in the characteristics which it seeks to measure." (Ref 17:155).
>
> "The validity of direct techniques depending on self-report, such as the questionnaire, is less often questioned - probably because of the obvious relevance of the questions to the characteristics they are intended to measure." (Ref 17:311).

Considering these things, and in view of the fact that the research is largely dependent upon the honesty of the respondent's self-report, the validity of the questionnaire rests upon the researcher. The care with which the questions are worded and the objectivity with which he gathers reliable data is of utmost importance. "In the final analysis, the validity of a questionnaire depends largely upon judgement." (Ref 10:207).

Upon completion of the first draft of the questionnaire it was administered to a small group of fellow students in the Systems Management program at the Air Force Institute of Technology. The purpose of the questionnaire was explained and each individual was asked to play the role of a flight controller. After the completion of the test, each student was ask to critique the instrument and make suggestions for improvement. The questionnaire was revised based on the critique received from the first pre-test.

The revised questionnaire was administered to a group of ten FAA RAPCON controllers. These personnel were selected for two reasons. First, they perform work similar to that of the flight controller. Second, they are civil service employees who have shift work experience. Upon completion of the test, the controllers were ask to critique the instrument. Using their suggestions some items were changed for clarity.

Sample Selection. The MSC Flight Control Division flight controllers were the respondents in this research effort. There are approximately 180 flight controllers within the division. To insure that an adequate and representative sample was taken, it was decided that a percentage of each branch would be sampled. There are six branches within the division supplying flight controllers for mission support. Each branch is a mixture of civil service and contractor employees. Both perform the same support functions, therefore, no distinction was made between civil service and contractor in sample selection. A representative sample was desired and 50 responses were considered adequate. Since the expected response rate for questionnaires is usually 60% to 70% (Ref 58:46), 80 questionnaires were distributed.

A request for employee names in participating FCD branches was submitted. A listing of each employee name, branch, and employer was received. Each flight controller was assigned a number for use in identifying a random sample. A table of random numbers was used to select the sample. The sample was checked to insure that a true representative sample had been obtained. This was accomplished by cross referencing the percentage of samples selected in each branch to the percentage of division population in the branch. If the sample was out of proportion (greater than a total percentage of that group in question) the last samples were rejected and new samples drawn until a representative sample had been obtained.

The 80 questionnaires were mailed directly to the respondents. Each questionnaire was accompanied by a cover letter requesting the respondent's cooperation, asking for assistance, and giving instructions. A copy of this questionnaire and letter appear in Appendix E.

III. Schedules and Their Important Factors

Scheduling techniques and systems in use today are reviewed in this chapter. This includes information about the schedule in use and the type of work the organization accomplishes.

According to Webster a schedule is:

> "a list of times of recurring events, projected operations, a timed plan for a procedure or project." (Ref 20:1303).

Employee scheduling, thus becomes an assignment of personnel or employees required to support projected operations or a timed plan or procedure to accomplish a project.

Scheduling Factors

To develop a schedule adequately there are a variety of factors that must be considered. In discussing the main features or variables in scheduling systems Niland states:

> "To develope a plan or schedule it is necessary to have in hand an explicit statement of production requirements - a list of work to be done. Given such a description a system for generating a schedule will have four main features. The first of these is a measure of plant capacity available. Second, there will have to be a way to measure the amount of capacity needed to produce the work required. A third requirement is a systematic method of allocating the capacity available to the shop orders being scheduled. The fourth general feature of a scheduling system is its provisions for a method and a cycle for rescheduling." (Ref 15:53).

He is basically discussing production scheduling, but in enumerating his features he points out that these features apply to scheduling in general "depending upon what is being scheduled." (Ref 15:53). Looking closely at each of these factors in terms of personnel scheduling then one can see the applicability to this research effort.

The first factor, plant capacity available, may be interpreted as "manpower skill classification." (Ref 15:53). In dealing with people and scheduling them to perform any task or project it is clearly necessary to be able to classify the skills required and those available. Without this classification the scheduler does not know what skills are required or available. This also implies that the scheduler must have an intimate knowledge of the project or operation that is to be undertaken.

The second factor, capacity needed, is concerned with the identification of the type of equipment and the sequence of operations required to produce the required end item. The scheduling of personnel is also concerned with capacity, but in a slightly different context. In this area of endeavor the scheduler must be concerned with what the requirements are to support each phase of the operation in terms of numbers of qualified personnel. This factor, as does the first, ties in very closely with the operations to be undertaken.

Examination of the third factor, allocating the capacity to the shop orders, brings one to the actual scheduling of the flight controller to support each mission operation. The method used may be a simple rule of thumb. A priority decision, or dispatching rule, is discussed by Buffa for scheduling. He asks the question, "Does this priority decision rule work better than some other rule?" (Ref 4:586). In developing a flight controller scheduling system the scheduler should also ask himself this question and develop a decision rule to assign or allocate his available personnel to support the operations. To provide the most efficient use of personnel, the decision rule should consider the human factors such as fatigue, morale, shift length and cycle, etc.

The fourth feature is a method and a cycle for rescheduling. Niland was primarily concerned with rescheduling of unperformed jobs or changes in sequence of operations. In the spaceflight operations area it is often necessary to reschedule events or to account for unexpected occurances. This requires schedule flexibility since the changes are accomplished concurrently with the continuous flow of the operations.

A review of the basic factors of a scheduling system as proposed by this author are:

1. An intimate knowledge of the spaceflight mission is required for developing a scheduling system.

2. The scheduler must be able to classify the qualifications or skill of the flight controller in

comparison with the skill levels needed to support the operation.

3. The scheduler must be able to define the requirements for support of each mission phase in terms of numbers of qualified controllers and when they are needed.

4. The scheduler must have a systematic method of, or decision rule for, assigning available flight controllers to the spaceflight operations.

5. The scheduler must develop flexibility in his scheduling system to account for the unexpected events that occur during a mission.

This writer, thus, proposes five main factors of a flight controller scheduling system.

The first factor, knowledge of the mission, is of such importance and so connected with the other factors that this researcher feels it should be a separate factor. Mission requirements are not a factor that the scheduler can manipulate or control. It is, however, the main shaping force of the schedule. Due to this fact mission requirements are not discussed at any greater length.

In researching the remaining four factors, the works of many authors were studied. Each of these works included in-depth discussions of the factors that were important to that particular effort. The analysis of the scheduling systems and their factors led this writer to list and catalogue the variables. Further analysis of some 17 variables resulted in combining and condensing this list into a group of nine. Each of these variables were then studied, examined and analyzed. The following discussion is the result of this effort. The scheduling variables are presented in alphabetical order and are not directly related to, although a part of, the five basic factors presented above. These variables are: fatigue, flexibility of schedules, length of shift, morale, office work, over-time, qualifications of personnel, shift cycle, and training requirements.

Fatigue. Fatigue is a word which has many definitions. Some authors suggest that it is too indefinite to be used in any scientific discussion because it is in fact a meaning-less term. McFarland stated that fatigue, "Does not have a specific meaning in a scientific sense. It refers generally speaking to a group of phenomena associated with loss of efficiency and skill and the development of anxiety." (Ref 11:336). Others conceive fatigue to be an outcome of conflict and frustration within the individual, which results in a reduced output of work. (Ref 11:336). K.F.H. Murrell suggests that an operative definition of fatigue is, "... the detrimental effect of work upon continued work, which may manifest itself as a decrement in performance." (Ref 14:408). O. G. Edholm, in the Biology of Work, defines fatigue as:

"... a term used to cover all those determinable changes in the expression of an activity which can be traced to the continuing exercise of the activity under its normal operational conditions, and which can be shown to lead, either immediately, or after delay to deterioration in the expression of that activity, or more simply, to results within the activity that are not wanted." (Ref 9:187).

From these definitions it can be seen that there is general agreement with the belief that fatigue is caused by work and results in a decrement of task performance.

Fatigue is a field of study in itself. Many volumes have been written and much research conducted to determine what fatigue is, what are the causes and what are the effects. The majority of such studies deal with a specific group, trade, or profession working under specific conditions. From this it is difficult to draw generalities that apply to areas or groups. To define fatigue as a specific term, it is necessary to carefully segregate the area of interest. This research effort is not of sufficient scope to completely define fatigue as related to the manned spaceflight flight controller. Therefore, only the general nature of fatigue, as applied to the flight controller, will be briefly discussed.

There are basically two general aspects of fatigue: physiological and psychological. "Physiological fatigue is the actual impairment in muscle tissue caused by over activity." (Ref 34:2). Psychological or mental fatigue, on the other hand, "is the experienced feeling of tiredness, anxiety, boredom, apathy or loss of motivation to continue work." (Ref 34:3). Although there are two types of fatigue one is not independent of the other. The end result, in either case, is a decline in the effectiveness of the worker.

Physiological fatigue is primarily the result of muscular activity. Everyone at one time or another has experienced this type of fatigue after participating in strenuous exercise, games, or hard physical work. This type of fatigue has real meaning and it can be defined and measured. For example, heavy work has been identified as requiring an energy expenditure of more than 5000 calories per minute. (Ref 14:378). A cause of fatigue from muscle exercise has been determined to be due to a build up of lactic acids. If one works for an extended period of time without rest, the lactic acid content builds up and fatigue is experienced. A rest break, however, will disipate this build up and postpone fatigue. (Ref 14:409). Lighter work with smaller caloric requirement has a slower accumulation of lactic acid and consequently less physiological fatigue. There appears, however, to be a trade off between physiological and psychological fatigue. The less physical demand the greater the probability of experiencing mental fatigue. (Ref 2:307). The flight controller's work requires relatively little or no physical activity. It does require continual mental alertness, perceptual, and visual activity. These requirements produce the conditions that promote mental fatigue.

The symptoms of psychological or mental fatigue are tiredness, weariness, exhaustion, lassitude. "The subjective aspects of fatigue are complaints of aches and pains, usually rather vague and generalized, malaise and sensations described as tiredness." (Ref 9:187). These sensations are variable and inconsistant and relate to an increase in muscle activity. The muscles that should be relaxed become tensed, which is unwanted muscle activity. As the primary muscles become fatigued the secondary muscles are relied upon to do the task, which further increases the state of fatigue. The ache of the tired muscles is the outward symptom of mental fatigue. The symptom of the tired brain, a disinclination for further mental exertion, is often disregarded.

There are many causes of psychological fatigue. Researchers cite monotony, boredom, repetition, and sustained requirement for attention and responsibility as causes of mental fatigue. (Ref 11:16). Often the working environment, noise and temperature, contribute to mental fatigue. (Ref 34:9). Psychological fatigue can be aggravated by excessive stress and anxiety. (Ref 11:211).

Boredom results from monotony and differs very little, if any, from fatigue itself. Boredom generally refers to the feelings of the individual characterized by such terms as disinterest, satiety, irksomeness,etc. Monotony is the individual's perception of his surroundings. Fatigue, on the other hand, is more intimately a part of the person and is described by such terms as lassitude, weariness, and inability. (Ref 2:323). Boredom, monotony and fatigue, although not synonymous terms, are often used interchangably. This points to one of the problems in the study of fatigue - that is: how to distinguish it from boredom.

In discussing fatigue, one finds that it is intimately connected with stress. Stress, according to Lyons, is "Everything that places a strain on a man's ability to perform at his best." (Ref 26:15). It is a factor which detracts from your ability to do your best, or it may so confuse the mind to the extent it is almost impossible to concentrate. Stress is caused by such things as noise, uncomfortable temperatures, taxing work conditions, obstacles in the path of goals, fear or threat to security, or incompatible demands. (Ref 34:49). Stress is often thought of as the antonym for boredom. For example, if a worker has insufficient work he is often bored, however, if his work demands are too great he experiences stress. There is evidence that stress increases the number of errors and consequently lowers the quality of performance. (Ref 34:49).

Anxiety and fatigue are interrelated. Anxiety is regarded, very generally, as the pattern arising in a conflict situation. It is personal, tends to be cumulative, and evolves from personal disorganization. (Ref 2:382). Anxiety can develop to the neurosis state, where the loss of efficiency and skill occur. (Ref 11:336).

The effect of fatigue is generally agreed to be a decrement in performance. As fatigue develops, performance declines. Along with the decline of performance there is increased effort, and this may for a time prevent the decline of performance. Where visual displays are monitored, as in the case of the flight controller, increasing fatigue results in erratic attention to the display. Less essential elements may be increasingly ignored and attention concentrated on the most important portion of the display. Conversely, too much emphasis may be placed on the peripheral elements at the expense of the central ones. (Ref 9:189). The effect is that the right actions may be performed at the wrong time and some actions may be left out. With fatigue comes erratic and increasingly poorer performance.

In summary, fatigue is the condition whereby man can no longer respond to stimuli in an adequate manner. It may be either physiological or psychological, but is usually both in jobs requiring minimum physical activity. There are many factors that contribute to fatigue such as boredom, monotony, stress, and anxiety. When fatigued, characterized by feelings of tiredness, weariness, disinterest, etc., an individual's performance continues to decline as the level of fatigue increases.

Flexibility of Schedules. The scheduling variable, flexibility, is important not only from the manager's point of view, but also from the employee's. Any scheduling system must be capable of accounting for the unexpected. This may result from any of a variety of conditions or acts. The requirement to change the schedule often comes from changes in the operations' activities. In discussing production schedule flexibility, Powell Niland states:

> "Even with careful provision for contingencies, it is quite likely that after a time there will be significant cumulative difference between the work scheduled to be done and the work actually done." (Ref 15:74).

When such contingencies do occur, regardless of the system being scheduled, changes must be made to accommodate them.

Some of the most frequent sources of change in manned spaceflight lies in the mission itself. Jim Hannigan, Chief of Lunar Module Systems Branch, MSC, stated in an interview:

> "It takes no more than a small failure in a spacecraft to cause extensive change in the mission plan. The most serious of such failures, of course, involves crew safety. This type of failure requires immediate positive reaction. As far as change to the mission profile, however, the failure of non-crew safety items perhaps is the cause of the more frequent and far reaching changes to the mission." (Ref 69).

It appears to this writer that such changes in mission plan often do not involve changes in personnel scheduling. This is due to the equal skill level of each flight control team supporting the mission. There are times, however, when a unique specialist is required to support a particular experiment or activity. When this need is present the schedule must be flexible enough to provide the required support.

A more frequent source of change in the scheduling of personnel is because of personnel nonavailability. Over long periods of time, it is virtually impossible to predict illness, personal emergencies, accidents, etc. Occurrence of any or all of these situations necessitates the alteration of the schedule. The resulting changes can generate serious consequences.

> "The scheduling problem becomes more complicated when one unscheduled change, requiring a crew or member replacement, multiplies into several chain reaction type replacement changes." (Ref 44:27).

The chain reaction that is being spoken of is the absence of one individual requiring a person who is scheduled for another activity. The replacement must be replaced and so on. In some instances, a single absence can affect five or six individuals, and consequently several other activities.

Another type of absence that must be accounted for is the planned or personal desire absence. Generally, this type of absence causes less problems than emergencies, if the scheduler knows about it in advance. The schedule should be flexible enough to accommodate the desires of the individuals.

> "The scheduler's role is to know the desires of the crew members and to attempt to incorporate them into the schedule. The scheduler must also provide some means to satisfy personal request as long as they do not infringe upon the rights of others." (Ref 62:75).

It is further pointed out that this type of request is a "two way street" with the team member sharing the responsibility for such change. "Of course, the crew member has the responsibility to request this favor far enough in advance so that it can be programmed into the original schedule." (Ref 62:76).

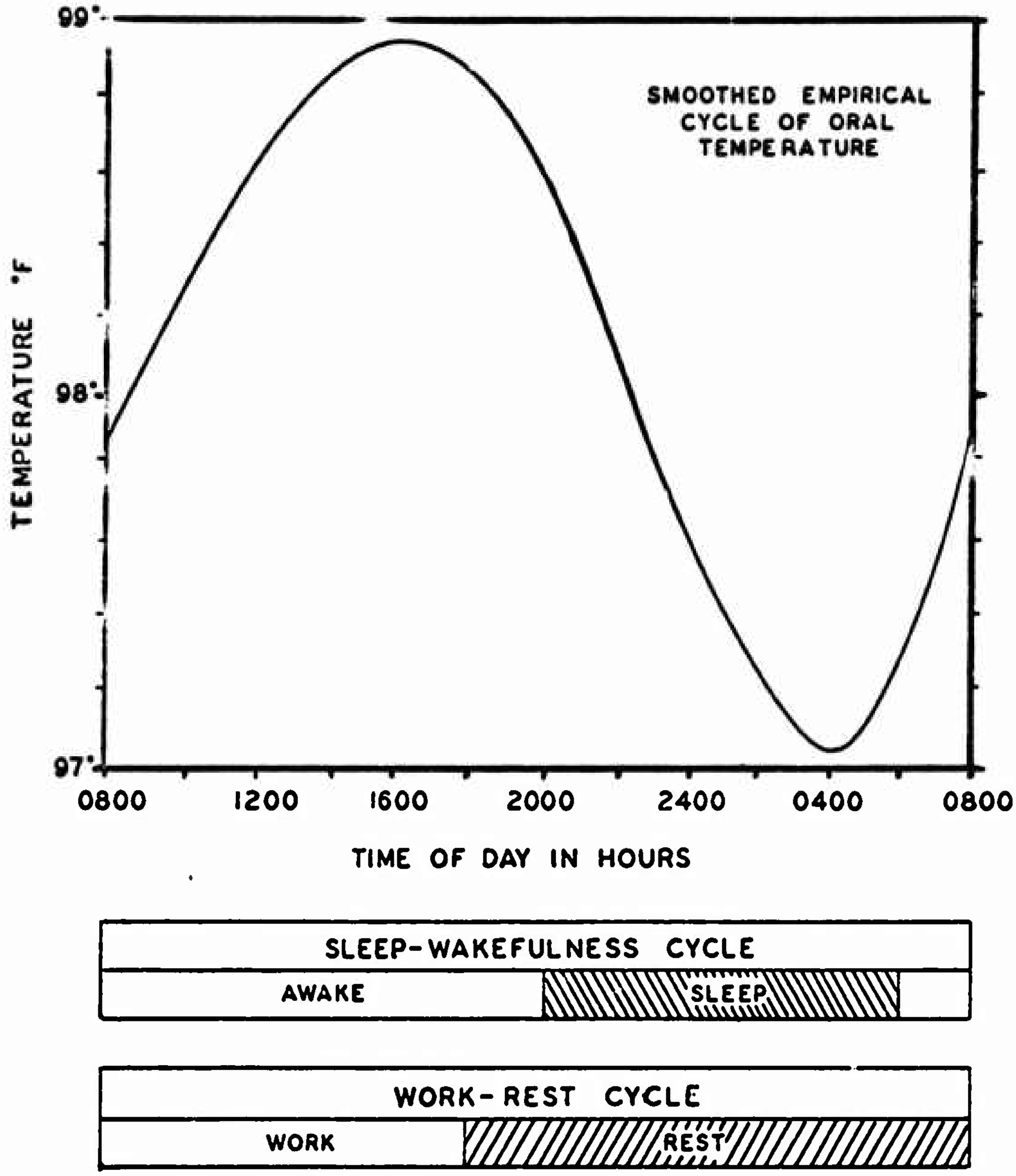
In summary, the scheduling variable, flexibility, is the ability of the schedule to account for unexpected changes. These changes can come from equipment or system failure, personal emergency, or personal desire. Regardless of the source of the change, the mission activity must be supported. The scheduling system must be able to change to meet the demand.

Length of Shift. The normal 24 hour day can be divided into either a work-rest or a sleep-wakefulness cycle. Each contains the same basic elements - a period of work, wakefulness (rest), and sleep. The work-rest cycle is defined as being dichotomized into work and rest periods. The rest period contains both a sleep and wakefulness (rest) time. The sleep-wakefulness cycle is likewise divided up into two parts - work and wakefulness (rest). (Ref 52:3). The main difference lies in the emphasis placed on the length of the work and sleep period.

As man approaches adulthood he progressively reduces his sleep-wakefulness ratio. At the same time there normally occurs changes in the way his wakeful activity is structured which produces both physiological and psychological changes. By the time he reaches adulthood, he has obtained well established physiological and psychological rhythms. (Ref 52:4). These rhythms are generally identified as the diurnal rhythm, circadian rhythm, or day/night metabolic clock. This rhythm or cycle is a definite well documented cycle of alertness or awareness and restfulness and dictates the schedule of work and rest. The importance of this cycle lies in the effect which it may have on the individual's ability to do his job efficiently.

It is an established fact that the diurnal rhythm and body temperature are closely related. The research conducted by Kleitman, and others, has verified and explored this relationship. Figure 2 graphically illustrates the relationship between body temperature and the typical work-rest or sleep-wakefulness cycle.

Kleitman's study of performance under different schedules found that performance varied directly with body temperature. Further there is a correlation between performance, alertness, reaction time, vigilance, and the diurnal cycle. (Ref 47:23). This study further revealed:



SLEEP-WAKEFULNESS CYCLE

FIGURE 2

Source: Ray, James T., O. E. Martin, Jr., Earl A. Alliusi, Human Performance as a Function of the Work-Rest Cycle, National Academy of Sciences - National Council, page 4.

> "... that an activity which requires memory, muscular coordination, an ability to attend to several indices simultaneously, as well as a prolonged maintenance of effort is the type of activity where high body temperature level shows its best influence in high performance." (Ref 47:23).

From this one can support the hypothesis that when body temperature is the highest, a greater degree of alertness and performance is evident.

The term alertness, attention, and vigilance have often been used to discuss various aspects in the length of time an individual can work without his performance decreasing. Each of these words have different meanings under different conditions. To avoid such semantic problems, Murrell suggests the term "actile period" be used. It is defined as:

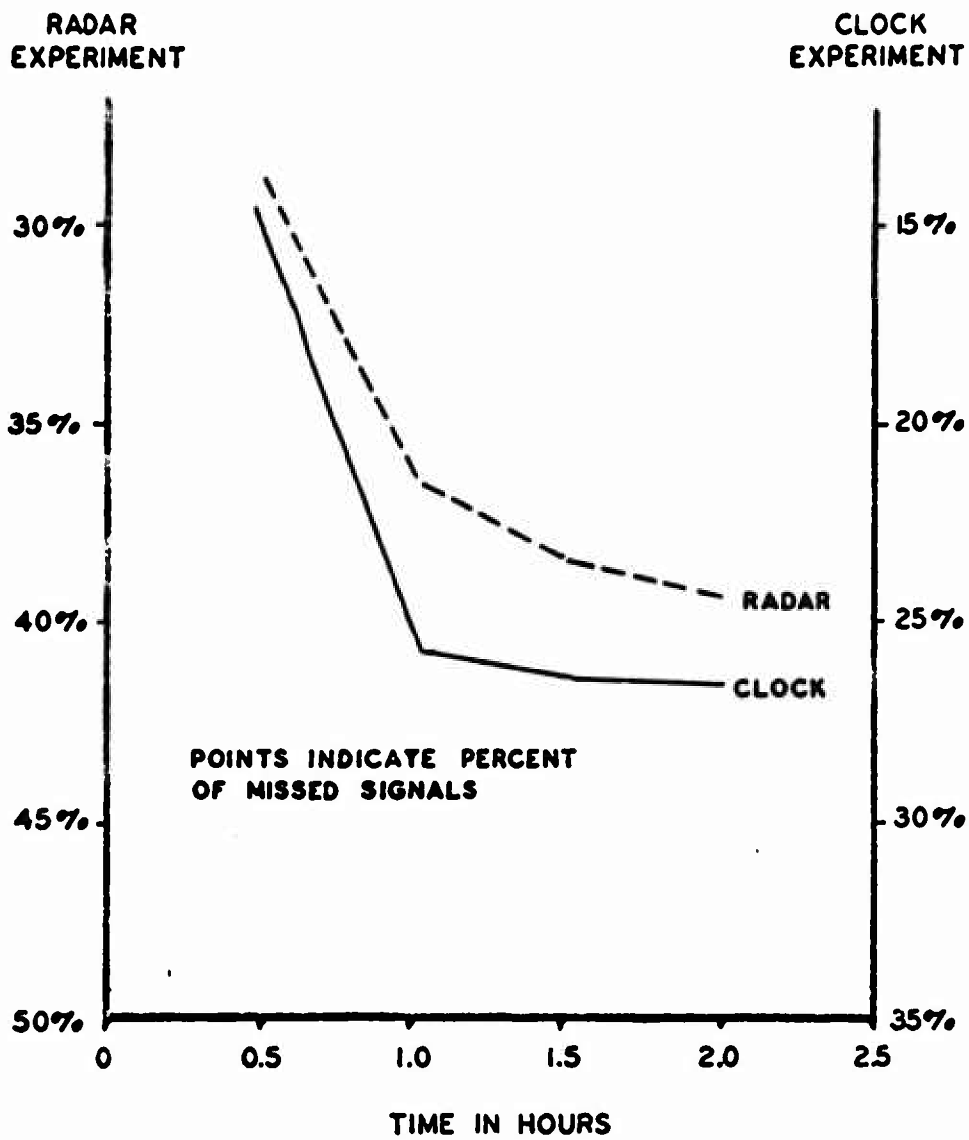
> "... a period during which there is a state of preparedness to respond optimally to stimulation either discretely or continuously - the period during which a worker can maintain concentration upon the task in hand." (Ref 14:379).

The actile period has a finite length which depends upon the individual and task undertaken. When the end of this period is reached, performance begins to deteriorate, thus the actile period is the optimum length of time during which mental work or light physical work should continue.

To adequately explore the actile period it is necessary to look at specific areas that are related. These areas are vigilance and alertness. Vigilance is defined as, "the probability of detecting rare and near threshold events, or a state of exitation of the nervous system which maintains in a state of readiness to respond to stimuli."(Ref 3:34).

"Alertness is a state of awareness or watchfulness" and is therefore implicit in vigilance, as used in this research. (Ref 14:401). Vigilance, as used by this writer, is related to the monitoring task. The worker is required to respond promptly and correctly to stimuli. Failure to do so can occur in two ways. First, a signal for action may not be perceived, or secondly if it is perceived, the wrong action may be taken. Not perceiving a signal, according to Murrell, is related to strain imposed by the task. When the operator is less alert and a signal occurs, the probability is greater that the wrong action will be taken during the time he is becoming fully aware of the situation.(Ref 14:403).

The primary tasks this research is concerned with have been identified as mental work and/or monitoring. Extensive research has been conducted in these areas. Adams and Webber conducted several laboratory tests to determine the effects of long term visual monitoring. They exposed several subjects to continual visual stimuli for up to six hours. The result of this series of experiments was the conclusion that there was some decrement over the period involved, but not much more than experienced in three hours. (Ref 61:8). Mackworth's study of radar operators observing a signal echo found that numerous signals were missed after only 30 minutes. These results were verified by performing a clock experiment.(Ref 34:34). The results of these experiments, shown in Figure 3, seem to indicate that tasks requiring constant vigilance are extremely fatiguing.



RADAR TEST AND CLOCK TEST
EXPERIMENT

FIGURE 3

Source: Alexander, Robert M., An Analysis of The United States Air Force Pilot Training Program Relative to Human Fatigue, Air University, Maxwell AFB, Ala., 1966, page 6.

The length of time a man is required to work is related to the efficiency of his work, his health, and safety. Vernon studied munition workers in England in the early 1940's and found that when working 12 hours per day, workers experienced three times as many accidents as when working ten hours. (Ref 34:12). The Industrial Health Research Board found that working more than 60 hours per week was accompanied by an increase in time lost due to sickness, injury, and absence without permission. (Ref 34: 32). This was accompanied by a decrease in output and labor turn over. In another study it was found that when working two hours of overtime per day, output decreased by 6.5 percent. (Ref 34:33). Mental efficiency was found to decline over a 12 hour period in experiments conducted by Arai, Huxtable, Harker, and Abernethy. Figure 4 shows the average hour by hour decline in efficiency over a 12 hour period. (Ref 52:9). Kent reports that over an eight and nine hour daily work period decrements in reaction time, visual and auditory acuity were noted. He further found that these decrements increased from the beginning to the end of the work week. (Ref 52:10). Figure 5 illustrates the decrement in performance over an eight hour period for each of three shifts. This data is from an investigation of a monitoring task in a gas works.

One of the most effective ways to prevent fatigue is to introduce periods of rest at regular intervals throughout the working day. (Ref 9:190). The work break does not

DECREASE IN MENTAL EFFICIENCY OVER A 12 HOUR PERIOD

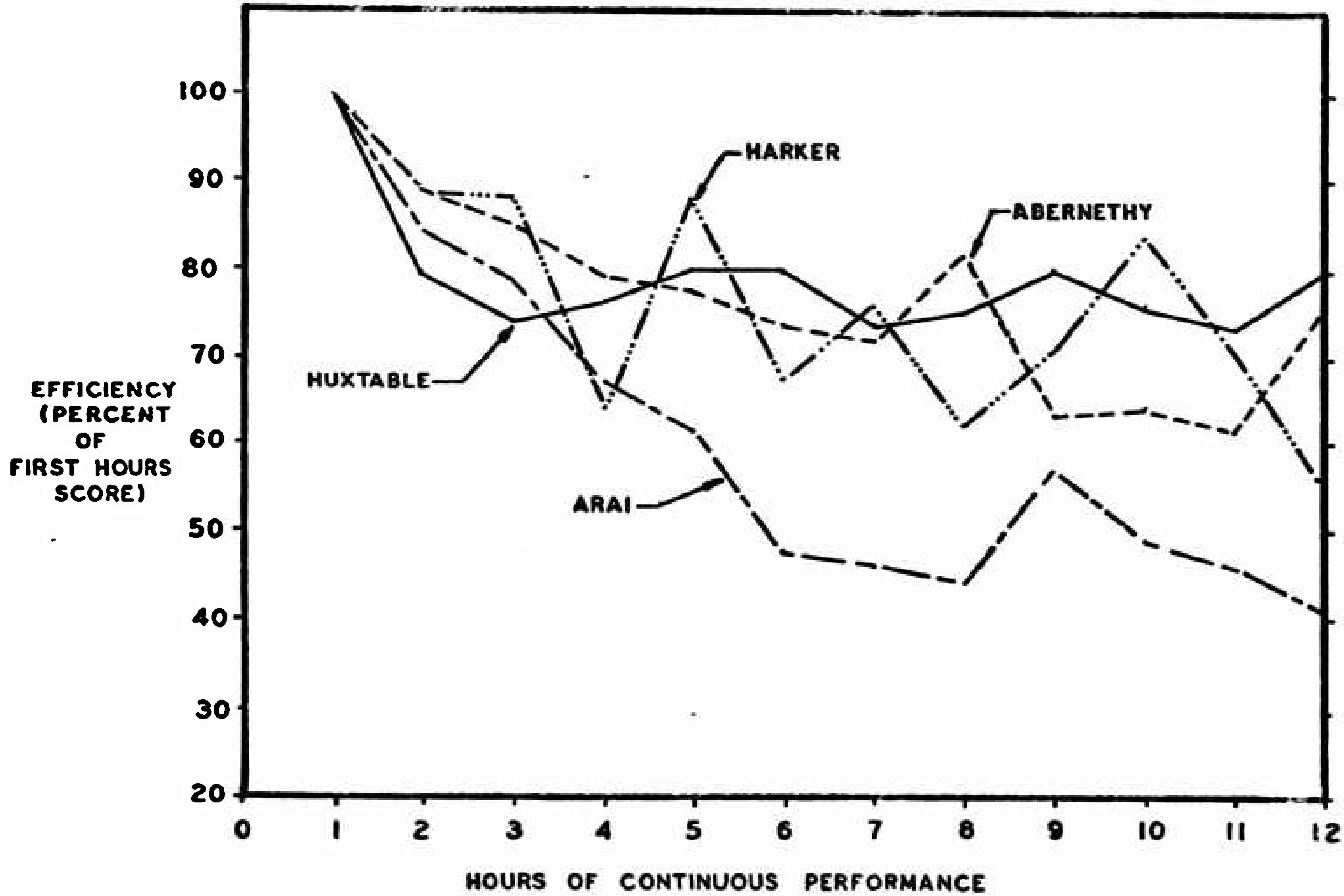
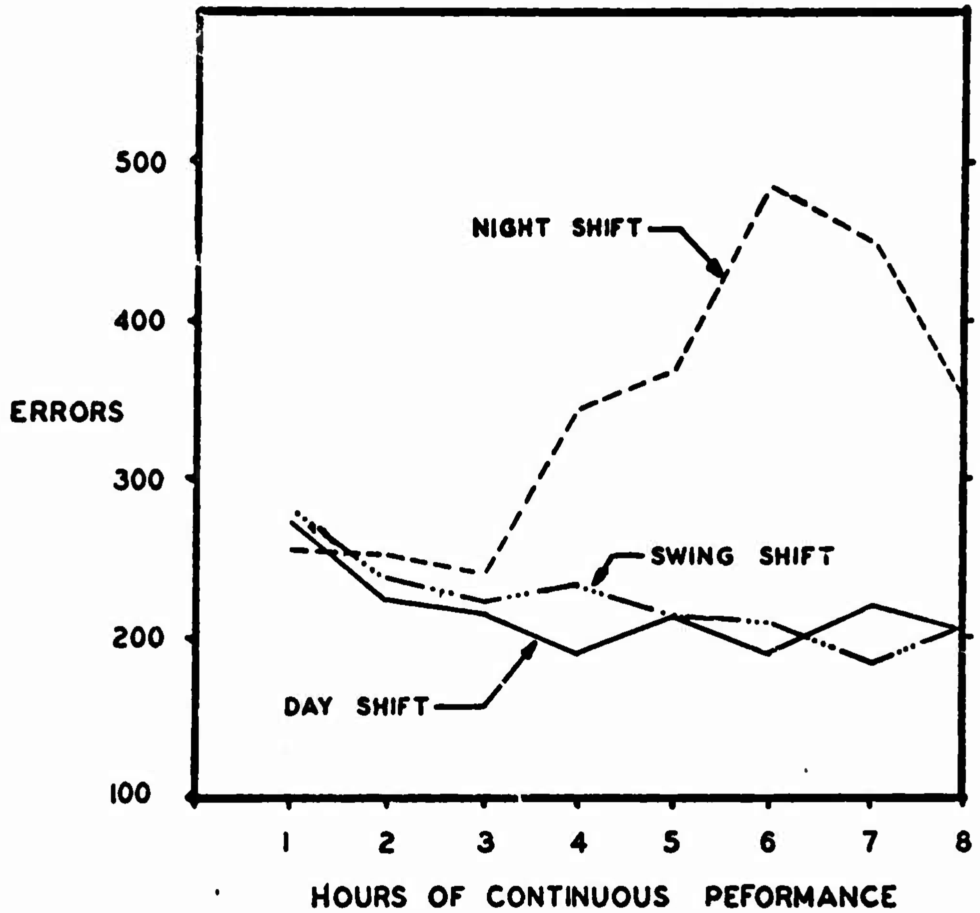


FIGURE 4

Source: Ray, James T., O.E. Martin, Jr., Earl A. Alliusi, Human Performance as a Function of the Work-Rest Cycle, National Academy of Sciences - National Resources Council, page 9.



NUMBER OF ERRORS MADE
DURING AN 8 HOUR SHIFT

FIGURE 5

Source: Murrell, K.F.H., Ergonomics: Man and His Working Environment, Chapman and Hall, London England, 1969, page 432.

necessarily have to be rest but may be a change of occupation. A change in occupation may be as effective in relieving fatigue as actual rest. The length of the work pause generally varies from five to ten minutes. The total rest period, as found by Shephert is between 16.7 percent and 20 percent of the work period for optimum efficiency. (Ref 34:27). He also determined that when the worker scheduled his own break his efficiency declined somewhat. A pause that is too long may be unsatisfactory since the work rhythm may be lost. The length and time a work break is scheduled depends upon the nature of the work. It appears that the approach of the end of the actile period should be the point at which a break should be scheduled. (Ref 14:382). This is often difficult to do since little data is published on the actile period for various tasks. For flight controllers, if one can rely on the clock watching experiment, the actile period could be approximately one-half hour. To specifically determine such a period, however, is beyond the scope of this effort. It is suggested that due to the nature of the flight controller's tasks a pause of approximately five minutes should be taken every one to one and one-half hours to prevent fatigue.

In conclusion, the length of time that a worker performs his task without a break is largely dependent upon his work. Continuous monitoring functions and mental labor tend to have relatively short actile periods of one-half hour to an hour. After this time period his performance begins to decline. Less intense vigilance tasks have longer actile periods or the actile period can be lengthened by frequent short rest periods. There is experimental evidence to show that decrement of performance in vigilance tasks occurs in six hours. Eight hours may produce a greater decrement and twelve hours may be unacceptable.

Morale. The subject of morale has been investigated and studied at great lengths by many researchers and authors. The resulting volume of books and articles point to the scope and importance of the subject. An in-depth study of morale and motivation is not included in this research. The following is a discussion of the relationship of morale and motivation. This will be explored briefly as motivation and morale pertain to this research.

Morale has many definitions. Keith Davis defines morale as:

> "... the attitudes of individuals and groups toward their work environment and toward voluntary cooperation to the full extent of their ability in the best interests of the organizations." (Ref 7:58).

He points out that high morale increases production, reduces absenteeism and aids many other human aspects of work. Morale and motivation are often used interchangably. Motivation comes from within the person. It is what he himself wants. Morale on the other hand effects attitudes.

There is a relationship between morale, motivation and work. Davis points out that this relationship is not absolute. It is quite possible to have high morale, yet have low productivity due to lack of motivation. There are a number of factors affecting morale, motivation and productivity and generally there is some positive correlation between them. (Ref 7:60).

Motivation has an effect on production. Inadequate motivation may simply reduce the general level of performance without influencing other factors such as the actile period. McFarland points out that:

> "The working efficiency of employees is frequently more influenced by inadequate motivation, boredom, or domestic difficulties than physical and environmental factors." (Ref 11:341).

This leads one to think about the relationship between morale, motivation and fatigue.

> "Motivation is found to be a factor in all forms of fatigue in the sense that the rate of fatigue for almost any type of task varies inversely with the intensity of the motivation. When motivation is high the evidence of fatigue may not be apparent until considerable exhauston is manifest." (Ref 34:43).

The relationship of morale and fatigue then is very real. Lack of motivation and morale tends to effect the efficiency with which one works and consequently his level of fatigue. The level of fatigue can increase to the point that it reaches "motivational fatigue". This is the point at which there exists a lessened eagerness to perform the task or duty. (Ref 48:29). Motivational fatigue can be increased by prolonged exposure to factors which lower the morale and motivation of the worker.

The relationship of morale and motivation to fatigue is well established. Husband points out that hard labor is much less tiring than light labor. One can experience such a variation in fatigue level by comparing how you feel after playing a fast game of tennis (or some other sport) with your feeling after doing some light labor such as weeding a flower bed. Several experiments in industrial fatigue found that fatigue is produced as soon as interest in the task is lost. (Ref 34:43). The importance of this, is the inference that increased motivation of the flight controller may reduce his fatigue and increase the level of mission support.

The importance of morale and motivation cannot be over emphasized. This factor directly effects the desire to accomplish a task effeciently and effectively and is important in any area of work. Such an attitude is vital as it not only effects the job, but also the career of the individual. In discussing the effect of morale and motivation on combat crews, Krautkramer states: "A high level of morale makes it possible for an officer or airman to perform his tasks with energy, enthusiasm, and self dicipline sustained by a conviction that, in spite of immediate physical and emotional stress, obstacles, and conflict, his personal and military ideals are worth persuing." (Ref 48:23). He further indicates that an effective scheduling system which satisfies the needs of the worker tends to increase morale and motivation. An inefficient system, on the other hand, tends to weaken the main drive toward the task or duty. (Ref 7:29). One method of improving morale and increasing the satisfactions of the worker is to encourage worker participation in the scheduling process. This must be used with some caution, however, as some individuals would have changes made to benefit themselves and be detremental to others.

Thus, morale and motivation is an important variable in a scheduling system. It effects worker productivity and efficiency and is also a factor in fatigue. The importance of morale cannot be over emphasized since it bears a direct relationship to the worker and his job.

Office Work. The scheduling variable, office work or administrative duties, is somewhat unique. It is found only in those areas of activities where the worker has two types of tasks to perform. He is expected to provide support to some sort of operations activity which is a 24 hour, seven day a week job. Secondly, he is required to plan, train, and do other tasks to prepare for the time when he must support the operations activity. This is usually an eight hour day, five day a week job. This type of dual occupation is usually found in such areas as aircraft operations, defense surveillance, certain research and development testing operations, and space operations.

Harold Miller, past Chief of FCD Simulations Branch, reports that the support of space operations requires extensive mission planning, development of mission rules, mission activities timelines, operations procedures, detailed vehicle systems knowledge, and training for the operations support activities. In addition, it is often necessary to travel to various other organizations to gain specific and detailed knowledge of the vehicle or its components. (Ref 50:83). In the operations of the Air Force Satellite Control Facility, time is required for administrative duties such as reading or preparing documents required to maintain an acceptable level of support to SCF operations. Air crews are required to perform certain administrative work primarily to maintain proficiency in their flying. The engineer involved in a research and development test must carefully plan his test activities and, after the test is completed, assist in analyzing the data obtained.

The activities outlined above clearly cannot be accomplished concurrently with the operations activities. This requires that the office work be accomplished;

(1) between periods of operations activities,

(2) concurrently with the operations activities, but by personnel not directly involved in those activities, or

(3) concurrently with the operation provided that

sufficient slack time exists that would allow these duties to be conducted without interference with the operations.

In summary, the routine office work must be accomplished because it is vital to subsequent operations activities. The schedule must provide some opportunity to accomplish such activities. The scheduler must be aware of the volume and nature of the office work required to be able to schedule sufficient time to accomplish it without decreasing mission support.

Overtime. Overtime is defined in Webster's New World Dictionary as "time beyond the established limit, especially beyond the regular number of working hours." (Ref 20:1045). For the purpose of this research overtime is further restricted to those hours worked in excess of the standard 40 hour work week. The 40 hour work week is currently accepted throughout the United States. The average industrial employee today works about two or three hours overtime per week. (Ref 8:139). In the past the worker spent these extra hours by relaxing. Now that he is spending his free hours in extra work, what is the cost?

Usually each hour of overtime worked produces pay for time-and-a-half. The worker in turn looses some of his free time that could be used to rest and reduce his fatigue level. The employers' costs are, (1) the additional pay, (2) the loss resulting in decreased productivity.

Bartley points out that when both factors are considered, the real cost of overtime is actually 2 3/4 times the base pay rate. (Ref 2:179).

Quantitative studies indicate that when the hours worked per day increase the output decreases. Bartley's discussion of this subject points out that the hourly production, on an assembly line, decreased on the days in which overtime was worked. This point is strengthened by Edholm's studies. He states that "long hours lead inexorably to a decline of efficiency and a decline in health." (Ref 9:191). A suggested reason for this lowered efficiency is that the workers slow down to conserve their energy for the overtime periods. (Ref 34:34). One might conclude from this that scheduled overtime should be avoided to maintain efficiency, maintain a normal production rate, and reduce fatigue.

In discussing the scheduling function and its relation to overtime, York points out that the schedulers' "chief responsibility, from the human side, is to design a schedule that keeps (overtime) duty to a minimum." (Ref 62:75). Niland, however, points out that the "failure to make any allowance for such contingencies (overtime requirement) means that schedules produced by the scheduling system will be unrealistic." (Ref 15:70). It is true that the schedule should be flexible enough to account for any contingencies, and they may well require that overtime be worked. It is essential, however, that the resulting work load be kept as even as possible and that everyone be treated equally.

Overtime, like each of the other variables, is interrelated to fatigue, efficiency and morale. Thus to maintain the highest level of worker efficiency and morale and at the same time minimize fatigue, overtime whould be kept as low as possible.

Personnel Qualifications. Thomas Ryan in his book Work and Effort defines a worker's qualifications as the "knowledge and skill essential for performance of his job." (Ref 16:78). He further discusses skill as simply the "capacity for performance of a particular kind measured under some standard condition. It represents the effect of aptitude, plus training and experience." (Ref 16:211). Waldin, in discussing Air Traffic Controller skill and qualification, sites skill as being the effect of aptitude, experience and age. Analyzing these definitions one finds a person's qualifications depend upon his skill level. Skill level in turn is the accumulative effect of aptitude and experience. Experience may be further disected into the components of training, knowledge, practice, and age. This definition of a worker's qualifications implies a link with the success of his endevor and consequently the importance of the factor.

It is generally recognized that the higher the qualification or skill level of an employee the greater his productivity. In the development of personnel schedules it follows that skill level, or qualification, is very important. This point was confirmed by Walker in his study of schedule forecasting support for missile and space systems testing. He queried 120 experts within this field to determine what scheduling factors were of greatest importance. The most important factor, according to those surveyed was personnel qualifications. (Ref 60:64). Niland further supports this opinion by proposing that personnel skill level must be considered by the scheduler in both long-range and short-range planning. (Ref 15:60). The worker's qualifications are essential to the performance of his job.

Knowledge of the duties a man performs in a job and the qualifications and skill necessary can serve several useful purposes. Glen Davis points out several uses. Among those that are useful to this research are:

(1) Personnel qualifications form the basis for a selection program.

(2) They identify the criteria for evaluation.

(3) They form a basis for the distribution of the workload. (Ref 39:37).

The selection program he refers to is the selection of those persons who are qualified to hold particular positions or perform certain tasks. Evaluation refers to the testing of employees to insure that a certain skill level is maintained over a period of time. The third item discussed is perhaps the most important to personnel scheduling. This refers not only to the level of qualification but also the number of qualified persons available for duty. This determines the level of mission support available and how the workload is distributed.

Sufficient qualified personnel must be available to support the operation. Quantity as well as quality is important in scheduling. "Too few people will certainly require a longer time to do a job, too many may cause schedule extension and make work." (Ref 60:51). In either case the worker may experience fatigue more rapidly, which may result in decreased productivity.

Fatigue and skill level are linked together. "As proficiency increases, the length of time required to produce fatigue progressively increases with learning. After a while a steady state of maximum efficiency is reached and proficiency is attained." (Ref 2:25). During this learning period and after proficiency is attained, variations in productivity occur. The variations are due to changes in skill or effort or both. Effort involves energy, and refers to the rate of performance or efficiency. There are tasks which may involve very little expenditure of energy, but which may be carried on at a very high level of effort. (Ref 16:22). The task of a flight controller is low energy - high effort.

Thus personnel qualifications is an important factor in scheduling flight controllers. This variable includes not only the individual's skill level but also the total numbers of personnel with that skill level that are available for support activities. The degree of proficiency is also important since the better qualified controller can work for longer periods without experiencing fatigue.

Shift Cycle. Work in many occupations must continue 24 hours a day, seven days a week. The scheduling of personnel to support such activities has many aspects. It is well recognized that shift work effects man in an economical, socialogical, physiological, and psychological manner. It is beyond the scope of this research to discuss the sociological and economical aspects. The importnace of the psychological and physiological consequences dictate a need for further examination.

The psychological disturbances that accompany the shift work are difficult to separate from the sociological and physiological effects. The individual who goes from the day shift to the night or afternoon shift continues to live in a social environment geared to the usual pattern of day work and night sleep. Social contacts are difficult or diminished. This may be a more serious or severe disturbing influence than physiological changes. (Ref 9:185). The result of these changes is that working efficiency is effected.

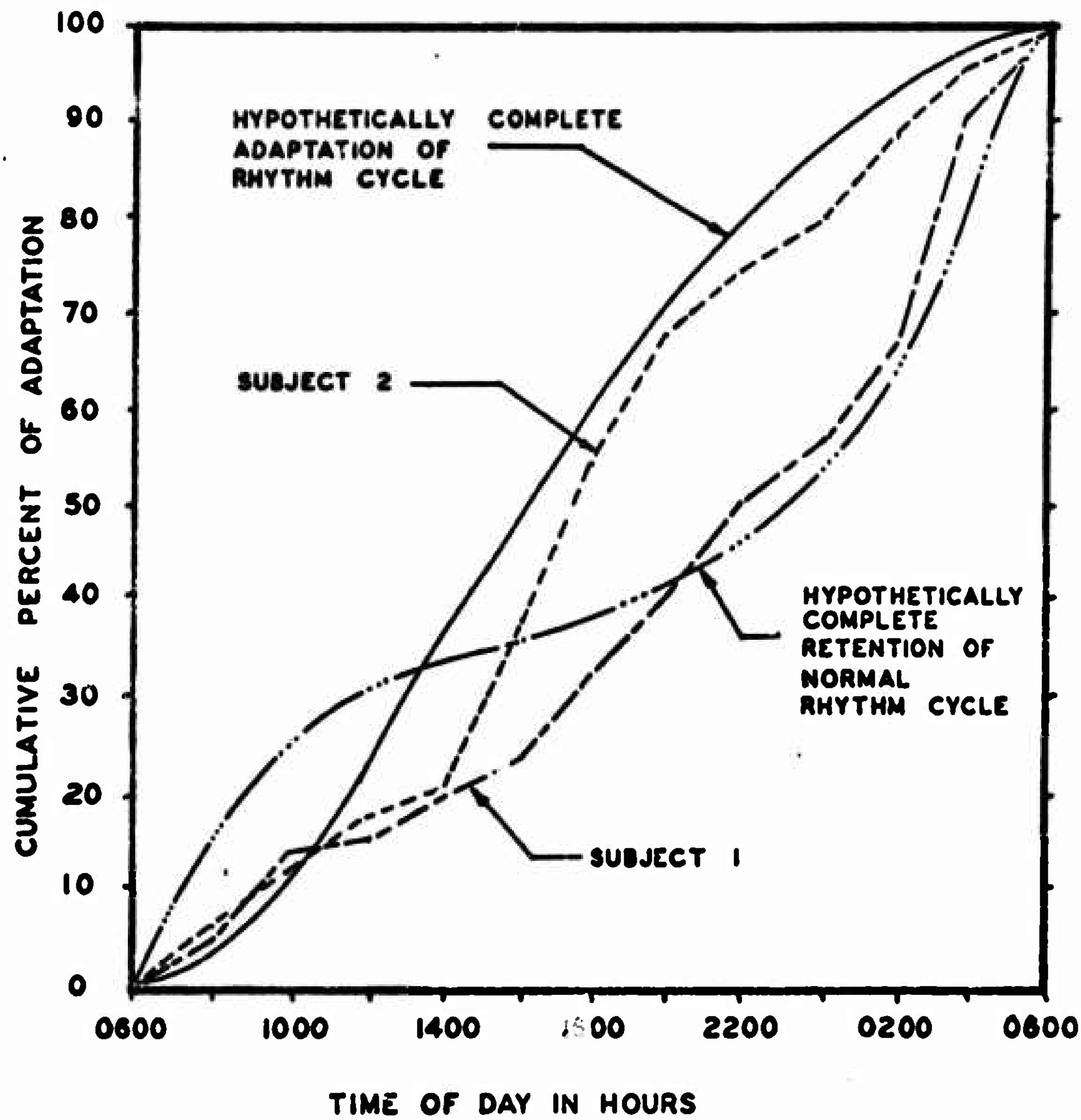
Adjustment of the worker's role behavior is an important aspect of psychological adjustment to shift work. The research conducted by Mott, Mann, McLoughlin and Warwick indicates:

> "The difficulty that the worker reports in performing his roles may not be due entirely to conflicting time schedules of his job and his other role behavior. It may be also due to his physical inability to perform these role behaviors. It seems likely that a worker who is fatigued much of the time because he cannot adjust physically to his shift would be less willing or inclined to perform in his other roles, especially if they require much physical effort." (Ref 13:288).

Further analysis points to the loss of sleep as the heart of the physical adjustment problem. The Mott, et.al. studies seem to indicate that the difficulties encountered with the other rhythmic functions seem to be keyed to the loss of sleep. The worker feels fatigued and he is less inclined to fulfill his various role obligations. He begins to perceive that his shift is interfering with his other activities and problems of conflict arise. This perception of his role difficulties is related to shift satisfaction, which in turn effects his level of anixety, conflict, pressure and self-esteem. The greater the difficulty in adjusting to shift work, the greater his psychological health is likely to suffer.

The physiological aspects are concerned with the existance of diurnal and renal rhythms. The functions of the body exhibit a rhythmical pattern that is related to the 24 hour sleep-work-recreation pattern day. The best known of these is the body temperature rhythm. Other rhythms such as urine secretion, hormone content in the blood, waste elimination, etc. show definite relationships to the pattern of daily activity. When the individual alters his daily routine, as in changing from the day to night shift, these rhythms do not immediately change. The lack of adaptation of the diurnal rhythms to the daily activity often results in feelings of fatigue or a sense of malaise. (Ref 9:183).

Many experiments concerning the adaptation of the worker to shift work have been conducted. Figure 6 shows the comparison of total diurnal rhythm adaptation, total lack of adaptation, and the achieved adaptation of two subjects. (Ref 52:21). Black's eight hour shift - three shifts per day experiment also points out the difficulty of adapting to the night shift. He found that six days were required before any evidence of a change in the diurnal cycle was noted. In 12 days the adaptation was not complete. (Ref 23:533). The period required for adaptation to a different shift is related to the bodily activity required. A person who has a fairly active job is more likely to achieve a temperature inversion (diurnal cycle change) than a person who is relatively inactive. After a man has achieved an inversion he may revert to a "normal rhythm" on a single day off. This would force a worker to continually be in a process of adaptation if he had a day off each week.



ADAPTATION OF RHYTHM CYCLE
TO WORK HOURS

FIGURE 6

Source: Ray, James T., O.E. Martin, Jr., Earl A. Alliusi, Human Performance as a Function of the Work-Rest Cycle, National Academy of Sciences - National Resources Council, page 21.

Mott, et.al. found that the difficulties encountered were accompanied by loss of sleep, feelings of fatigue, and dulled appetities. These conditions if allowed to continue for a long period of time result in lowering of resistance to disease. (Ref 13:301). This is further substantiated by Dankert's studies. He found that disorders resulting from changing work schedules often result in serious health problems such as upper gastro-intestinal disorders and ulcers. (Ref 6:116).

The shift cycles employed in industry are endless in variety. The 24 hour sleep-work-recreation cycle is divided in such a manner as to obtain maximum worker efficiency and satisfaction. The accepted shift schedule in industry today consists of three eight hour shifts. There is, however, a great deal of experimentation with ten and 12 hour shifts being currently conducted. There are several companies using the ten hour day, four day week, or three day, 12 and one-half hours per day week.(Ref 24:102). It should be noted that even though longer shift hours are being adopted, the total work week remains at 40 hours or less. The optimum work week length varies somewhat with the nature of the job, work regulations, and union/management agreements.

Fixed and rotating shift scheduling cycles are used in industry. The fixed pattern maintains the same working hours for long periods of time. The rotating shift requires the worker to change shifts relatively frequently. Both patterns may be adopted to a variety of working periods. "The fixed shift pattern seems the better arrangement than the weekly rotating shift pattern for the well being of the worker." (Ref 6:123). This is primarily due to the worker not continually trying to alter his basic body rhythms each month or week. This seems to be somewhat contradictory to Murrell's studies in that diurnal reversion to the normal rhythm can occur in a single day, therefore, after having a day or two off the fixed shift worker must affect a body rhythm change (from work, to normal, to work) which is the same situation as the rotating shift worker. This difficulty appears to be eased somewhat for the fixed shift worker with tenure of service on a shift and age. (Ref 13:298). Dankert and Mott, et.al. report that fixed shift workers do not experience limitations on their informal social life - visiting friends and relatives. They do, however, tend to belong to fewer voluntary associations. (Ref 13:299). Those steady shift workers who experience interference with their social life are generally the younger workers. They usually are better educated, have small children at home, and have relatively short lengths of service on their shifts. They also experience some difficulty with the time-oriented body functions - sleeping, eating, and eliminating. This interference is particularly encountered by night and afternoon shift workers. (Ref 13:300).

The rotating shift requires a continual adjustment of the body rhythms since the employee works a different shift each time period. The period remaining on one shift varies from one day to two or more weeks. Figure 7 shows several examples of shift schedules worked in industry. The rotating shift workers experience the disadvantages of working each shift. Mott, et.al. point out that rotating shift workers "report relatively greater difficulty in all activity areas (roles)." (Ref 13:298). The rotating shift worker is reported to have fewer friends and difficulty in maintaining informal social relationships. This appears to be due to friends not being able to keep track of his working shift. Those working rotation shifts report greater difficulty in adjusting their needs. They are fatigued much of the time, appetities are dulled and they are constipated much of the time. (Ref 13:299). Several studies present evidence that rotating shift workers are more likely to contract serious physical disorders than fixed shift workers. (Ref 6:117).

From studying the various experiments and research efforts concerning the length of shift cycle, it appears that there is wide spread disagreement as to the best. Murrell states that ideally periods of about one month on each shift will give the best results. Others believe that two or three days are better than seven. Still others propose the two week cycle as best. The fact is that in industry all of these shift schedules are worked and are

TYPICAL INDUSTRIAL SHIFT SCHEDULES

2-2-2 SCHEDULE

	M	T	W	Th	F	S	Su
TEAM 1	D	D	S	S	N	N	O
TEAM 2	S	S	N	N	O	O	D
TEAM 3	N	N	O	O	D	D	S
TEAM 4	O	O	D	D	S	S	N

ROTATING 6 DAY SCHEDULE

	M	T	W	Th	F	S	Su
TEAM 1	D	D	D	D	D	D	O
TEAM 2	S	S	S	S	O	O	D
TEAM 3	N	N	O	O	S	S	S
TEAM 4	O	O	N	N	N	N	N

WEEKLY 2-3 SCHEDULE

	M	T	W	Th	F	S	Su
TEAM 1	N	O	D	D	D	O	O
TEAM 2	D	D	S	S	S	O	N
TEAM 3	S	S	N	N	N	O	O

WEEKLY 6-5-4 SCHEDULE

	M	T	W	Th	F	S	Su
TEAM 1	D	D	D	D	D	D	O
TEAM 2	S	S	S	S	S	O	O
TEAM 3	N	N	N	N	O	O	O

D INDICATES WORKING DAY SHIFT
S INDICATES WORKING SWING SHIFT
N INDICATES WORKING NIGHT SHIFT
O INDICATES HAVING A DAY OFF

FIGURE 7

Source: Murrell, K.F.H., Ergonomics: Man and His Working Environment, Chapman and Hall, London England, 1969, page 437.

reported to be successful. There is a belief that the majority of men become habituated to a shift system and do not outwardly wish to change. Research indicates, however, that more rotating shift workers would like to change their shift work than those working fixed shifts. It is pointed out that perhaps a better reason for maintaining rotating shifts is that it is cheaper and fewer men are required in comparison with the fixed shift system. (Ref 13:309).

Regardless of the shift system utilized the worker is required to work either days, afternoons (swing), or nights (graveyard) shifts. There are advantages and disadvantages to each. The day shift workers diurnal rhythm is essentially normal. This is the major advantage of day shift. The worker is able to conform to most of his normal role functions. Commercial activities, such as shopping and banking, are restricted to days off or evenings. This is the same as the normal eight hour day. The afternoon shift is perhaps the most socially disadvantageous of all shifts. This is particularly true for the younger worker with small children. The social advantages are few, but many workers highly value them. (Ref 13:305). It is easier to conduct business activities. The time-oriented body functions are not altered greatly as he can sleep during "normal" hours. The night shift, on the other hand, requires serious adjustment of the diurnal cycle. The workers' sleeping habits must be changed and this effects the other members of his family. The night shift worker gets less sleep than other shift workers. In general he must live in a physically unpleasant situation. The social roles are seldom interfered with to any great extent. The greatest difficulty in role achievement for men is as sexual partners and protectors for their wives. (Ref 13:306).

In summary, there are a variety of scheduling systems that require varying degrees of adjustment from the worker. The general opinion of the working man is that he would rather not work shift work. Shift work places many demands upon the man's family as well as himself. Adjustment is usually difficult, efficiency usually falls, and he is fatigued and looses sleep. Frequently he suffers serious illness from working shift work. In many industries, such as manned spaceflight, around the clock support is necessary. The discomforts must be tolerated to insure the job is completed. The scheduler must attempt to devise a scheduling system that minimizes the discomforts as much as possible, while providing the necessary support.

There is no one system that is optimal as research has found. Generally, it appears that if rotating shifts are necessary, it is best to rotate at two to four week intervals. If possible, it is best to gain support from the worker by allowing him to assist in devising the shift schedule. In this way he is a part of the system and can obtain a degree of job satisfaction. With satisfied workers comes higher productivity and better support.

Training. In most occupations the worker goes through a continual process of learning. This is particularly true of such occupations as air traffic control, spaceflight, air defense and many others. In each of these occupations, the level of knowledge is always in a state of flux due to changes in procedures, equipment, vehicle characteristics. This requirement to maintain a currency in a particular field forms the sound and logical basis upon which a training program is constructed.

Functionally man does not ordinarily perform well without training. Training programs, therefore, are generally designed to develop new skills, increase the skill level, or maintain a level of skill or currency in a task. The first use of training, to acquire a new skill, can be seen in almost every occupation. The unskilled worker, through several methods of instruction, learns the rudiments of his skill. At the completion of this phase of training he can perform the majority of the tasks assigned. To reach the journyman level, however, he must undergo further training. Increasing his skill level often depends upon the experience and guidance of a senior worker. A great deal of knowledge is received through material studied on the man's own time. (Ref 39:104).

The last phase of training is one that continues throughout an employee's career. Zeller points out that man's "memory is not perfect" and in any activity, review is necessary. (Ref 29:21). This is particularily true when an individual is required to be knowledgable about a great number of different tasks. Learning the tasks is well within the capability of the individual. To expect him to remain proficient in all of the tasks at the same time is completely unrealistic. Therefore, periodic training and review are required. (Ref 29:21). The amount of training and review required is largely dependent on the level of mental judgement required. According to Verdier those tasks that require a low level of judgemental demand require little review effort since the tasks are easily learned and retained. Judgemental demand is defined as being required to make decisions based on knowledge acquired from intense training. (Ref 19:29). Tasks requiring medium level judgemental demand are generally of the technical or practical nature. This level of effort requires moderate training and is retained with minimum practice. High level judgemental decision tasks, on the other hand, can only be retained through continuous training and constant application of knowledge. (Ref 19:29).

Scheduling of personnel must consider all three levels of training. The scheduler must have a constant flow of data with which to properly schedule the training requirements as well as operations support requirements. He must know what each employee's skill level is and the requirements for the task to be accomplished. Gehrke points out that "a well constructed schedule which integrates all relevant data in accord with principles is indispensable since it enables projection and planning." (Ref 44:28). Therefore, the data used by the scheduler must be complete, accurate, and timely.

Training is an essential factor in maintaining efficient mission support. The experienced controller must maintain his proficiency and new people must be made proficient. This requires that training become a factor of the scheduling system.

Related Scheduling Techniques

There are a wide variety of organizations that provide continuous 24 hour, seven day per week personnel support to operations activities. To adequately understand personnel scheduling for operations support, it is necessary to analyze currently used scheduling systems. The choice of organizations' scheduling systems to study was based on:

1. The general similarity of type of work performed by the worker who must monitor dynamic data continuously.
2. Operations require 24 hour support.
3. That data be readily available.

Using these criteria, this writer selected for study the following organizations:

a. United States Air Force Strategic Air Command Combat Crew Scheduling

b. United States Air Defense Command Surveillance Operations Scheduling

c. Air Traffic Control Operations Scheduling

d. United States Air Force Satellite Control Facility Operations Scheduling

e. National Aeronautics and Space Administration Project Apollo Operations Scheduling.

Air Force Strategic Air Command Combat Crew Scheduling. The defense posture of the United States requires 24 hour, seven day a week readiness. This requires 24 hour support from Strategic Air Command (SAC) air and missile combat crews. The scheduling of these crews is an important aspect of maintaining this readiness. This discussion will consider the general nature of work and scheduling system used.

The SAC aircraft combat crew is made up of various types of occupations, pilots, navigators, gunners, flight engineers, and refueling technicians. The crew members perform largely mental work. They primarily monitor a battery of instruments, event and warning lights, and their environment. Each is a dynamic source of information which must be analyzed, evaluated, and requires decisions and judgements be made. Failure to correctly evaluate any stimuli could result in disaster and, therefore, it is a stressful job.

Missile crew composition varies with the type of missile system. Each crew member, however, is responsible for certain portions of the system. To insure continual readiness they must monitor instruments and sensing indicators. Each is a dynamic source of data that must be monitored very closely. All indications must be quickly evaluated, analyzed, and decisions made as to the correct action to be taken. Wrong actions can result in a serious situation or disaster.

The system used to schedule both air and missile crews is a centralized system. The Chief of Programs and Scheduling works for the Deputy Commander for Operations and is in close coordination with the training branch. (Ref 54:2-14). "The inherent nature of the SAC centralized scheduling process makes the scheduling branch a focal point in a complexity of human relationships." (Ref 62:56). The scheduler has a difficult task in that he must insure the operational requirements are supported and sufficient time is available to complete the training requirements.

> "The scheduler must know the strength, the weaknesses, and the desires of the crews that he schedules. He must know their problems, their like and their dislikes. These in turn, must be balanced against the needs of the mission, but not to the point of ignoring one for the other." (Ref 62:56).

In addition, he must operate under the constraints set down by Air Force and Command regulations, manuals and directives.

There is no set shift schedule system in SAC. The primary limitations for air crew scheduling are: the maximum length of alert duty is seven consecutive days;

combat crews must be granted rest and recuperation after each alert duty tour of at least 50 percent of the total time spent on alert, and the maximum work week cannot be longer than 74 hours. (Ref 56:11-6,7). The vast majority of organizations use an alert tour of seven consecutive days, and the remainder use an alternating four and three day tour. After completing the rest period the crews are then eligible to be scheduled for training or other routine duties.

Missile crew scheduling is also performed by a centralized scheduling branch. The constraints are somewhat different in that single 24 hour alert tours are generally used. The combat crew rest and recuperation policy is also in effect here. The average work week is approximately 58 hours, with a maximum of 74 hours. (Ref 56:17-4). Generally the crews are scheduled for an alert tour every third or fourth day.

The factors that are generally considered when developing combat crew schedules are: qualified personnel available, training requirements, balance of work load, schedule flexibility, personal preferences and schedule stability. The factors presented here are a consensus of factors presented by several authors writing on the subject of SAC combat crew scheduling.

__Air Force Air Defense Command.__ The Air Defense Command (ADC) performs several important functions in the defense of the United States. Among these is the task of surveillance of the air space above and around this country. It was necessary to selectively sample this organization to determine a typical scheduling system in use within the command. With the aid of ADC Headquarters' personnel, the 20th Surveillance Squadron at Eglin AFB, Florida, was selected to provide the desired information. Captain Sidney Brockman, Operations Training Officer, provided the information about the scheduling system in use in his organization.

The controllers in his organization continuously monitor dynamic data. The data is presented on displays, processed by an IBM 225D computer. The system presents tabular information about radar status and satellites under track. (Ref 64).

The scheduling system in use is not governed by any specific regulations. It is based on the mission support requirements and the number of qualified personnel available for support activities. They work eight hour rotating shifts - working two days, two swings, two nights, and have two days off. (Ref 64). According to Captain Brockman, this schedule system gives the best possible coverage and support for their operations.

When discussing the factors that govern this scheduling system, several variables were identified. Qualified personnel, skill level, and numbers of personnel available, and shift length are recognized as the most important variables. Flexibility, morale, fatigue, and training are also considered to be variables of scheduling personnel in this organization. (Ref 64).

Air Traffic Control. The Air Traffic Control operation consists of several sub-elements. These elements are approach control, precision approach (final approach) control, and control tower operations. Due to the criteria for selection of operations activities only the approach control (RAPCON) and precision approach control (PAR) units were studied. The approach control performs the task of maintaining altitude and distance separation on instrument flight requirements (IFR) for both arriving and departing aircraft. (Ref 82). The precision approach control duties consist of assisting IFR aircraft on their landing approach by giving them information about distance, altitude and position in reference to landing. (Ref 66). At Wright-Patterson AFB, Ohio, the approach control responsibilities belong to the Federal Aviation Agency (FAA). The precision approach control responsibility is assigned to the Air Force Communications System Squadron.

In both areas the Air Traffic Controllers (ATC) perform essentially the same task. They monitor radar displays which contain dynamic data. The "data" is in the form of small squares of light. Each square represents a different aircraft. The controller must identify the particular aircraft he is working with and direct it to the proper location without endangering it or other aircraft in the area. The controllers are carefully selected and highly trained to perform their tasks. Their work places a high demand on their memory and ability to keep many things in mind while arriving rapidly at well-reasoned solutions to complex problems under conditions of stress.

> "Controlling air traffic is not necessarily a stressful activity, but in situations with a high traffic density the job of the air traffic control specialist becomes stressful because it requires pushing man's capability to its limit to maintain continuous peak performance." (Ref 59:321).

The distinctive feature of the job is the ATC does not directly control his rate of work. A primary difference between RAPCON and PAR lies in the nature of their task. The RAPCON controller must keep track of many different aircraft and often must work with more than one aircraft. He vectors each aircraft in turn to or from the proper airport. When the aircraft arrives at the airport and begins its landing approach the PAR controller assists one aircraft at a time to a safe landing. It is necessary that both the RAPCON and PAR controllers work together as a team to insure the safety of those they direct.

Scheduling of FAA controllers is restricted by general policy guide lines set down in FAA handbooks. Briefly, the ATC is restricted from working more than ten consecutive hours. (Ref 41:5). He normally works an eight hour day. He must have a minimum of eight hours between shifts for rest. (Ref 41:5). It is also suggested that the number of people be matched to traffic density. There is no prescribed shift schedule, which results in a variety of systems being used throughout the agency.

Some groups use a week cycle (five consecutive days on the same shift) scheduling system. Others use a daily rotation system. The local RAPCON unit system requires a controller to work two nights, two swings, and a peak density shift (10 AM to 6 PM). The next week he would work two days, two nights and a swing shift, and so on. According to Mr. Sizer, Deputy Chief of RAPCON, this system gives maximum operations support. It also gives the controller the maximum amount of time off. An important factor in developing this schedule is that the controllers themselves were requested to plan the scheduling system that best suited their desires. (Ref 82).

There are several factors, other than the restrictions just mentioned, that are considered in development of a scheduling system for FAA controllers. Skill and qualifications of the controllers are very important. Morale, fatigue, anxiety and stress, shift rotation pattern, training, and office work are also factors. (Ref 82).

The Air Force Air Traffic controllers schedules are controlled by both FAA regulations and Air Force regulations and manuals. In general, the Air Force manuals are more restrictive than the FAA directives. This is seen in the stated maximum normal shift length of eight hours as compared with the FAA maximum of ten hours. The Air Force Air Traffic Controller standard shift length is six hours. Not more than 40 hours per week shall be worked. The only exception is in an emergency situation where 48 hours per week can be worked, but not for more than 60 days. The off-duty time cannot be less than 12 hours between each shift, and 16 hours is desirable. In addition there must be at least one 24 hour period of rest each week. (Ref 33: 2-6). The period of shift change over is also specified by regulation as not less than fifteen minutes and this time is not considered as duty time. (Ref 33:3-2).

Several other factors are considered in schedule development for the PAR controllers. Personnel qualifications and skill level is perhaps the most important single factor. (Ref 66). The team concept used in supporting the operations activities is based on the skill level of the team members. An effort is made to insure that a strong supervisor is placed with a weak team or that a relatively weak supervisor has a highly skilled team. Other factors considered are schedule flexibility, morale and training.

The scheduling system used by the Air Force PAR group is a three day rotating system. The length of shift and starting times are dictated, at this facility, by the normal traffic density. The shift lengths vary from five hours to seven hours in length. The shorter shift being during that time when the air traffic density is expected to be the greatest. A controller works three shifts and has a day off. (Ref 66). If manning permits, a spare controller is scheduled to support the operations during normal duty hours.

<u>Satellite Control Facility</u>. The Satellite Control Facility is engaged in monitoring unmanned spacecraft. Due to the nature of their work, this area is not studied in detail. It is presented since it does meet the criteria established and the data available is of sufficient interest to warrent a cursory study.

The controllers at the Satellite Control Facility monitor data collected from orbiting satellites. The data is processed by computers and is monitored on either computer driven printers or closed circuit television. (Ref 67). The prime concern of the controller in monitoring the data is the quality of the data received and the status of the space vehicle. He is required to analyze the information received and respond with the correct actions. (Ref 71).

This type of operation requires 24 hour, seven day a week support. There are no Air Force or local directives governing the scheduling of personnel for this support. According to the interviews, management decision and controller preference dictates the shift cycle and length. A rotating eight hour shift system is used. A controller is scheduled to work a particular shift for a period of time, have a few days off, then rotate to the next shift. (Ref 71). The length of time a particular shift is worked depends upon the area of support in which the controller works. This is also true of the times at which the shifts start. It was pointed out that other schedules have been tried, but for the present support level, the shift cycles in use are favored.

An indication of the effect of different management directives upon scheduling is seen in the scheduling factors used by two schedulers, each working in different programs. They agreed that personnel qualifications and skill level, and schedule flexibility are factors that should be considered. One of the schedulers feels that the training requirements, maintaining routine office work, and getting to and from work are factors that are important in a scheduling system. (Ref 71). Another proposed that shift length, fatigue and morale were important scheduling factors. (Ref 67). They both agree, however, that in their organization qualified personnel and skill level were the most important factors.

Manned Spacecraft Center. The Manned Spacecraft Center (MSC) has many responsibilities in the space program. Among them is planning and conducting manned spaceflight missions. The organization primarily responsible for this task is the Flight Control Division (FCD). This division supplies highly trained and motivated engineers, scientists, and technicians to monitor and support all phases of each flight. This discussion considers this organization, and its flight controllers, and the scheduling system used to support the Apollo moon missions. The reason for studying FCD and its scheduling techniques is to formulate a data base to compare other schedules with and for the development of a scheduling system to be used to support future spaceflight programs.

The Flight Control Division is subdivided into seven technical branches. Each branch specializes in a particular technological function. For Project Apollo these branches are: Flight Control Operations Branch, Flight Dynamics Branch, Mission Simulations Branch, Command Service Module (CSM) Systems Branch, Lunar Module (LM) Systems Branch, Lunar/Earth Experiments Branch, and Space Science and Technology Branch. The expertise of each branch is unique in that there is no cross-training between branches. This limits the individual flight controller to being able to support one system or flight function. (Ref 65).

To gain specific knowledge of the tasks the flight controllers accomplish and the type of scheduling systems used, experts within the division were interviewed. Fourteen interviews were conducted with management personnel. Those interviewed ranged from the Division Chief down to certain section heads within the branches.

The general tasks a flight controller performs consist of (1) monitoring real time data displayed on a television screen, (2) monitoring analog chart recorded data in real time, (3) assessing the status of the particular system for its capability to continue the mission and insure crew safety. The data displayed on the television screen is computer processed digital information. It is dynamic in nature, being up dated each second. The difference in jobs between systems or functions is in the manner in which the data is displayed on the television screen and the meaning of the data itself. The flight controller must be intimately familiar with his system, the mission, the mission rules, vehicle and environment. With these things in mind he must continually assess, evaluate, and make decisions concerning his system. (Ref 72). These decisions can determine the success or failure of a mission as well as directly effect crew safety. As a result each flight controller works under stress inducing conditions.

The mission activities require 24 hour, seven day a week support for the duration of the flight. This support requires the careful scheduling of the flight controllers within each branch. The design of a mission support schedule begins with the assessment of the requirements for support and the qualifications of the available flight controllers. The branch chief requests from each of his section heads recommendations for assignment of their personnel to support the various mission activities. The recommendations from each section are then brought together to form a branch schedule to support the flight. At this point each branch has developed a schedule that fits their particular needs and considers those factors they feel are the most important. The next step is for the branches to meet and formulate a single schedule that provides maximum support to the mission. The emerging schedule is an amalgamation of the individual branch schedules.

The factors that are considered to be important in schedule formulation are personnel qualifications, schedule flexibility, overtime, fatigue, morale, shift cycle, and the length of each shift. The majority of those interviewed placed more emphasis on the qualifications of their personnel. Since crew safety is paramount only those flight controllers with the highest qualifications are utilized for critical mission phase. Those that are less qualified are placed in support of less critical or non-critical activities. There is an effort to increase the skill level of each controller. (Ref 63). This effort is actually a training program, but is not often recognized as such. The other factors are considered to a smaller degree. Fatigue and morale are considered, but as a consequence of shift length and shift cycle.

The shift cycle presently used in Apollo support is a rotating eight hour shift. The flight controllers are assigned to one of three teams or shifts and work with the same team throughout the mission. (Ref 65). Due to the time of initiation of critical events it is often necessary to alter the time that the shifts begin. This results in a flight controller starting each shift at a different time. (Ref 63). Even though the shifts are basically eight hour shifts, the addition of shift change-over times, approximately one-half hour to a full hour at beginning and end of shift, stretches the shift length into nine or ten hours.

Summary

Continuous 24 hour day operations support activities are relatively common throughout industry today. A great deal of investigation has been done to insure that the production processes used are optimized. Very little, however, has been done in the area of efficient scheduling of the personnel to support these processes. The investigations that have been conducted have primarily been to determine the physical, psychological and social limitations and effects of working at various times of the day. This chapter briefly discussed some of these factors or variables that limit the effectiveness of the individual in his work environment. In particular, the environment requiring continuous visual monitoring of information sources.

Investigating the various aspects of the subject, this writer determined that there are five basic factors to be considered in developing a personnel scheduling system. These are the mission requirements, classification of personnel qualifications, identification of skill levels required, decision rule for assigning personnel to a schedule, and schedule flexibility. From these five factors are developed nine variable factors that should be considered to insure maximum efficiency and satisfaction of the worker in performance of his job. The application of these factors and variables appear to be a function of local desires and directives.

The intent of this research is to apply the information gained to the manned spaceflight support scheduling. To determine the best scheduling system for MSC-FCD several other organizations were surveyed. These groups perform similar work to the MSC flight controller, and therefore, present a picture of usable scheduling systems. The primary result of this survey has been that for the type of task accomplished, an eight hour day is the most common and provides generally acceptable results. A wide variation of shift cycle periods is used with, what appears to be, some degree of success. The majority of organizations contacted indicated that the working personnel assist in setting up the shift cycle. They also feel that consideration of the variables discussed are important to the success of shift work.

IV. Data Analysis

This chapter describes the methods and procedures used in analyzing, processing, and presenting data related to the results of this research effort. The implications of this analysis are discussed in Chapter V.

The data analyzed in this chapter are gathered from interviews and questionnaires. In each of the data sources, two areas of scheduling were discussed - scheduling factors/variables and scheduling systems.

Scheduling Factors

The following discussion presents a consensus of opinion, as interpreted by this writer, as to the validity and importance of each of the factors developed in Chapter III.

Fatigue. All of the respondents felt that fatigue is a factor that must be considered in a scheduling system. The personnel at MSC appear to be accutely aware of their personal limitations and the result of the onset of fatigue. Such things as a decreased ability to see impending or occurring failures or problems, a tendency to overlook details, a loss of mental activity, or general impairment of the thinking processes were frequently mentioned. (Ref 70). The more fatigued they become, the less cooperative they are. This results in a strain on interpersonal relationships, thereby inhibiting efficient mission support.

Complaints of physical problems such as eye strain and nervous stomachs were present. The fatigue tolerance level depends on the individual, his off-shift activities, and his dedication to the mission. Eugene Kranz, Chief of FCD, feels that fatigue will be one of the main problems of the long duration earth orbital missions. (Ref 72).

Flexibility of Schedules. Of those organizations studied, the majority declare that scheduling flexibility is necessary. They feel that flexibility is a required factor, but should not dominate the construction of the schedule. To the flight controller, this factor concerns the availability of additional qualified personnel to step into a position in an emergency. (Ref 78). It insures sufficient manpower and technical ability to support the mission. Their interest in flexibility of the scheduling system, however, appears to be the ability of the schedule to provide for leave or emergencies. The management personnel interviewed pointed out that the primary schedule flexibility requirement was to allow changes in the mission as it progressed.

Length of Shift. The employees interviewed are concerned with the number of hours worked on each shift. They feel that there are several factors which should be considered when choosing a shift length. Some of these are the distance to and from work, the length of shift team change-over time, the task loading or criticality of the mission activities, and the number of shifts worked without a day off. (Ref 70). They also feel that short breaks during the shift are important. The majority feel that an eight hour shift is the maximum shift length for maintaining mental alertness. There is a small group, however, that feel a 12 hour shift is acceptable.

Morale. "Morale can be a significant factor in personnel scheduling." (Ref 43). It is highly affected by many factors, i.e. the supervisors' methods of operation, poor scheduling, worker recognition, family problems, and job satisfaction. Interviews revealed approximately two in three felt that they had no voice in determining their scheduling system. (Ref 70). John Sizer, Deputy Chief of RAPCON, points out that this factor has a definite effect on the success of a scheduling system. (Ref 82). There appears to be general agreement that recognition is very important to morale. Unfortunately, more than half of the flight controllers feel that they receive very little individual recognition. (Ref 70). It was also pointed out that the scheduler must pay attention to the personal problems of the worker to maintain maximum worker efficiency. (Ref 68). The flight controller, in general, feels that morale has a large effect on both the individual and group, and that poor working conditions become very magnified when stretched out over long periods of mission support.

<u>Office Work</u>. The importance of office work was stressed by the higher level FCD managers. They discussed planning for the next mission, design reviews, and mission reports in connection with this factor. Carl Shelley, Chief of Space Science and Technology Branch, believes that the office work must be committed to planning for future missions. (Ref 73). Arnold Aldrich, Chief of Command Service Module Systems Branch, further states that such effort, "Requires the most knowledgable people." (Ref 75). This appears to create a delimma since the mission support activities also require the "best" people. The flight controllers view office work as a necessary evil. They feel that during periods of mission support it should be deleted or at least minimized - used only for items needing immediate attention, not long term planning. (Ref 70). They do, however, recognize the need for periodic office work to stay abreast of program progress and changes.

<u>Overtime</u>. This factor, like office work, is considered necessary by the majority of employees and employers. The flight controller feels it should be avoided if possible. Schedules should not include overtime as a requirement unless a manpower shortage dictates. They feel that overtime leads to fatigue and morale problems, which result in a decrease in mission support. Approximately 80 percent of those interviewed report that overtime pay is less motivating than time off. (Ref 70). They feel that overtime should

only be required in emergencies or on rare occasions. Overtime seems to be a relative thing - most men seem to initially like the money, but after extended periods they seem to prefer more or less normal time off for families, hobbies, etc. (Ref 63).

Personnel Qualifications. The personnel interviewed unanimously feel that this factor is extremely important to the success of their operations. Major Thomas Crowley, Chief of Wright-Patterson AFB, Air Traffic Control Facilities Branch, states that, "Skill level and experience is the most important factor in our scheduling system." (Ref 78). Eugene Kranz agrees and states that, "The success of the mission is directly dependent upon how well qualified the flight controllers are." (Ref 72). The flight controllers themselves believe that this is an extremely important factor. The more qualified the person the less his mental fatigue. They also feel that the best qualified people should be used to form a nucleus for mission support. (Ref 70). They should be evenly distributed among shifts to assist the less qualified personnel.

Shift Cycle. A concern of most personnel interviewed seemed to be their adaptability to various shifts. Approximately half the respondents felt that they have difficulty in adjusting to shift work - in particular the night shift. (Ref 70). A prime problem in 24 hour scheduling is the shift rotation pattern. (Ref 80). The flight controllers feel that this is a very important factor as it can accelerate fatigue and affect morale. The frequency of shift rotation is important since sufficient time is needed to adjust to a shift. The time off between shifts is also important to allow the employee time to rest and recuperate. There is also a desire for time off during normal business hours. This can best be accomplished by a schedule that requires everyone to work a balance of day and night shifts.

Training. Training and related proficiency is seen by FCD as one of the most significant problems that must be faced in the MEOL type mission. "We must teach the flight controller to be knowledgable enough to deal with the increased complexity of the spacecraft and the ground support systems." (Ref 72). Training of the flight controllers takes many forms and is continuous. The best training method is on-the-job training. Inexperienced personnel should be able to have limited responsibility while working with a senior flight controller. The controllers feel that training should be required during the long duration mission to achieve or maintain a desired proficiency level. Caution should be exercised, however, to really train a person for his speciality in detail and not give him a lot of extraneous information to "just fill in the squares". (Ref 70). A large part of the training of the flight controller can be left up to him. It is his responsibility to complete his training. Adequate training opportunities for new personnel as well as experienced controllers must be a factor in scheduling so it will not fall short or conflict with the real mission schedule.

Verification of Factors

The first task in analysing the questionnaire data is to verify the tentative factors as being important to the scheduling process. If a factor is not verified then it will be discarded from the list of variables.

In Chapter II, the discussion of the design of the questionnaire indicated that verification of the tentative factors will be accomplished by asking the respondent whether or not he perceives the variables as being factors. The number of yes responses are then counted.

> "... an appropriate data analysis technique for this type of data is counting the number of yes responses and computing the percent of yes responses for each factor. The remaining question is how many percent of the respondents must answer yes for that factor to be verified." (Ref 58:52).

An arbitrary process can be used to arrive at such a decision rule. The decision rule that was used by Stahl can also be used for this research.

> "The decision rule that was adopted is to arrange the factors in descending order by percent of yes responses and then to discard those factors that appear on the list after a large jump downward in percent of yes responses between two successive factors." (Ref 58:52).

The magnitude of this jump is dependent upon the researcher. Stahl used a 15 percent jump, but suggests that any number can be used as easily. The size of the jump, in this writer's opinion, should be at least 15 percent or larger.

A total of 80 questionnaires were sent to selected personnel in FCD. Seventy-two were sent to a random selection of flight controllers. Eight were sent to FCD supervisors. Fifty flight controllers returned their questionnaires. Of this number, 43 were complete, six were incomplete, and one was blank. Only four of the eight supervisors returned their questionnaires. For analysis the questionnaires were divided into four stratifications. They were: (1) supervisor, (2) flight controllers - but not supervisors, (3) civil service flight controllers, and (4) contractor flight controllers.

Table I lists the factors and the percentage of respondents answering yes. These percentages are based on 49 flight controller and four supervisor respondents. The flight controller sample is further stratified into 29 civil service employees and 20 contractor employees.

Table II shows the variables in order of decreasing percentage of yes responses. Each stratification is shown separately.

The largest decrease in percent of yes responses is six percent for the flight controllers as a group. When looking at the civil service and contractor subdivisions

TABLE I

Percent of Affirmative Responses to Scheduling Factors

	Factor	Percent of Supervisors	Percent of All Controllers	Flight Controllers Percent of Civil Service	Percent of Contractor
1.	Fatigue	100%	100%	100%	100%
2.	Flexibility of Schedules	100%	94%	97%	90%
3.	Shift Length	100%	94%	97%	90%
4.	Morale	100%	92%	93%	90%
5.	Office Work	100%	80%	79%	80%
6.	Overtime	100%	82%	83%	80%
7.	Personnel Qualifications	100%	98%	97%	100%
8.	Shift Cycle	100%	96%	97%	95%
9.	Training	100%	88%	90%	85%

Note: Above percentages based on responses from 49 flight controllers, of which 29 are civil service and 20 are contractors, and four supervisors.

TABLE II

Ranking of Scheduling Factors

According to Yes Responses in Decreasing Order

Flight Controllers Ranking of Factors			Civil Service Flight Controllers Ranking of Factors			Contractor Flight Controllers Ranking of Factors		
1.	Fatigue	100%	1.	Fatigue	100%	1.	Fatigue	100%
2.	Personnel Qualifications	98%	2.	Flexibility of Schedules	97%	2.	Personnel Qualifications	100%
3.	Shift Cycle	96%	3.	Length of Shift	97%	3.	Shift Cycle	95%
4.	Length of Shift	94%	4.	Shift Cycle	97%	4.	Length of Shift	95%
5.	Flexibility of Schedules	94%	5.	Personnel Qualifications	90%	5.	Flexibility of Schedules	90%
6.	Morale	92%	6.	Morale	93%	6.	Morale	90%
7.	Training	88%	7.	Training	90%	7.	Training	85%
8.	Overtime	82%	8.	Overtime	83%	8.	Office Work	80%
9.	Office Work	80%	9.	Office Work	79%	9.	Overtime	80%

Note: The supervisors' ranking of factors is not shown since all factors were considered essential to scheduling systems and rated at 100%.

this percentage increases to seven percent and five percent respectively. This is not a sufficient decrease in response to fail to verify the scheduling variables. Therefore, the entire list of tentative factors is verified.

Respondent Suggested Factors

Several additional factors were suggested by the respondents as being important to scheduling. There were a total of 15 factors suggested. All but four can be directly catalogued into the nine verified scheduling factors.

The four suggested factors that cannot be directly placed within the variables concern mission requirements. As was stated in Chapter III, mission requirements shape the personnel support schedule. For this reason it is not considered as a factor in this research. A brief enumeration of these four factors, however, may give the reader a better view of the importance of mission requirements. The suggested factors were:

1. Type of mission and ground coverage during the mission
2. The degree of support required
3. Mission length
4. Mission activities.

Some of the remaining eleven suggestions should be listed due to their importance to the success of mission support.

Four of the suggested factors are identified as being associated with morale. Respondents suggested that the work environment is important. This includes the physical facilities as well as work atmosphere. The general cleanliness, accessibility to food, restrooms, supplies, and allied support personnel is vital. Developing and working with a team to pull together is important as is enthusiasm and dedication to get the job done.

Seven respondents made suggestions concerning schedule flexibility and the shift cycle. Vacation, leave and emergencies must be accounted for in the development of the schedule. Personal business, however, should be accomplished during the normal days off provided for in the shift cycle. The time of day the shift starts is important as is the number of days on a particular shift. There may also be certain personal limitations that a controller may have that would not permit working a particular shift.

Ranking of Factors

The respondents were ask to rank the variables in order of importance after deciding whether the items are a factor of scheduling systems.

> "The rating an individual (factor) receives indicates simply his relative rank or position in the group being studied; it would not necessarily be of any usefulness apart from the specific group whose members are being compared." (Ref 17:350).

The usefulness of ranking the variables is to assess their relative importance as seen by the flight controller. In knowing this, the scheduler can then place more emphasis on one than on another if necessary.

In ranking a series of items there are inherent sources of unreliability. One of the most frequent is the frame of reference of the one who does the rating. When different people rate a list of factors it is possible that they will use different frames of reference. To minimize this effect, the characteristics being measured must be carefully defined and the scale of the rating system must be clearly specified. (Ref 17:353). Explicit instructions and careful definition of those factors being ranked were provided. A certain amount of unreliability is present simply due to the individuality of each flight controller. Therefore, this effect can only be minimized.

Table III lists the scheduling factors in order of preference as seen by the FCD supervisors, subordinates, civil service employees, and contractor employees. The relative ranking of these factors between groups is different. The question arises, is there a significant difference between groups?

To test the degree of significance between rankings the Spearman rank-correlation coefficient test was used. This technique establishes the covariability between two groups drawn from a bivariate population whose distribution is unknown. (Ref 5:628). This rank-correlation is applied to a set of ordinal ranked numbers for n pairs of individuals

TABLE III

Scheduling Factor Preference

Factor	Supervisors	Flight Controllers	Civil Service Flight Controllers	Contractor Flight Controllers
1. Fatigue	1	2	3	2
2. Flexibility of Schedules	6	6	6	7
3. Length of Shift	4	4	4	4
4. Morale	3	5	5	5
5. Office Work	8	9	8	9
6. Overtime	9	8	9	8
7. Personnel Qualifications	2	1	1	1
8. Shift Cycle	5	3	2	3
9. Training	7	7	7	6

Note: Rankings are based on responses from 49 flight controllers and four supervisors.

or items.

The Spearman's rank-correlation coefficient is defined as

$$r_s = 1 - \frac{6 \sum d_i^2}{n\ (n^2 - 1).}$$

The d_i is defined as $(x_i - y_i)$, where x_i is the rank of the ith variable of one group and y_i is the rank of the ith variable of the other group, and n is the number of pairs in the bivariate population. A r_s coefficient value of +1 indicates the ranking agrees perfectly. A value of -1 indicates the ranks are exactaly opposite. A zero r_s represents the absence of any relationship between the two sets of ranks. (Ref 5:629).

For values of n greater than 8 but less than 20 the equation should be corrected to

$$r_s = 1 - \frac{\sum d_i^2}{1/6\ (n)\ (n^2 - 1) + 1.}\quad \text{(Ref 5:629).}$$

This coefficient can then be used to test an appropiately worded hypothesis against an alternative by using the Student t distribution with n-2 degrees of freedom. The t statistic is given by

$$t' = \frac{r_s\sqrt{n-2}}{\sqrt{1 - r_s^2}\ .}\quad \text{(Ref 5:629).}$$

This test is appropiate when no ties in rank exists.

It was desired to test the correlation of the rankings between respondent groups. The correlation was tested between (1) supervisors and flight controllers, (2) supervisors and civil service flight controllers, (3) supervisors and contractor flight controllers, and (4) civil service and contractor flight controllers.

No ties were experienced in the data presented, therefore, the Spearman rank-correlation test can be used with appropriate hypotheses. The hypotheses were tested at a .05 significance level. For each of the tests conducted H_0 represents the null hypothesis and H_1 is the alternate hypothesis.

<u>Hypothesis 1</u>. H_0: There is no correlation between the rankings of the scheduling variables by the supervisors and flight controllers.

H_1: There is correlation between the rankings of the scheduling variables by the supervisors and flight controllers.

The data used in testing this hypothesis are contained in Table III. The calculated Student t' value (6.54) exceeds the Student t critical value (2.365) at .05 significance level and 7 degrees of freedom. These values require H_0 to be rejected and H_1 to be accepted. Thus, there is correlation between the rankings of the variables by the supervisors and flight controllers.

<u>Hypothesis 2</u>. H_0: There is no correlation between the rankings of the scheduling variables by the supervisors and civil service flight controllers.

H_1: There is correlation between the rankings of the scheduling variables by the supervisors and civil service flight controllers.

The data used in testing this hypothesis are contained in Table III. The calculated $t'_{.05,7}$ value of 5.03 exceeds the critical $t_{.05,7}$ value of 2.365. The null hypothesis is therefore rejected and H_1 accepted. That is, the rankings of the variables between the supervisors and civil service flight controllers is correlated.

<u>Hypothesis 3</u>. H_0: There is no correlation between the rankings of the scheduling variables by the supervisors and contractor flight controllers.

H_1: There is correlation between the rankings of the scheduling variables by the supervisors and contractor flight controllers.

Table III contains the data that were used to calculate the Student t values. A $t'_{.05,7}$ value of 9.89 is greater than the critical $t_{.05,7}$ value of 2.365. The null hypothesis is therefore rejected and the alternate is accepted. Thus, the ranking of the variables between the supervisors and civil service flight controllers is correlated.

Hypothesis 4. H_0: There is no correlation between the rankings of the scheduling variables by the civil service flight controllers and the contractor flight controllers. H_1: There is correlation between the rankings of the scheduling variables by the civil service flight controllers and contractor flight controllers.

Table III contains the data used to calculate the hypothesis test values, The $t'_{.05,7}$ was calculated to be 4.02 as compared to a $t_{.05,7}$ value of 2.365, which results in rejecting H_0. The alternate hypothesis is accepted, which indicates there is correlation between the rankings of the scheduling variables by civil service and contractor flight controllers.

Table IV shows the correlation factors and the results of testing the above hypotheses. All of the null hypotheses were rejected. Therefore, there is no significant difference at the .05 level of significance, in correlation between the ranking of supervisors and flight controllers or between civil service and contractor controllers.

Ranking of Scheduling Systems

Part Three of the questionnaire contained five suggested scheduling systems. The systems presented were designed to present a variety of conditions to the flight controller. Their preferences for a particular system would also indicate a preference for that particular set of conditions.

TABLE IV

Schedule Factor Rating Hypothesis Test

Group	Correlation Factor	Student t Critical Value	Calculated t'	Accept H_0
Supervisors vs Flight Controllers	0.912	2.365	6.54	No
Supervisors vs Civil Service Controllers	0.835	2.365	4.02	No
Supervisors vs Contractor Controllers	0.885	2.365	5.03	No
Civil Service Controllers vs Contractor Controllers	0.994	2.365	9.89	No

Note: 1. Critical Student t based on a .05 level of significance and 7 degrees of freedom.
2. The null hypothesis H_0 is rejected if calculated t' exceeds the Student t critical value. This indicates that there is correlation between the rankings.
3. The correlation coefficient is a measure of degree of agreement between groups as to rank of the factors. A correlation factor of 1 indicates perfect positive agreement.

<u>Scheduling System One</u>. The first scheduling system proposed required the flight controller to work four 12 hour shifts, have three off, work three 12 hour shifts, followed by four off. The cycle would then repeat. After completion of two cycles of day shifts, the flight controller would rotate to working the night shift. Upon completion of two night shift cycles, he would rotate to the office to perform a routine 40 hour week office work. This is assuming that there are enough qualified personnel available to form at least five teams. If only four teams are available, the controller would rotate from day to night to day shifts for the duration of the mission. This scheduling system requires the flight controller to work 84 hours per two week period (pay period) during mission support. This does not include the time required for team change-over, which would be at least seven hours. If five teams are available 80 hours per pay period of office support time is required. Six teams require 160 hours of office time per pay period, and four teams require no office time.

The primary disadvantage of this schedule is that the flight controller works 12 hour shifts. The data presented in Chapter III points out that this length of shift is unacceptable due to fatigue and decrease in mental awareness. The flight controllers themselves feel that 12 hour shifts are entirely too long. The amount of overtime is high in comparison with the eight hour shift schedules. One significant advantage is that the number of people required is less than an eight hour shift.

Reducing the length of shift in this scheduling system accomplishes three things. The overtime is reduced to zero. The number of hours required for office work is reduced to 16 hours each two week period. This assumes one hour additional time is required per shift for team change-over. The third item is the length of shift is reduced to a more acceptable eight hours. This reduces fatigue and increases efficiency. The disadvantages of an eight hour shift are: six flight controller teams are required and the schedule flexibility is slightly decreased. Due to the number of people required for mission support fewer are available to substitute for, or supplement, the mission support flight controllers.

Scheduling System Two. This scheduling system requires the flight controller to work four 12 hour shifts, have two off, work four, etc. After working two cycles of four day shifts on and two off, the controller would rotate to the night shift. Completion of the night shift cycles would find the controller working normal days (40 hour week) in the office. Teams assigned to office duties would be required, on a rotating basis, to perform two days of mission support each six days. A minimum of five teams are required, with six providing more optimum support. The overtime requirement is approximately 30 hours per two week period with six teams and 40 hours with five teams. The time devoted to office work is approximately 40 hours each two week period for either five or six teams.

The primary disadvantages of this shift schedule are length of shift, high overtime, and office time requirements. The relatively short time between shifts is also a disadvantage since it could promote fatigue. The advantage is that a minimum of five teams is required.

Using this system and an eight hour shift requires the flight controllers on some two week periods to not achieve 80 hours for pay. This would occur only every third pay period. Approximately ten hours of overtime would be accrued during each of the other two pay periods. Using the eight hour shift, a minimum of six teams would be required. As in System One an advantage is reduced fatigue. Flexibility is slightly improved over System One as the controllers assigned primary office duty are available on four of six days for substitution into a mission support position.

Scheduling System Three. In Scheduling System Three the flight controller works three shifts and is off three. Each shift is 12 hours long plus team change-over time. The same shift is worked four times before rotating to another shift. At the end of four cycles of day shifts, the controller would rotate to the night shift. After completion of the night shift cycles, he would begin working normal office hours (40 hour week). A minimum of four teams is required, however, this number would not support office work. Five teams are required to support both the mission and office duties. A flight controller would average four hours of overtime each two weeks. With five teams, 80 hours per two week period is required for office time. The office time requirement for six teams is 160 hours per pay period.

This scheduling system closely approximates Scheduling System One. The 12 hour shift length is a primary disadvantage. The time required on mission support is very short and adjustment would be difficult to achieve - particularly on the night shift. The advantage is that a minimum of five teams are required to support both the mission and office duties.

An eight hour shift instead of 12 hours requires six teams be available. Personnel available for office work is reduced as is the availability of substitute flight controllers. The flight controllers would be required to spend one to two days of their days off each pay period in the office. This is required to reach the 80 hour pay period requirement. Overtime is reduced to zero.

<u>Scheduling System Four</u>. Scheduling System Four is a continuously rotating eight hour shift. The flight controller would work two days, two swings and two night shifts, then have three days off. At the end of the time

off the cycle would repeat and continue throughout the duration of the mission. Six teams are required to support this system. The number of hours of overtime varies from zero to twenty, including team change-over time, and depends on the number of shifts worked in a pay period. Every second two week period requires one day of office support to meet the 80 hour requirement, with the other periods having the overtime. The flight controller's work week varies from 36 to 54 hours, including team change-over time.

The advantage of this schedule is the eight hour shift length. This minimizes fatigue, aids effectiveness, morale and improves mission support. The distribution of the good and bad aspects of all three shifts are evenly shared by the controllers. This is often considered an advantage. It is also often considered a disadvantage as the individual rarely becomes physiologically adjusted to this work pattern. The result is increased fatigue and decreasing effectiveness. The amount of schedule flexibility and support for office work is limited since very few controllers are available for these duties at any one time. Other effects may be seen in poor morale.

Scheduling System Five. In this scheduling system, six teams are required. The flight controller works four shifts followed by four off. At the end of two cycles on a shift he would rotate to another shift. If working days he would rotate to the swing shift or from swing to nights or nights back to days. The rotation is continuous and occurs every 16 days. The controller must spend from one to two days of his "off days" each two week period working in the office. This is required to meet the 80 hour pay period requirement. The actual number of days required is dependent on the number of shifts worked and the length of time he requires for team change-over each shift. This scheduling system has no overtime.

The advantage of this scheduling system is that an eight hour shift is worked. This minimizes fatigue. The rotation cycle is of sufficient length to allow for at least partial physiological adjustment. It is a stable system that allows the controller to plan his off time. The four days off are sufficient to allow him to be fully rested when he returns to work. A disadvantage, however, is that he may loose the continuity of mission activities during these four days off. This would reduce the level of support during the first shift back at work. This, however, is also true of schedules One and Three. The schedule flexibility does suffer somewhat from lack of people in the office as does office work and training requirements.

The five proposed scheduling systems present a narrow, and hopefully representative, view of scheduling systems. There is a multitude of schedules that can be devised and successfully implemented. This writer realizes that the changing of one or more aspects, such as shift length, would have possibly altered the flight controllers' stated preferences. The systems were devised, based on data available, to be representative of the most favorable scheduling systems for the flight controller.

Evaluation of the Systems Ranking. The respondents were ask in the questionnaire, based on his understanding of the schedules and the factors previously evaluated, to rank the schedules. The rank order indicates his order of preference of the systems proposed. Table V contains the tabular listing of the ranking of the scheduling systems. Comparison of the four stratifications reveal that there is complete agreement as to their preference. This indicates a decided preference for an eight hour shift that rotates every 16 days. If, however, a 12 hour shift is required, they would prefer to work three days followed by three days off. There is also definite agreement that frequent shift rotation is least desirable.

Miscellaneous Factors

Part Two of the questionnaire also requested information concerning the working hours of the flight controller. The questions were stated to gain an idea of their preference to the number of hours to be worked, the shift most desired, the time preferred to begin work, and the frequency of shift rotation. This information was gathered to provide an insight to the type of shift system that would be most preferred by the flight controllers.

TABLE V

Rating of Proposed Scheduling Systems

Scheduling System	Supervisors	Flight Controllers	Civil Service Controllers	Contractor Controllers
1. System One (4 on-3 off 3 on-4 off)	3	3	3	3
2. System Two (4 on-2 off)	4	4	4	4
3. System Three (3 on-3 off)	2	2	2	2
4. System Four (2-2-2-3)	5	5	5	5
5. System Five (4 on-4 off)	1	1	1	1

Note: A value of 1 indicates the most prefered schedule, while a value of 5 indicates the least preferred.

The rankings based on the responses of 43 flight controllers and four supervisors.

Table VI lists the preferences of the employees' desired working hours. A majority of the respondents, 78 percent, prefer to work eight hour shifts. In the course of the interviews this was highlighted by the comments received. The majority feel that the type of work they perform is too taxing to work more than an eight hour shift. They are mentally and physically exhausted at the end of this time. Another factor that cannot be forgotten is the time required for shift change-over which often stretches the shift length to nine or ten hours.

Three choices of shift rotation periods were presented: (1) rotate on short intervals - two to three days; (2) rotate at intervals of two weeks; (3) not rotate, but work the duration of the mission on the same shift. The results indicate that 56 percent of the flight controllers desire to rotate their shifts at some interval of approximately two weeks. When looking at the subgroups this preference is also evident. The dislike of frequent rotation is evident in that only 14 percent of those responding preferred to rotate shifts at short intervals. A larger group preferred fixed shifts, 26 percent, but this was not a significantly large number. In the contractor group the percentage of controllers preferring fixed shifts was not as high as for the other groups.

When given the choice of working an eight hour day, swing, or night shift, approximately half chose the day shift. The swing shift was preferred by 24 percent, and

TABLE VI

Expressed Preference for Shift Hours

Factor	Total Sample	Civil Service	Contractors
Prefer 8 Hour Shifts	78%	79%	86%
Prefer 12 Hour Shifts	22%	21%	14%
Prefer Shift to Rotate Daily	14%	11%	21%
Rotate every Two Weeks	56%	68%	43%
Rotate every Four Weeks	26%	21%	36%
Given that he must work 8 hours a day the flight controllers preferences were:			
Prefer the Day Shift	57%	50%	79%
Prefer the Swing Shift	24%	32%	7%
Prefer the Night Shift	19%	18%	14%
Prefer to start the day shift at:			
6 AM	19%	18%	21%
7 AM	21%	18%	37%
8 AM	36%	43%	21%
9 AM	24%	21%	21%
Given that he must work 12 hours a day the flight controller preferences were:			
Prefer the Day Shift	71%	68%	79%
Prefer the Night Shift	21%	32%	21%
Prefer to start the day shift at:			
6 AM	38%	39%	43%
7 AM	17%	14%	29%
8 AM	14%	14%	21%
11:30 AM	29%	29%	7%
2 PM	2%	4%	-

Note: The percentages are based on responses from 43 flight controllers, 27 of whom are civil service and 16 of whom are contractor flight controllers.

the night shift by 19 percent. These figures were approximately the same for the civil service and contractor groups. The contractors, however, expressed a greater preference to work days rather than nights or swing shifts. No conclusive results are evident about the time of day the controllers prefer to start the day shift. A slight preference for a normal day is seen in the number favoring the 8 AM start time.

To explore the 12 hour shift, the same type of questions were ask as for the eight hour shift. Again the day shift is preferred by a large majority, 71 percent. There seems to be two preferences as to the time of the day shift starts. Approximately 38 percent prefer to begin work at 6 AM, while 29 percent prefer to start at 11:30 AM. The contractor group did not show this characteristic. A 6 AM start time is preferred by 43 percent of this group. When considering the total group, however, a small preference does exist for a 6 AM shift start time.

Summary of Scheduling Systems in Use

Table VII graphically illustrates the scheduling system in use in each of the eight organizations studied. Five of these organizations work eight hour shifts. A variation of a rotating shift is used with each having a different rotation period. The two most consistant points are the eight hour shift length and the 7 to 8 AM time of starting the day shift.

TABLE VII

Scheduling Systems In Use Today

	Length of Shift	Shift Rotates	Shift Cycle	Day Shift Starts	Hours Regulated by Reg.
Strategic Air Command Air Crews	24 hr	no	7 on 3½ off	6 AM	yes
Missile Crews	24 to 40 hr.	no	1 on ½ off	6 AM	yes
Air Defense Command	8 hr	yes	2-2-2-2	7:30 AM	no
Air Traffic Control FAA	8 hr	yes	2 days per shift	8 AM	yes
Air Force	5 to 7 hr	yes	rotates daily	7 AM	yes
Manned Spacecraft Center	8 hr	no	fixed	varies	no
Satellite Control Facility System 1	8 hr	yes	every 4 days	7:30 AM	no
System 2	8 hr	yes	every 2 weeks	8:30 AM	no

Note: 1. The SCF scheduling is different for each system or spacecraft being orbited.

2. The MSC schedules are based on the Apollo program.

3. The data presented in this table represents the opinions of individuals and not necessarily that of the organization.

Table VIII is a comparison of the scheduling factors that each organization studied uses. The only factor that is considered important to all organizations in their scheduling systems is qualified personnel. This is natural since without qualified personnel the organization cannot function.

TABLE VIII

Scheduling Factors of Various Organizations

Factor	Organizations						
	SAC air crews	SCF		ATC		ADC	MSC
		Sys. 1	Sys. 2	FAA RAPCON	AF PAR		
Fatigue	yes	yes	-	yes	yes	yes	-
Flexibility	yes	yes	yes	yes	yes	yes	yes
Length of Shift	-	yes	-	yes	yes	yes	yes
Morale	yes	yes	-	yes	yes	yes	-
Office Work	yes	-	yes	yes	-	-	yes
Overtime	-	-	-	yes	yes	-	yes
Qualified Personnel	yes	yes	yes	yes	yes	yes	yes
Shift Cycle	yes	yes	-	yes	yes	-	yes
Training	yes	-	yes	-	yes	yes	yes

Note: 1. The SCF scheduling is different for each system or spacecraft being orbited.
2. The MSC schedules are based on the Apollo program.
3. The data presented in this table represents the opinions of individuals and not necessarily that of the organization.

V. Summary, Conclusions and Recommendations for Further Study

Summary

In mid 1973, NASA will initiate the first of a series of manned earth orbiting laboratory space missions. To support these vehicles and their crews a large ground based staff of engineers, technicians, and scientists will be required. The efficiency with which this support is provided will determine the success or failure of the program.

This research was designed to explore personnel scheduling systems and the factors that govern these systems, as applied to the manned spaceflight effort. The objective was to provide a basis for the development of a scheduling system that could provide efficient flight controller mission support.

A literature search revealed that many authors have written about the scheduling of production processes. Few have explored personnel scheduling per se. Analysis of the areas related to the scheduling of workers uncovered a great deal of material about the effects of scheduling systems on the employee and his environment. The majority of these efforts, however, has been conducted in the laboratory. From the literature search, a number of tentative scheduling factors was identified. To be listed as a factor an arbitrary decision rule was used - the factor must be identified by three or more authors or organizations. Using this decision rule, a list of nine variable factors was developed.

To support and supplement the theoretical data obtained from the literature studies, interviews were conducted at six organizations. The organizations were chosen for similarity of work along with other criteria. Data were also obtained from approximately 75 interviews. The information gathered provided data on scheduling systems currently in use in industry. Data on the interrelationships of the scheduling factors were also obtained.

To verify whether or not the tentative scheduling factors are important to the scheduling of the flight controller for long duration missions, a questionnaire was used. The questionnaire verified the factors by asking the respondent if he perceived it to be important to him. He was asked to rank those factors he perceived as being important. In addition, he was asked to express a preference as to the length of shift, shift to be worked, shift rotation cycle, and the time of day he would begin work. This information presents a picture of the preferences and relative importance he places on the various scheduling factors. The questionnaire also contained five proposed scheduling systems. A random selection of 72 flight controllers and eight supervisors from the Flight Control

Division, Manned Spacecraft Center, were selected to receive this questionnaire.

The data obtained from the questionnaires were classified in four catagories: supervisor, all flight controllers, civil service flight controllers, and contractor flight controllers.

The scheduling factors were verified by counting the affirmative responses for each factor. An arbitrary decision rule was developed to determine whether to reject any of the factors or not. None of the factors was rejected. The ranking of the factors was classified into their respective catagories and analyzed.

Four hypotheses were developed to test the degree of correlation between the ranking of the four groups. The Spearman rank-correlation test was used to test the significance of correlation. In each case the null hypothesis was rejected. This indicates the ranking of the factors by each group is essentially the same.

The data obtained from the questions concerning shift working hours were tabulated as percentages of affirmative responses.

The controller's preference for working any of the proposed scheduling systems was indicated by his ranking of the scheduling systems. The sample ranking is considered indicitive of the entire Flight Control Division. This data was also catalogued into the four groups. The inferences that are drawn from this data are presented in the conculsions.

Conclusions

One of the primary purposes of this research was to identify the factors that govern scheduling of flight controllers. The results of the literature study, interviews, and questionnaires are a list of nine variables that are identified as being essential to flight controller scheduling for MEOL type missions. These factors are: fatigue, flexibility of schedules, length of the work shift, morale, office work, overtime, personnel qualifications, shift cycle and training.

It was desirable to determine the relative importance of these factors, and whether or not there is a difference in importance as perceived by the supervisors and flight controllers. The factors were ranked by these groups and a correlation between them was calculated. The correlation coefficients indicate a strong positive correlation in the rankings. Based on four hypotheses, statistical tests were calculated. Table IV contains the results of this testing. In each case the null hypothesis was rejected. It is therefore concluded that the supervisors and flight controllers perceive the relative importance of the nine scheduling factors in the same order.

The rankings of the scheduling factors is an indication of the importance they have on the efficiency of the flight controller support. The most important being personnel qualifications, fatigue, shift cycle and length, morale, and flexibility of the schedule. It is concluded that the scheduler should carefully consider these factors for maximum flight controller support. It is also concluded that worker participation in the development of a scheduling system assists in the success of the system.

In analyzing shift work and schedules, the flight controller was asked to state his preference as to work hours and shift rotation systems. Table VI is a summary of these results. It is concluded that the flight controllers prefer to work eight hours per shift and generally prefer a shift that rotates not more often than every two weeks.

Approximately 57 percent of the flight controllers expressed a preference to work the day shift, 24 percent wish to work the swing, and 19 percent prefer the night shift. The inference is that the supervisor and schedulers should identify and use those flight controllers to work the shift they most desire. This would promote better morale and could increase worker efficiency.

The scheduling systems in use in the organizations studied are displayed in Table VII. The scheduling systems used are generally based on an eight hour shift. The type and frequency of shift rotation varies widely and is a function of the type of work done, the desires of the personnel, and regulations. To promote maximum efficiency of the worker, the factors discussed previously must be considered in the scheduling system. Therefore, it is concluded that the scheduling system must be tailored to the task and the needs of the worker.

A primary purpose of the author was to propose a scheduling system that best satisfies the needs of the FCD organization, its mission and the flight controller. The schedule that is chosen must consider the nine variable factors and be accepted by the flight controllers. The system should require the flight controller to work no more than eight hour shifts. The work week should be no longer than 40 hours. The shift rotation cycle would be no less than two weeks. Overtime and office work must be minimized. The schedule should tend to increase morale. Fatigue can be minimized by proper schedule design. The flight controller should be afforded the opportunity for short breaks - every one to one-and-one-half hours. Time must be available for training and the scheduling system should be able to absorb unexpected events. Personnel qualifications must also be considered. With these factors and the data presented in this research, it is concluded that of the proposed scheduling systems, the fifth schedule is the best. This system requires the controller to work four shifts followed by four days off. This system is discussed in detail in Chapter IV.

This schedule requires the flight controller to work eight hours per mission support shift and an average of 64 hours per two week period not including team change-over time. Considering the time required for team change-over, he is required to work one to two days in the office each two week period to meet the 80 hour pay period requirement. This can reduce the necessity for overtime. The shift rotation cycle is 16 days. The effects of fatigue are minimized both by the eight hour shift and the four days of rest between work periods. This schedule is preferred by most of the FCD personnel responding to the questionnaire. Table V illustrates their preference for the proposed scheduling systems. From this, it is inferred that this schedule will provide maximum mission support and at the same time maintain maximum flight controller efficiency. In addition morale would be better working on this schedule than the others. Flexibility, personnel qualifications and training requirements must be incorporated by the scheduler as required.

To summarize, the following conclusions are drawn. There are nine factors that should be considered in developing a scheduling system. There is strong agreement in the relative importance of these factors as perceived by the personnel in FCD. These factors are best incorporated in a scheduling system that has eight hour shifts, and works four shifts, with four days off.

Recommendations for Further Study

It is recommended that a study be conducted in Flight Control Division to investigate the degree of job satisfaction of the flight controller as a function of schedule parameters. This study should be conducted in two phases. The first phase should be conducted prior to the completion of the Apollc program. The second phase should be accomplished after the first Skylab mission is completed. The degree of job satisfaction can then be compared to determine the effects of long duration mission support on the flight controller.

It is also recommended that a study be conducted to determine the feasibility of a computerized scheduling system for FCD. This would use the data presented in this effort as a base for development of the system.

Finally, it is recommended that a study of the effects of fatigue on the flight controller be conducted. This should be accomplished to explore the effects of eight and 12 hour shifts, the length of flight controllers' actile period, and the optimum length and frequency of the rest period. This study should be accomplished under conditions closely approximating those experienced in mission support activities.

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Appendix A

Flight Controller Mission Support Activities

Flight Controller Mission Support Activities

The Manned Spacecraft Center is located in Houston, Texas. The Center's responsibilities include: "Design, development and testing of the spacecraft and associated systems for manned flight; selection and training the astronauts; planning and conducting the manned missions; and scientific experiments that are helping man understand and improve his environment." (Ref 49:1). Within the Center are a variety of divisions, each responsible for a particular phase of the Center's mission. Flight Control Division has the responsibility for planning and conducting the manned missions.

The Flight Control Division consists of seven branches, each responsible for a particular phase of the Division's mission. The FCD organizational chart is shown in Figure A. This chart shows the relationships of the branches and the sections within the division. Each of the branches have specific responsibilities that are not duplicated in any other branch. The personnel assigned to FCD are highly trained technicians, engineers, and scientists - flight controllers.

Each flight controller is a specialist. His speciality is limited to a specific system within a specific type of spacecraft. He is required to know initmately every detail of his system within each spacecraft prior to flight.

FLIGHT CONTROL DIVISION
ORGANIZATION CHART

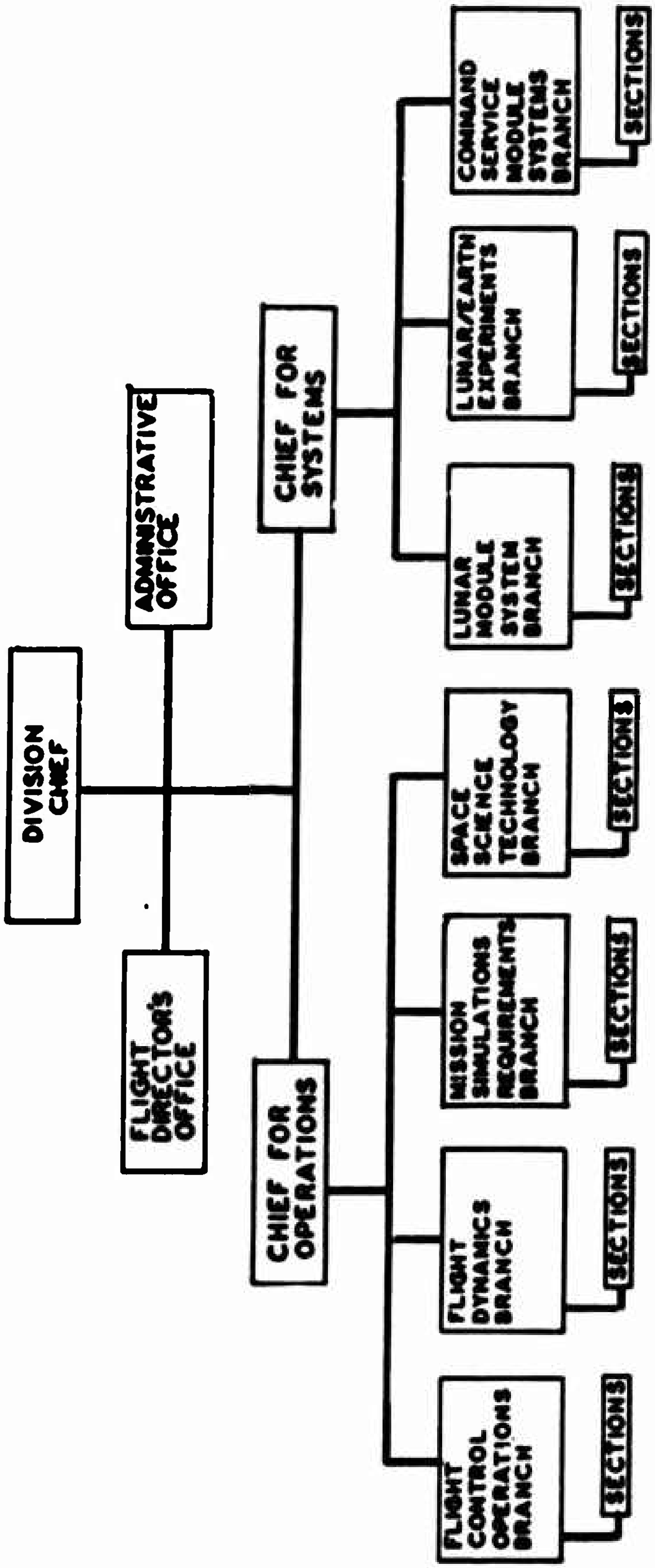


FIGURE A

The preparation for a mission never ceases. The flight controller must plan every phase of the mission in the most minute detail. Every conceivable failure of the system must be carefully thought out - its failure indications, the implications and effect on other systems, and what actions must be taken to protect the astronauts, the vehicle and the mission. These are written into mission rules, abort plans and contingency actions that govern the controller's actions throughout the mission. (Ref 50:83). This planning of mission rules, test objectives, abort plans, and flight plans is an iterative cycle until the mission occurs, at which time the flight controller must implement the plans he has made.

During the mission the flight controller is assigned to a console where he monitors data received from the spacecraft. His primary equipment is a closed circuit television display (DTV). Computer processed data, in digital form is continuously displayed on the DTV as long as data are received from the spacecraft. The data are dynamic and is updated once each second. This allows the controller to closely monitor and evaluate his system. Secondary sources of data that he views are event lights, caution and warning indicators, communication displays and analog chart recorders. He must continuously monitor and assess all of these indicators during the time he is on duty.

On each duty shift the flight controller monitors his data and interfaces with the flight crew, support personnel, and other flight controllers. This is a critical interface, established during training, and is continually exercised. This interface is the exchange of the right information and words at the right time between the ground and the flight crews. It is critical as the safety of the crew and the success of the mission depends on it. The flight crew and ground must know what to expect of each other and the kinds of data to be received.

The organization of the flight controller team varies for the type of mission being supported. A typical Apollo lunar mission is shown in Figure B. The Flight Operations Director is much like a coach on a football team in that he monitors the mission closely and makes suggestions to insure its success. The Flight Director is the quarterback of the team. He directs and leads each of the mission operations. He makes the critical decisions and is responsible for the mission. Each of the flight controllers shown are specialists in a particular field. They are responsible for their system and report directly to the Flight Director. Each of these controllers have a staff of specialists who provide them with detailed information that is used to make decisions and recommendations.

TYPICAL APOLLO MISSION SUPPORT ORGANIZATION

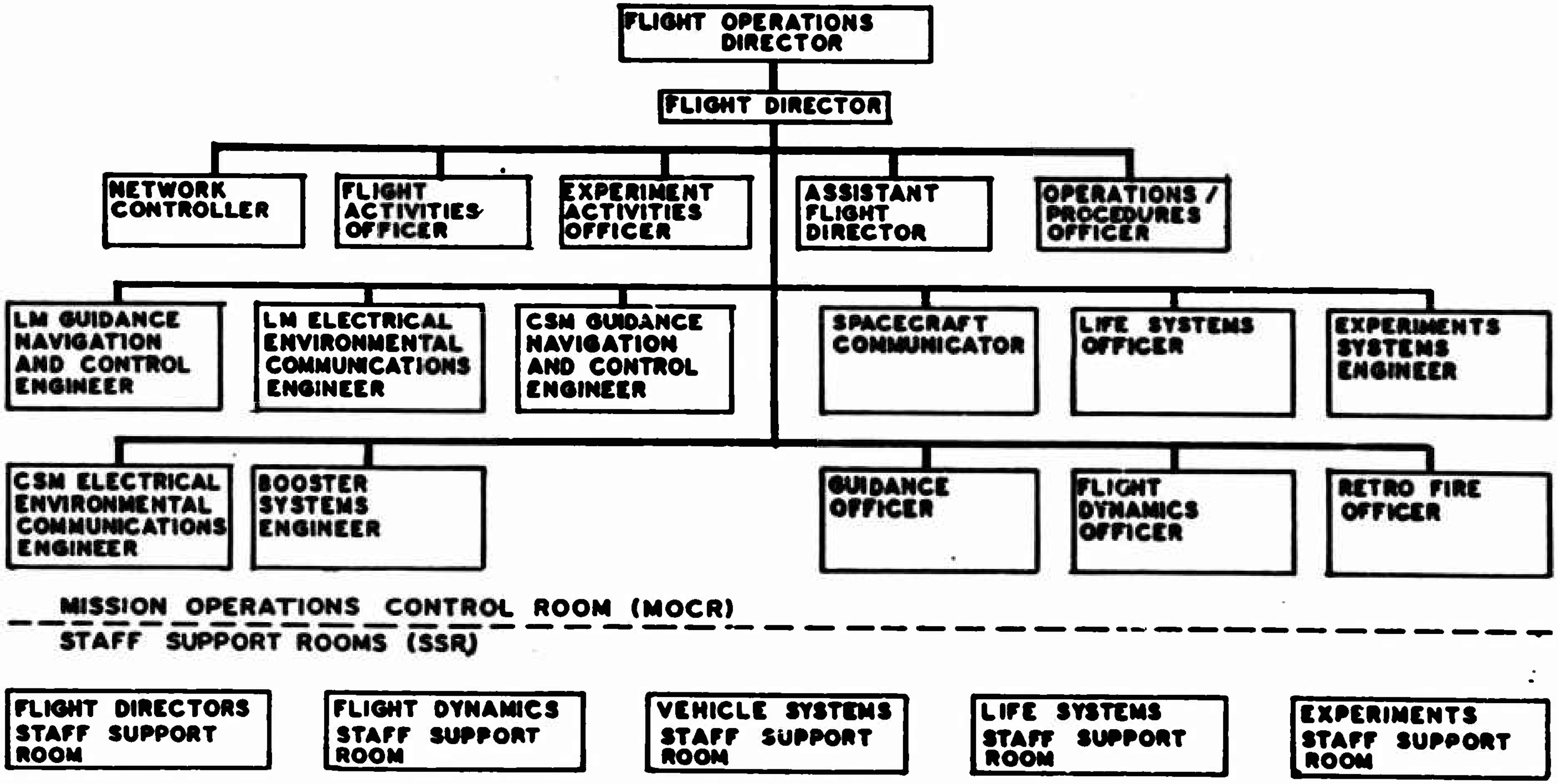


FIGURE B

Figure C shows a typical Skylab flight control mission organization chart. The primary difference in the organization for the two types of missions is the number and type of systems monitored. In Skylab, an earth orbiting laboratory program, the amount of data received is approximately three times greater than that of Apollo. (Ref 72). There are three vehicles, rather than two, that must be observed. The complexity of each is great, therefore, the flight controllers must be very knowledgable in their area.

TYPICAL SKYLAB MISSION SUPPORT ORGANIZATION

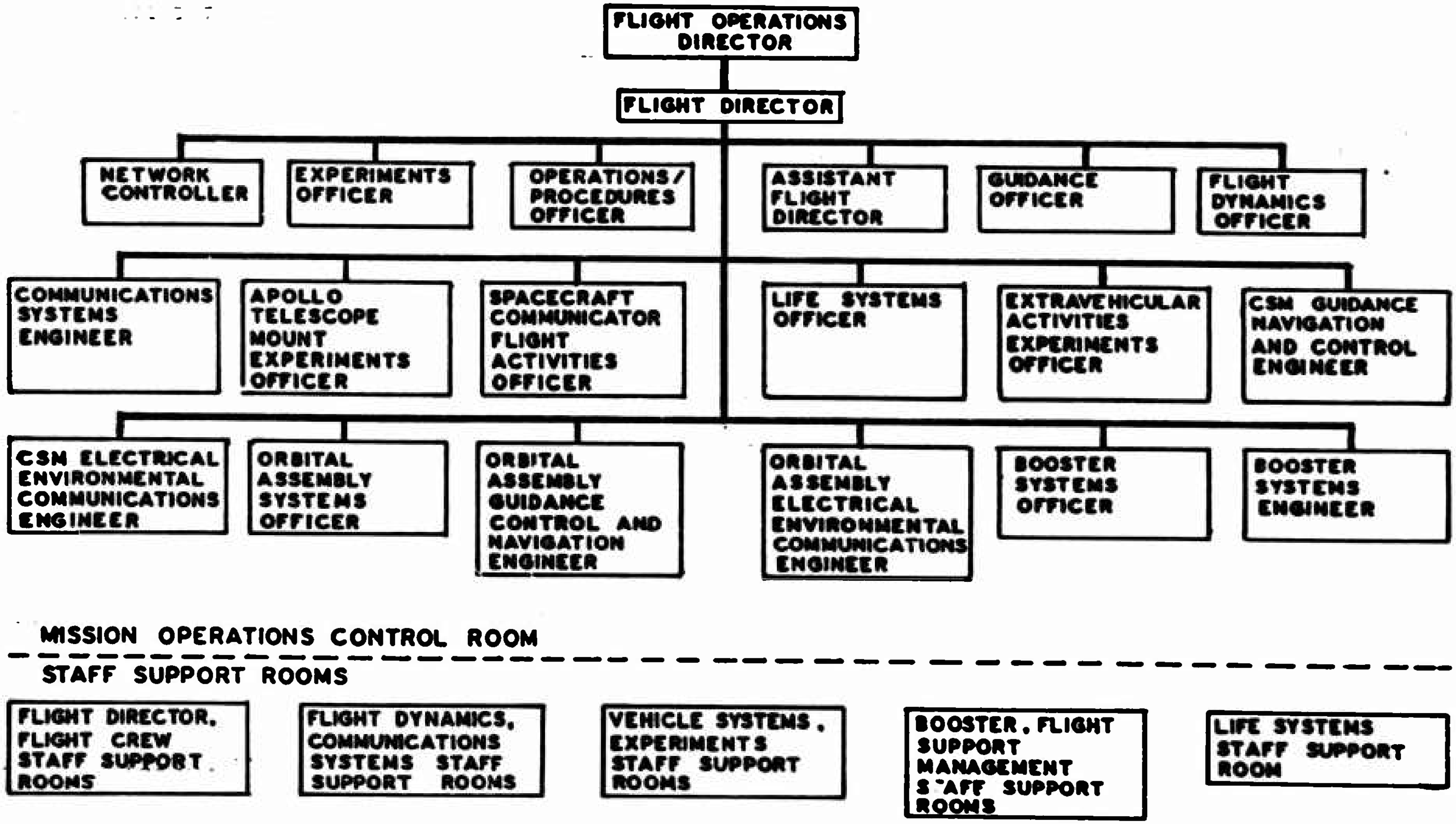


FIGURE C

Appendix B

Project Skylab

GSM/SM/71-6

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

SKYLAB

MANNED ORBITAL SCIENTIFIC SPACE STATION

Skylab is the name of an experimental space station program of the National Aeronautics and Space Administration (NASA). An extension of the manned Mercury-Gemini-Apollo space programs, the Skylab Program will make extensive use of the hardware and technological base developed during those previous missions.

The Skylab Program is designed to expand our knowledge of manned earth-orbital operations and to accomplish carefully selected scientific. technological, and medical investigations.

The success of the Skylab Program is essential not only in achieving sound decisions on the content and configuration of future space vehicles, but in gaining the confidence and support needed for later, more advanced programs.

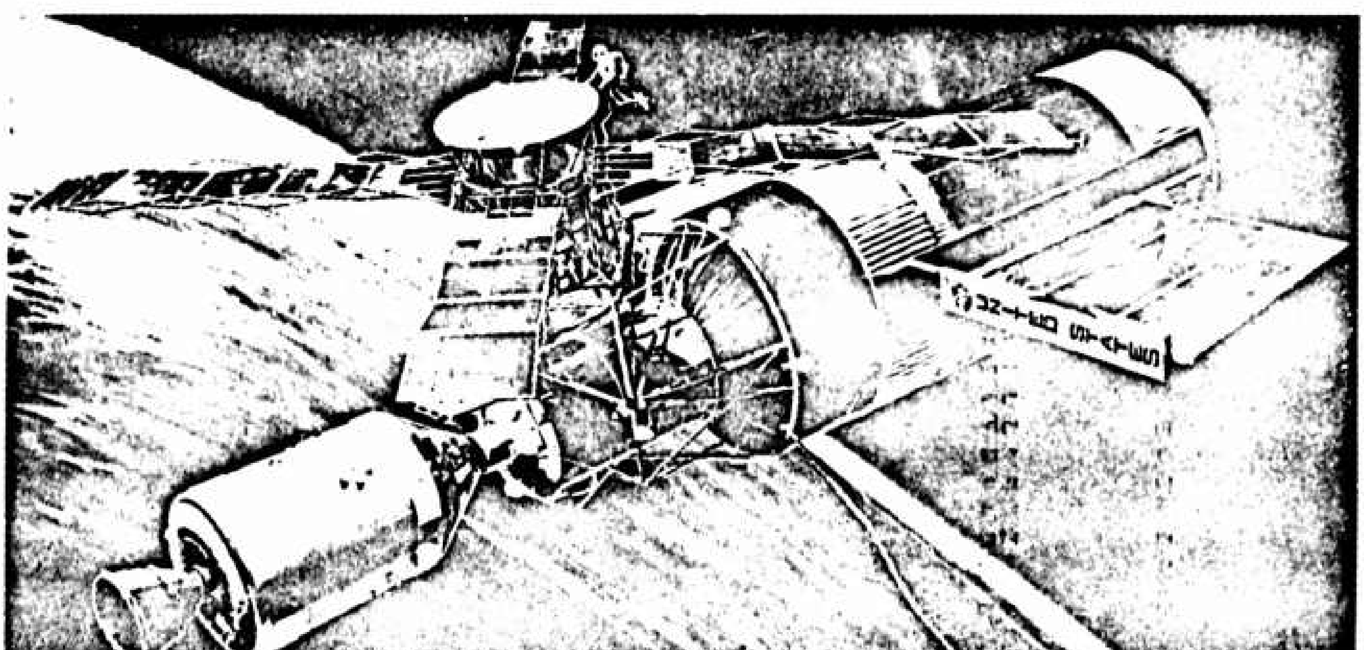
Three groups of experiments are of particular importance: an Earth Resources Experiment Package designed for investigating and application of remote sensing of the earth resources, a series of medical experiments associated with the careful extension of man's living and working in space for longer periods of time, and several high-resolution astronomical experiments for studying the sun at short wavelengths not observable from the earth.

The Skylab Program, scheduled to begin late in 1972, will consist of several low earth-orbital missions — approximately 235 nautical miles altitude — using the payload of the Saturn V and Saturn IB launch vehicles. The series of missions will begin with the orbital insertion of an unmanned Saturn workshop (SWS). Each subsequent launch will provide a manned command and service module (CSM) that will rendezvous and dock with the SWS. Because of the unique design, which incorporates the huge third stage of the Saturn V launch vehicle and provides an orbital facility equal in volume to a medium-sized home, the program is expected to provide the United States with the capability to develop and maintain permanent space stations that will be of increasing benefit to mankind.

The goal of the Skylab Program is the accomplishment of four basic objectives.

1. Scientific investigations in earth orbit. — These investigations are designed to take advantage of space operations to learn more about the universe, the space environment, the phenomena that exist in the solar system, and the manner in which these phenomena influence our earth environment.

2. Applications in earth orbit. — Applications experiments include the development and evaluation of efficient techniques using man for sensor operation, discrimination, data selection and evaluation, control, maintenance and repair, assembly and setup, and mobility. These experiments include studies in meteorology, earth resources, and communications. The



proper relationship between manned and unmanned applications operations will be examined.

3. Long-duration space flights of men and systems. — The unique capabilities of man as a participant in space flight activities will be exploited in the Skylab Program. Techniques are being developed for measuring the life-support systems and subsystems of space vehicles. Man's psychological responses and aptitudes in space will be evaluated and his postmission readaptation to the terrestrial environment will be analyzed as a function of progressively longer missions. Some of the major medical areas that will be studied include nutritional and musculoskeletal functions, cardiovascular function, hematology and immunology, neurophysiology, pulmonary function, and metabolism.

4. Effective and economical development of future space programs. — The Skylab missions will give man the capability to operate in space for increasingly longer periods of time. The technology developed will provide the basis for the design and development of future long-duration space stations. In addition, manned operational requirements for future extended planetary exploration will be further defined.

PROGRAM RESPONSIBILITY

The Skylab Program Office in the Office of Manned Space Flight, NASA Headquarters, Washington, D. C., has the responsibility for directing, integrating, and evaluating all phases of the program. Direction of the program is implemented by the Skylab office at each responsible NASA center. The responsibilities of the three major centers are as follows:

Manned Spacecraft Center, Houston, Texas —

- Development of the modified CSM
- Development of the spacecraft launch adapter for manned missions
- Development of assigned experiments, crew systems, medical equipment, food, and other crew-support items
- Integration of experiments carried in the CSM; stowage and return of experiment data and designated hardware from orbit
- Mission analysis, including mission-requirements development, detailed mission planning, and preflight preparations
- Flightcrew selection and training
- Mission control, flight operations, and recovery activities
- Mission evaluation

Marshall Space Flight Center, Huntsville, Alabama —

- Development of all Saturn workshop hardware elements
- Development of assigned experiment-support hardware, integration of assigned experiments and support systems
- Overall systems engineering and integration for each flight
- Flight evaluation
- Saturn IB and Saturn V launch vehicles

John F. Kennedy Space Center, Florida —

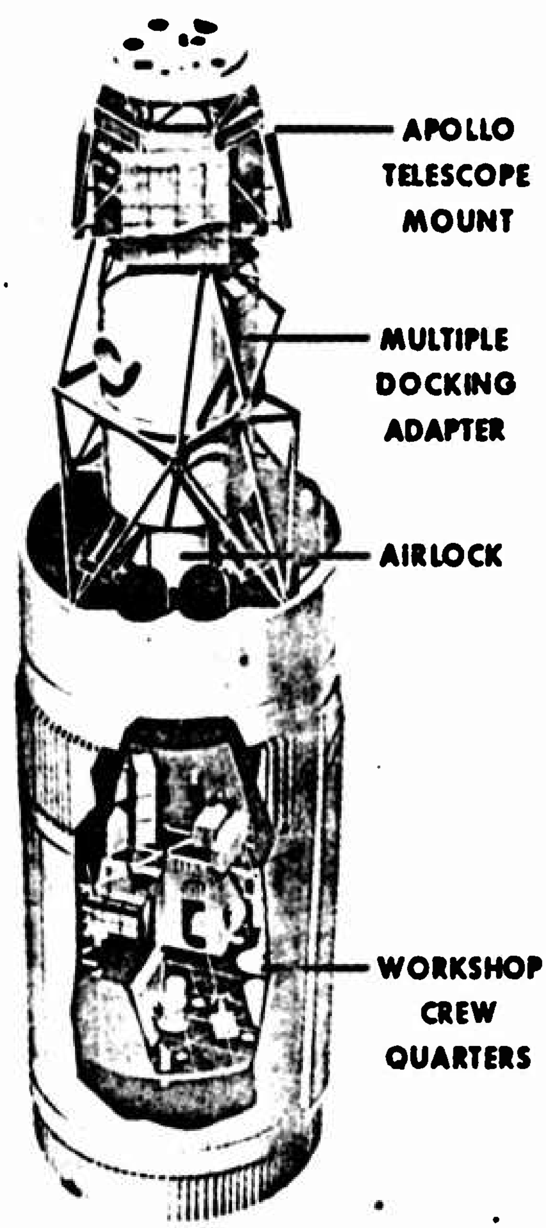
- Launch facilities for Skylab flights
- Preparations and implementation of prelaunch checkout procedures
- Launch operations

SKYLAB CLUSTER

The Skylab orbital cluster will consist of an SWS and a docked Apollo CSM. The SWS will be composed of an S-IVB stage modified into an orbital workshop (OWS), an airlock module (AM), a multiple docking adapter (MDA), an instrument unit, an Apollo telescope mount (ATM), and an ATM deployment assembly. The SWS will be launched by a two-stage Saturn V rocket.

In orbit, the Skylab cluster will be 118 feet long and will weigh 181,300 pounds. The total work area of the OWS, AM, MDA and CSM will be 12,763 cubic feet.

WORKSHOP (LAUNCH CONFIGURATION)



The ATM, AM, and MDA will be the only new major components of the cluster; the other components will consist of standard Apollo hardware converted for Skylab use.

The AM, a 5.5-foot-diameter circular tunnel, will be attached to the upper surface of the tank formerly used for liquid hydrogen storage in the third stage (S-IVB) of the Saturn V launch vehicle. The AM will provide a passageway for the astronauts to enter and exit the main workshop area. Capable of being depressurized, the AM will be used by astronauts whose work entails extravehicular activity. The majority of the workshop systems and controls will be located in the AM.

The MDA, when attached to the AM, will provide the docking ports for the CSM and the crew. The adapter, 10 feet in diameter and 17 feet long, will contain the Earth Resources Experiment package and the ATM film vault.

The SWS, including the ATM, will be completely outfitted before launch. The workshop will have 10,644 cubic feet of interior space, sufficient for kitchen, bath, and workroom facilities to support a crew of three men for one 28-day period and two 56-day periods. Certain experiments and the necessary experiment-support equipment will be installed in the OWS, which will be maintained in a dormant state during unmanned periods, then reactivated for use by a later crew.

The instrument unit, which will provide guidance and sequencing functions, will be used during launch and the first 7.5 hours of orbital operations. The unit will also be used during the initial deployment of the ATM and the solar arrays of the OWS and the ATM.

The ATM will be essentially a manned solar observatory that can be aimed with pinpoint accuracy. The structure and behavior of the sun, particularly during periods of solar-flare activity, will be observed, monitored, and recorded in the ATM. Astronauts equipped with extravehicular equipment will exit the AM to install and retrieve film from the ATM cameras.

LAUNCH VEHICLES

The Saturn V launch vehicle used to place the SWS in orbit will consist of two stages, the S-IC and the S-II. The total weight of the Saturn V and the SWS at lift-off will be approximately 6.2 million pounds. At launch, the entire vehicle will be 333 feet high.

A Saturn IB launch vehicle will place the CSM into orbit for rendezvousing and docking with the SWS. The Saturn IB, a two-stage vehicle — the S-IB and the S-IVB — with the CSM will have a combined lift-off weight of 1.3 million pounds. The height of the S-IB will be 223 feet at launch.

MISSION SEQUENCE

In the flight sequence, the fully outfitted but unmanned SWS and attached ATM will be launched into a 235-nautical-mile circular orbit by the two-stage Saturn V launch vehicle. The ATM will be deployed and the OWS will be pressurized to 5 psia with an oxygen-nitrogen mixture, so that the crew can enter immediately after the CSM is docked.

Then, 24 hours later, an S-IB launch vehicle will place the CSM and the three-man crew into an intermediate 81- by 120-nautical-mile orbit. The crew will rendezvous with SWS (using the CSM service propulsion system to attain the required 235-nautical-mile orbit) and then dock to a port of the MDA.

The crew will enter and completely activate the OWS, which will be their home and work area for the next 28 days. During the remainder of the mission, the experiment program (scientific, biomedical, technological, earth resources, and crew operations) will be conducted. Emphasis will be placed on the medical experiments and evaluation of the habitability of the SWS. The ATM experiments will be conducted and satisfactory operation of the experiments will be verified. The Earth Resources Experiment Package will be operated to a limited degree.

On the 26th day, the crew will exit the AM, retrieve exposed ATM film, and reload the cameras. Near the end of the 28-day mission, the crew will prepare the SWS for orbital storage, a dormant period scheduled to last 2 months until another crew visits the Skylab.

The CSM and crew will deorbit and make an ocean landing on the 28th day of the mission.

The second manned flight of the Skylab Program will be similar to the first, except that the open-ended mission may be extended to 56 days. Greater emphasis will be placed on the solar-astronomy experiments and on the Earth Resources Experiment Package during the second manned mission. A third crew of astronauts is scheduled to revisit the Skylab 1 month after the end of the second mission. On the third visit, 56 days long, the earth-resources, medical, and ATM experiments will be emphasized. Science, technology, and crew operations will be investigated on all three missions.

EXPERIMENTS

The inflight experiments, grouped into six major areas will be performed in the OWS, the AM, or MDA. The categories of experiments are as folows.

- Solar astronomy — The scientific experiments that comprise the ATM payload are the largest, most complex experiments ever designed for performing solar research from an orbital spacecraft. Special emphasis will be placed on observations that cannot be made by astronomers on earth because of spectral absorption by the atmosphere.
- Science — The 17 scientific experiments are designed to study geophysics, the physics of the upper atmosphere, the physics of the interplanetary medium, solar studies supplementing ATM data, and galactic and intergalactic astronomy.
- Biomedicine — The 15 inflight and postflight biomedical experiments are planned to determine the effects of long-duration space flight on the crew. The major areas of interest are nutritional and musculoskeletal functions, cardiovascular function, hematology and immunology, neurophysiology, pulmonary function, and metabolism.
- Technology — The three technological experiments are designed to make use of the orbital environment to study space effects on various scientific phenomena and industrial arts.
- Earth resources — The five experiments are planned to investigate practical applications of remote sensing of the earth resources and environment. During the research, the quality of earth-resources data taken through the atmosphere will be analyzed, and the data and possible applications will be examined. A multispectral photographic facility, an infrared spectrometer, a 10-band multispectral scanner, a microwave radiometer-scatterometer-altimeter, and an L-band radiometer will comprise the equipment used in the investigations.
- Crew operations — These experiments are planned to evaluate and demonstrate engineering developments and hardware designed to facilitate the functioning of the crew in the space environment.

SKYLAB EXPERIMENTS

TITLE	COGNIZANT AGENCY(a)	INVESTIGATOR AND AFFILIATION(b)	MISSIONS		
			1	2	3
White-light coronagraph	MSFC	Dr. Gordon Newkirk, High Altitude Obs.	X	X	X
X-ray spectographic telescope	MSFC	Dr. M. Zombeck, American Science and Engineering	X	X	X
uv scanning polychromator spectroheliometer	MSFC	Dr. Edward Reeves, Harvard College Obs.	X	X	X
Dual X-ray telescope	MSFC	Mr. James Milligan	X	X	X
Extreme uv coronal spectroheliograph	MSFC	Mr. J. D. Purcell, Naval Research Lab.	X	X	X
Extreme uv spectrograph	MSFC	Mr. J. D. Purcell, Naval Research Lab.	X	X	X
Nuclear emulsion	MSFC	Dr. M. M. Shapiro, Naval Research Lab.	X		
uv stellar astronomy	MSC	Dr. K. G. Henize and Dr. James Wray, Northwestern Univ.	X	X	
X-ray uv solar photography	MSC	Dr. R. Tousey, Naval Research Lab.	X		
Potato respiration	MSC	Dr. B. W. Pince, Space Defense Corp.			X
uv airglow horizon photography	MSC	Dr. D. Packer, Naval Research Lab.		X	
Gegenschein zodiacal light	MSFC	Dr. J. Weinberg, Dudley Obs.		X	
Particle collection	MSC	Dr. C. L. Hemmenway, Dudley Obs.	X	X	
Galactic X-ray mapping	MSFC	Dr. W. Kraushaar, Univ. of Wisconsin		X	
Multispectral photographic facility	MSC	Mr. A. L. Grandfield	X	X	X
Infrared spectrometer	MSC	Dr. T. Barnett	X	X	X
10-band multispectral scanner	MSC	Dr. C. L. Korb	X	X	X
Microwave scatterometer	MSC	Mr. D. Evans	X	X	X
Radiation in spacecraft	MSC	Capt. M. F. Schneider, USAF	X		
Expandable airlock technology	MSFC	Mr. F. W. Forbes, USAF Wright-Patterson Air Force Base (AFB)	X	X	
Thermal control coatings	MSFC	Mr. Carl Boebel, USAF Wright-Patterson AFB	X	X	
Material processing in space	MSFC	Mr. P. G. Parks	X		
Effects of zero-g on human cells	MSC	Dr. P. O. Montgomery, Dallas County Hospital	X		
Circadian rhythm, pocket mice	ARC	Dr. C. S. Pittendrigh, Princeton Univ.		X	
Circadian rhythm, vinegar gnat	ARC	Dr. C. S. Pittendrigh, Princeton Univ.		X	
Crew vehicle disturbances	LaRC	Mr. B. A. Conway		X	
Precision optical tracking	MSFC	Mr. John Gould	X	X	X
Coronagraph contamination measurement	MSC	Dr. G. P. Bonner		X	
Contamination measurement	MSFC	Dr. J. Muscari, Martin Marietta Corp.	X		
Zero-g flammability	MSFC	Mr. Howard Kimzey		X	
Gravity substitute workbench	MSFC	Mr. J. Rendall	X		
Extravehicular- and intravehicular-activity hardware evaluation	MSC	Mr. John Jackson	X	X	
Astronaut-maneuvering equipment	MSC	Maj. C. E. Whitsett, USAF		X	
Foot-controlled maneuvering unit	LaRC	Mr. D. E. Hewes		X	
Mineral balance	MSC	Dr. G. D. Whedon, National Institute of Health	X	X	X
Bone densitometry	MSC	Dr. Pauline Mack, Texas Women's Univ.	X	X	X
Bioassay of body fluids	MSC	Dr. C Leach	X	X	X
Specimen mass measurement	MSC	Col. John Ord, USAF, Brooks AFB	X	X	X
Lower-body negative pressure	MSC	Col. John Ord, USAF, Brooks AFB	X	X	X
Inflight lower-body negative pressure	MSC	Dr. R. J. Johnson	X	X	X
Vectorcardiogram	MSC	Capt. Newton W. Allebach, USN, Bureau of Medicine and Surgery	X	X	X
Cytogenetic studies of blood	MSC	Dr. M. Shaw, Univ. of Texas Medical Center	X	X	X
Man's immunity in vitro aspects	MSC	Dr. Stephen Ritzman, Shriners' Burn Institute	X	X	X
Blood volume and red-cell life span	MSC	Dr. Phillip Johnson, Baylor Univ.	X	X	X
Red-blood-cell metabolism	MSC	Mr. Charles Mengel, Univ. of Missouri	X	X	X
Human vestibular function	MSC	Dr. Ashton Graybiel, Naval Aviation Medical Institute	X	X	
Time and motion study	MSC	Dr. J. F. Kubis, Fordham Univ.	X	X	X
Metabolic activity	MSC	Mr. Edware Michel	X	X	X
Body-mass measurement	MSC	Col. John Ord, USAF, Brooks AFB	X	X	X
Thermal control coatings	MSFC	Mr. E. C. McKannon	X		
Inflight aerosol analysis	MSFC	Dr. W. Leavitt	X	X	X

(a) MSFC, Marshall Space Flight Center; MSC, Manned Spacecraft Center; ARC, Ames Research Center; and LaRC, Langley Research Center.

(b) If different from cognizant agency.

NASA — MSC — Coml., Houston, Texas

Appendix C

Interview Format

Interview Format

This interview is designed to gather information about scheduling systems. This information will be used to form a data base for thesis research. This research will provide information for the development of a scheduling system to schedule personnel in support of long duration manned earth orbiting laboratory spaceflights.

The questions I am about to ask will provide information about how you schedule your personnel to support your operations. The information you provide will be held in confidence and used as summary or concensus of opinion data. You will be directly quoted only if you give permission at this time.

Please feel free to anwer each question in as much detail as you desire. If the question does not apply please tell me.

1. Name.____________________

2. Orgaization.____________________

3. Division or branch.____________________

4. Position or title. ____________________

5. What type of work does your organization perform? What type of work is performed during support activities?

6. Does this work require continuous support - 24 hour a day, 7 days a week?

7. What are your scheduling responsibilities in terms of your organizatinn?

8. What techniques do you use to develop a schedule?

9. What regulations or manuals govern your schedule?

10. Do you use a rotating shift scheme? If so what is it and how long do they work a particular shift before rotating to another shift?

11. What is the duration of each work shift?

12. Are there any constraints or restrictions placed on the length of work shifts?

13. Do you feel such factors as normal leave, sick leave, emergency leave will effect your schedule? If so, how will it be effected?

14. How do you feel your day to day workload will be effected by long duration missions?

15. What economic factors do you consider important when developing a support schedule?

16. What factors do you consider when making selections for assignment to a shift or in the development of a schedule?

1. Mission requirements
2. Qualified personnel or skill level
3. Length of shift
4. Personal problems of the employee
5. Fatigue
6. Morale or motivation
7. Training requirements
8. Overtime
9. Time shift starts
10. Shift rotation cycle
11. Mission length

12. Any economic considerations
13. Maintaining office work
14. Schedule flexibility
15. Anxiety of the worker
16. Responsibility of the worker
17. Experience of the worker
18. Any others

17. Do you feel the worker should be ask to express his preference for a shift? If so, do you think this preference is honored?

18. Can you or any of your personnel qualify to perform duties in an associated speciality out side your branch?

19. Do you feel some people have difficulty in adapting to shift work?

20. Is it easy to come up to speed after being off for three days?

21. Are there any other factors that are connected with your shift work that makes your job better or worse?

22. Do you feel your scheduling system will change to meet furture mission obligations? How do you think it will change?

23. Do you feel your scheduling system is successful? Could it be improved?

24. Are there any other comments you would like to make in regards to schedules?

Appendix D

Letters of Request for Data

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (AU)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: Capt. Carroll Hopkins / AFITENS

SUBJECT: Request for Information 23 July 1971

TO: Col. George T. James

1. The purpose of this letter is to ask for your cooperation in gathering data for a masters degree thesis research.

2. The purpose of this research is to determine what factors are and/or should be considered in scheduling personnel who operate consoles in support of spaceflight efforts. The group of factors obtained from the schedulers will be synthesized with those factors found in various literary works. The result will be a concise list of those things a scheduler should consider when developing a schedule. Careful consideration of such things will ultimately produce a better schedule which will improve working conditions, worker efficiency, and productivity.

3. The attached list of questions present a general idea of the type of information that is desired. Please answer each question and provide any additional thoughts you have. I would appreciate a reply from each area in your organization that schedules personnel performing this type of work. For this reason additional copies of the question sheet is enclosed. The value of this study will depend upon the care and amount of thought you put into your responses.

4. A speedy return of this information by 9 August 1971 will be greatly appreciated. A self addressed envelope is enclosed to facilitate the return of your reply. Thank you very much for your cooperation.

Carroll E Hopkins

Carroll E. Hopkins, Capt., USAF
Master of Science Candidate
Air Force Institute of Technology
Wright-Patterson AFB, Ohio

Atch
Questionnaire (4 ea)

Strength Through Knowledge

GSM/SM/71-6

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (AU)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: Capt. Carroll Hopkins / AFITENS

SUBJECT: Request for Information 23 July 1971

TO: Capt. S. Brockman

1. The purpose of this letter is to ask for your cooperation in gathering data for a masters degree thesis research.

2. The purpose of this research is to determine what factors are and/or should be considered in scheduling personnel who operate consoles in support of spaceflight efforts. The group of factors obtained from the schedulers will be synthesized with those factors found in various literary works. The result will be a concise list of those things a scheduler should consider when developing a schedule. Careful consideration of such things will ultimately produce a better schedule which will improve working conditions, worker efficiency, and productivity.

3. The attached list of questions present a general idea of the type of information that is desired. Please answer each question and provide any additional thoughts you have. The value of this study will depend upon the care and amount of thought you put into your responses.

4. A speedy return of this information by 9 August 1971 will be greatly appreciated. A self addressed envelope is enclosed to facilitate the return of your reply. Thank you very much for your cooperation.

Carroll E Hopkins

Carroll E. Hopkins, Capt., USAF
Master of Science Candidate
Air Force Institute of Technology
Wright-Patterson AFB, Ohio

Atch
Questionnaire

SCHEDULING FACTORS QUESTIONS

1. What general type of work do your subordinates perform? Do they monitor a console containing event or status lights, data television, radar scope, etc.?

2. Does your operation require continious 24 hour a day, seven days per week support?

3. What type of shift scheme do you use?

4. Are your personnel scheduled on a rotating shift basis? If so how long do they work a particular shift before rotating to a different shift?

5. Have you ever tried a different shift scheme (s)? If so what were they and why were they dropped in favor of the present shift scheme?

6. Is your schedule controlled by any regulations, operating instructions, policies, etc.? Do they govern the schedule rotation, shift length, maximum working hours, or other human limitations? What are they? Is it possible to obtain a copy of these documents (other than AF or AFSC regs. and manuals) ?

7. What factors do you consider important to the development of your schedule?

(1) Are the mission requirements a factor?

(2) Is the number of qualified personnel available a factor?

(3) Is the number of personnel in training to become qualified a factor?

(4) Is the length of shift a factor? What is the shift length?

(5) Is the shift cycle (number of days worked before receiving a day off) a factor?

(6) Are the workers required to maintain office work or perform other routine duties? If so to what extent?

(7) Is schedule flexibility a factor? Can you take into account illness, emergencies, etc.?

(8) Is the skill level or experience level of personnel a factor

(9) Do you find some personnel have difficulty in adapting to shift work? If so can you make a general comment as to what group of personnel have this difficulty?

(10). Do you feel that subordinates should be ask for shift preference? Do you feel that it is a factor in scheduling personnel?

(11) Is overtime a factor and how is it handled? Do you utilize compensatory time off?

(12) Is fatigue of the worker a factor?

(13) Is the worker's anxiety a factor?

(14) Is the worker's morale a factor?

(15) Do you have dual qualified personnel (workers able to perform two or more different tasks equally well)? Is this a factor?

(16) Are the domestic problems of the worker a factor?

(17) Are there any other factors?

8. Please list at least five factors that you consider most significant to the scheduling of your personnel. Rank these factors from most to least important by assigning each a value from 1 to 10 based on its priority. An example is: flexibility, 10; length of shift, 8; fatigue, 4; morale,1; etc.

9. I would appreciate a short summary of your experience in spaceflight and personnel scheduling along with your name, rank, and duty (position) title. This information will allow establishment of your expertise and proper referencing of your data.

Appendix E

Questionnaire

GSM/SM/71-6

DEPARTMENT OF THE AIR FORCE

AIR FORCE INSTITUTE OF TECHNOLOGY (AU)

WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: Carroll E. Hopkins, Capt.

SUBJECT: Study of Scheduling for Flight Controllers 23 Aug 1971

TO: Selected Branch Chief

1. The purpose of this letter is to ask for your cooperation in completing and returning the enclosed questionnaire.

2. The approval and support of Eugene Kranz, Chief of Flight Control Division, has been obtained to conduct this survey. The data obtained will be of direct benefit to Flight Control Division. The information gained will be used to determine the most desirable schedule for flight controller support of long duration missions, and to determine what variable factors concerning such schedules are important. The data gathered from this questionnaire may be used to develope a scheduling system that will be used to schedule flight controllers for future missions.

3. A random selection of personnel in your branch has received questionnaires similar to the one you have received. The difference is in the amount of data presented in Part III. - Schedules. You have received more data since you must make the decisions. You are requested to not discuss this questionnaire with your subordinates as such a discussion could influence the respective opinions. This would invalidate the results.

4. The value of this study will depend upon the frankness with which you respond to the questionnaire. A one-hundred percent response is extremely important to successful completion of the study. The questionnaire should take no more than fifteen minutes of your time.

5. A self addressed envelope is provided to facilitate the return of the completed questionnaire. I would greatly appreciate the return of the questionnaire by not later than 9 September 1971. The speedy return of this questionnaire will be greatly appreciated. Thank you very much for your cooperation.

Carroll E. Hopkins

Carroll E. Hopkins, Capt., USAF
Master of Science Candidate
Air Force Institute of Technology
Wright-Patterson AFB, Ohio

Strength Through Knowledge

Please Complete the Following:

PART I: GENERAL DATA

1. Branch______________________________________

2. Source of employment (check one)

   _____ civil service   _____ contractor

3. Age (check one)

   _____ under 30   _____ 41-45
   _____ 30-35   _____ 46-50
   _____ 36-40   _____ over 50

4. Grade (GS level or equivalent)__________________

5. Number of years working as a flight controller__________

6. Married: _______yes _______ no
   Number of children at home____________

7. Have you worked 12 hour shifts in mission support?
   _____ yes _____ no

....

PART II. SCHEDULING FACTORS

Scheduling of scientist, engineers, and technicians to support long duration operations is a complex process. There are many scheduling variables that affect each individual differently. The manner in which these variables affect the man to a great extent determine how satisfied he will be with his job and how effectively he will work.

To assist in developing the best schedule, it is imperative to know what scheduling factors affect you. The following is a list of suggested variables. Please indicate whether or not each is a factor in scheduling controllers. A space is provided for your comments and such comments are welcome:

SUGGESTED VARIABLES

1. Fatigue may either be physical or mental and can reduce the output level of the individual.

   I feel that fatigue is a factor that should be considered when developing manning schedules.

   _____ yes _____ no

   Comments:

2. Flexibility in scheduling is found in the ability of the schedule to account for such things as personal emergencies, sickness, unexpected mission developments or situations.

   I feel that flexibility is a factor in scheduling.

   ______ yes ______ no
   Comments:

3. The length of the shift is the number of hours that the worker is required to work each day.

   I feel that the length of shift is a scheduling factor.

   ______ yes ______ no
   Comments:

4. Morale is defined as the attitudes of individuals and groups toward their work environment and toward voluntary cooperation to the full extent of their ability in the best interests of the organization.

   I feel that morale is a variable in scheduling.

   ______ yes ______ no
   Comments:

5. Office work may be defined as routine matters such as reading mail and preparation for future missions.

   I feel that provisions should be made in the design of a schedule to maintain office work.

   ______ yes ______ no
   Comments:

6. The number of hours worked in excess of the normal 40 hours per week is a definition of overtime.

   I feel that overtime is a factor in scheduling and should be considered.

   ______ yes ______ no
   Comments:

7. Qualified personnel may be defined as those who are sufficiently skilled to provide maximum support to the operations activities.

I feel that the number of qualified personnel and their skill level is a factor in scheduling.

______ yes ______ no
Comments:

8. The shift cycle is defined as the number of days a controller works, followed by the number of days off. It also includes the number of shifts worked before rotating to an alternate shift.

I feel that the shift cycle is a factor in scheduling.

______ yes ______ no
Comments:

9. To maintain proficiency level, prepare for a new mission, or equip new personnel with needed skills is defined as training requirements.

I feel that training requirements are a factor in scheduling personnel.

______ yes ______ no
Comments:

10. Please list any other factors that you consider essential to scheduling controllers to support long duration missions.

Please rank each factor in order of importance. A value of 10 indicates great importance and 1 of very little importance; do not rank those variables which you do not consider a factor.

______	Fatigue	______	Overtime
______	Flexibility in scheduling	______	Qualified personnel
______	Length of the shift	______	Shift cycle
______	Morale	______	Training requirements
______	Office work	______	Other factors (Please list)

Working shift schedules are required to support the mission objectives. To make such schedules as desirable as possible please indicate which of the following you prefer by a check mark by the appropriate response.

1. What is your preferred length of shift in providing mission support? This does not include shift change-over time.

   ______ (a) 8 hours
   ______ (b) 12 hours

2. There is some thought that half of the workers prefer to work the night shift. Working 12 hours per shift, which shift do you prefer?

   ______ (a) days
   ______ (b) nights

3. Working 8 hours per shift which shift do you prefer?

   ______ (a) days
   ______ (b) swing
   ______ (c) nights (graveyard)

4. What time of day do you prefer to go to work if you work the day shift and work:

   1) 12 hours per day?

   ____ 6 AM ____ 7 AM ____ 8 AM ____ 11:30 AM ____ other

   2) 8 hours per day?

   ____ 6 AM ____ 7 AM ____ 8 AM ____ 9 AM ____ other

5. When working shift work do you prefer:

   ______ (a) The shift to rotate at short intervals such as one to three days?
   ______ (b) The shifts to rotate at some long interval such as two weeks or longer?
   ______ (c) The shift that you are assigned to be held constant throughout the duration of the mission?

PART III: SCHEDULES

The support of long duration (greater than 3 weeks) space operations requires 24 hour controller support. This support requires scheduling the controller in shifts. The following is a list of proposed controller shift schedules. Please evaluate each schedule in light of the factors presented in Part I.

1. Shift Schedule One
   If you work this shift schedule as a prime mission support team member, you would work four days, have three days off, work three days, then have four days off. The cycle would

Each proposed schedule contains a shift diagram to illustrate how the schedule would work. The diagram is for a two week period utilizing six teams. The following symbols are used:

D - day shift work
S - swing shift work
N - night shift work
O - time off
R - routine office work

1. Shift Schedule One:

If this schedule is adopted, the flight controllers would provide mission support for four days, have three days off, work three days, followed by three days off. The cycle would then be repeated. Each mission support shift is 12 hours long plus the time required for team change-over. When the flight controller has worked two complete day cycles, he would rotate to the night shift. The night shift works four nights, three off, works three more nights and then has four complete days off. Upon completion of two complete night shift cycles, the flight controller would revert to working normal days (40 hour week) performing routine office duties. The length of time assigned to office work is four weeks. During this time he could also be used to substitute for another flight controller on mission support who cannot work. At the end of the four weeks of office work, the flight controller would return to mission support activities working days. This schedule requires an average of 2 hours of overtime per man on mission support per week. The time required for the schedule to repeat is 84 days. A total of 80 hours of office support time is required per week with six teams; with five teams, 40 hours per week; and none with four teams. Using four teams, however, requires the schedule to continiously cycle, which prohibits office work per se. A two week schedule is shown below.

Days / Teams	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Team 1	D	D	D	D	O	O	O	D	D	D	O	O	O	O
Team 2	N	N	N	N	O	O	O	N	N	N	O	O	O	O
Team 3	O	O	O	O	D	D	D	O	O	O	D	D	D	D
Team 4	O	O	O	O	N	N	N	O	O	O	N	N	N	N
Team 5	R	R	R	R	R	O	O	R	R	R	R	R	O	O
Team 6	O	O	R	R	R	R	R	O	O	R	R	R	R	R

2. Shift Schedule Two:

Implementation of this shift schedule for mission support activities assigns a flight controller to work four days, have two days off, work four days, followed by two days off. He would then work four nights, have two off, work four nights followed by two complete days off. Upon completion of the night shift cycle, the flight controller would be assigned to work normal days (40 hour week) doing routine office work. The teams doing office work would be assigned, on a rotating basis, to provide mission support (secondary support) for two days, when the prime mission support team is off. In addition he would be available to substitute for a prime support team member who could not work. Each mission support shift is 12 hours long plus team change-over time. Eighteen days would be devoted to routine office work before returning to mission support working days. This schedule requires 72 days to repeat if six teams are available; 58 days to repeat with five teams. An average of 15.3 hours of overtime per week per man on mission support is required. Twenty hours per week is expended on office time if six teams are used. If five teams are available the overtime is 19.3 hours per week per man, and office time required is 20.8 hours per week. Four teams cannot adequately support this schedule due to the requirement to work six consecutive shifts when rotating from prime to secondary mission support and vice versa. A two week schedule is shown below.

Days / Teams	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Team 1	D	D	D	D	O	O	D	D	D	D	O	O	D	D
Team 2	N	N	N	N	O	O	N	N	N	N	O	O	N	N
Team 3	O	O	R	R	D	D	O	O	R	R	D	D	O	O
Team 4	R	R	O	O	N	N	R	R	O	O	N	N	O	O
Team 5	R	R	R	R	R	O	O	R	R	R	R	R	O	O
Team 6	O	O	R	R	R	R	R	O	O	R	R	R	R	R

3. Shift Schedule Three:

This shift schedule requires the flight controller to work three days, have three days off, etc. Four groups of three day shift cycles would be worked on prime mission support before rotating to the night shift. Each shift is 12 hours long plus team change-over time. The same shift cycle would be followed for those flight controllers working nights; work three nights have three off, etc. After completion of four cycles of three night shifts, the flight controller would be assigned to office support activities working normal days (40 hour week). He would remain in the office for 27 days. During this time he could substitute for another mission team member who cannot work. Upon completion of the office duty assignment, the controller would then return to mission support activities working days. This schedule requires 71 days to repeat with five or six teams. The overtime requirememt for mission support is an average of 1.8 hours per man per week with six teams, or 2.3 hours per man per week with five teams. The number of hours of office work is 82.3 hours per week with six teams or 42.3 hours per week with five teams. Using four teams prohibits support of routine office work since the schedules would continue, working three shifts with three off. A schedule is shown below:

Teams \ Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Team 1	D	D	D	O	O	O	D	D	D	O	O	O	D	D
Team 2	N	N	N	O	O	O	N	N	N	O	O	O	N	N
Team 3	R	O	O	D	D	D	O	O	O	D	D	D	O	O
Team 4	R	O	O	N	N	N	O	O	O	N	N	N	O	O
Team 5	R	R	R	R	R	O	O	R	R	R	R	R	O	O
Team 6	O	O	R	R	R	R	R	O	O	R	R	R	R	R

4. Shift Schedule Four:

If this schedule is used the flight controller would work eight hour revolving shifts in prime mission support. He would work two day shifts, two swing (afternoon) shifts, two graveyard (night) shifts, and have three complete days off. Prior to starting the next work cycle, three days are available for routine office work or his substitution for another controller who cannot work his mission support shift. The number of days involved in office work is dependent upon the number of hours required to total to a 40 hour work week. The length of each shift, and normal office hours, is eight hours per day not including team change-over time. Upon completion of the office support activities, the flight controller would return to mission support working days. This schedule requires twelve days to repeat. Office time requirements are 64 hours per week for six teams, or 32 hours per week for five teams. There is no overtime accrued since the work day is 8 hours long regardless of the activity involved. If only four teams are available, the flight controllers would be required to work a continious cycle of two days, two swings, two graveyards, and two days off, with no time available for routine office work. This would also require an average of eight hours per man per week in overtime. A six team schedule is shown below.

Teams \ Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Team 1	D	D	S	S	N	N	O	O	O	R	R		D	D
Team 2	S	S	N	N	O	O	O	R	R		D	D	S	S
Team 3	N	N	O	O	O	R	R		D	D	S	S	N	N
Team 4	R		D	D	S	S	N	N	O	O	O	R	R	R
Team 5	R	R	R		D	D	S	S	N	N	O	O	O	R
Team 6	R	R	R	R		O	D	D	S	S	N	N	O	O

5. Shift Schedule Five:

In working this schedule for mission support the flight controller would work eight hours per shift, plus change-over time. He would work four days, have four days off, followed by working four days and having four days off. This would be followed by two shift cycles each of swing shifts (afternoons) and graveyard shifts (nights). Upon completion of the night shift cycles, the flight controller would rotate back to the day shift. The cycle would continue throughout the mission. Due to the shift being eight hours long, the flight controller will be required to work in the office a certain number of days each pay period to insure a minimum of 40 hours is worked each week. During this time he may be requested to substitute for another controller who cannot work his mission support schedule. No overtime is required by this schedule. Approximately 72 hours per week of office work is required. A two week shift schedule is shown below:

Teams \ Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Team 1	D	D	D	D	O	O	R	R	D	D	D	D	O	O
Team 2	S	S	S	S	R	O	O	O	S	S	S	S	R	O
Team 3	N	N	N	N	R	O	O	R	N	N	N	N	O	O
Team 4	R	R	R	O	D	D	D	D	R	O	O	O	D	D
Team 5	R	R	O	O	S	S	S	S	R	O	O	R	S	S
Team 6	R	R	O	R	N	N	N	N	O	O	O	R	N	N

After studying the proposed mission support schedules, and referencing the scheduling factors and your personal desires, please rank the schedules. Rank each of the shift schedules by assigning a value of from 5 to 1. Assign a value of 5 if in your opinion that schedule best incorporates those scheduling variables and best suits your desires (the shift you prefer to work). A value of 1 indicates that schedule system that you least prefer to work and does not incorporate the scheduling variables as well as the others.

______ Shift Schedule One

______ Shift Schedule Two

______ Shift Schedule Three

______ Shift Schedule Four

______ Shift Schedule Five

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (AU)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO ATTN OF: Carroll E. Hopkins, Capt.

SUBJECT: Study of Scheduling for Flight Controllers 19 Aug 1971

TO: Selected Flight Controller

1. The purpose of this letter is to ask for your cooperation in completing and returning the enclosed questionnaire.

2. The approval and support of Eugene Kranz, Chief of Flight Control Division, has been obtained to conduct this survey. The data obtained will be of direct benefit to Flight Control Division. The information gained will be used to determine the most desirable schedule for flight controller support of long duration missions, and to determine what variable factors concerning such schedules are important. The data gathered from this questionnaire may be used to develope a scheduling system that will be used to schedule flight controllers for future missions.

3. Your name was obtained from personnel records by a random process. Let me assure you that your answers will be kept in absolute confidence, and only summarized results will appear in the finished thesis.

4. The value of this study will depend upon the frankness with which you respond to the questionnaire. A one-hundred percent response is extremely important to successful completion of the study. The questionnaire should take no more than fifteen minutes of your time.

5. A self addressed envelope is provided to facilitate the return of the completed questionnaire. I would greatly appreciate the return of the questionnaire by not later than 1 September 1971. The speedy return of this questionnaire will be greatly appreciated. Thank you very much for your cooperation.

Carroll E Hopkins

Carroll E. Hopkins, Capt., USAF
Master of Science Candidate
Air Force Institute of Technology
Wright-Patterson AFB, Ohio

Strength Through Knowledge

Please Complete the Following:

PART I: GENERAL DATA

1. Branch________________________________

2. Source of employment (check one)
   ______ civil service ______ contractor

3. Age (check one)
   ______ under 30 ______ 41-45
   ______ 30-35 ______ 46-50
   ______ 36-40 ______ over 50

4. Grade (GS level or equivalent) ____________________

5. Number of years working as a flight controller __________

6. Married: ______ yes ______ no
   Number of children at home __________

7. Have you worked 12 hour shifts in mission support?
   ______ yes ______ no

....

PART II. SCHEDULING FACTORS

Scheduling of scientist, engineers, and technicians to support long duration operations is a complex process. There are many scheduling variables that affect each individual differently. The manner in which these variables affect the man to a great extent determine how satisfied he will be with his job and how effectively he will work.

To assist in developing the best schedule, it is imperative to know what scheduling factors affect you. The following is a list of suggested variables. Please indicate whether or not each is a factor in scheduling controllers. A space is provided for your comments and such comments are welcome:

SUGGESTED VARIABLES

1. Fatigue may either be physical or mental and can reduce the output level of the individual.

   I feel that fatigue is a factor that should be considered when developing manning schedules.

   ______ yes ______ no

   Comments:

2. Flexibility in scheduling is found in the ability of the schedule to account for such things as personal emergencies, sickness, unexpected mission developments or situations.

   I feel that flexibility is a factor in scheduling.

   ______ yes ______ no
   Comments:

3. The length of the shift is the number of hours that the worker is required to work each day.

   I feel that the length of shift is a scheduling factor.

   ______ yes ______ no
   Comments:

4. Morale is defined as the attitudes of individuals and groups toward their work environment and toward voluntary cooperation to the full extent of their ability in the best interests of the organisation.

   I feel that morale is a variable in scheduling.

   ______ yes ______ no
   Comments:

5. Office work may be defined as routine matters such as reading mail and preparation for future missions.

   I feel that provisions should be made in the design of a schedule to maintain office work.

   ______ yes ______ no
   Comments:

6. The number of hours worked in excess of the normal 40 hours per week is a definition of overtime.

   I feel that overtime is a factor in scheduling and should be considered.

   ______ yes ______ no
   Comments:

7. Qualified personnel may be defined as those who are sufficiently skilled to provide maximum support to the operations activities.

   I feel that the number of qualified personnel and their skill level is a factor in scheduling.

   ______ yes ______ no
   Comments:

8. The shift cycle is defined as the number of days a controller works, followed by the number of days off. It also includes the number of shifts worked before rotating to an alternate shift.

   I feel that the shift cycle is a factor in scheduling.

   ______ yes ______ no
   Comments:

9. To maintain proficiency level, prepare for a new mission, or equip new personnel with needed skills is defined as training requirements.

   I feel that training requirements are a factor in scheduling personnel.

   ______ yes ______ no
   Comments:

10. Please list any other factors that you consider essential to scheduling controllers to support long duration missions.

Please rank each factor in order of importance. A value of 10 indicates great importance and 1 of very little importance; do not rank those variables which you do not consider a factor.

______ Fatigue
______ Flexibility in scheduling
______ Length of the shift
______ Morale
______ Office work
______ Overtime
______ Qualified personnel
______ Shift cycle
______ Training requirements
______ Other factors (Please list)

Working shift schedules are required to support the mission objectives. To make such schedules as desirable as possible please indicate which of the following you prefer by a check mark by the appropriate response.

1. What is your preferred length of shift in proiding mission support? This does not include shift change-over time.

   _____ (a) 8 hours
   _____ (b) 12 hours

2. There is some thought that half of the workers prefer to work the night shift. Working 12 hours per shift, which shift do you prefer?

   _____ (a) days
   _____ (b) nights

3. Working 8 hours per shift which shift do you prefer?

   _____ (a) days
   _____ (b) swing
   _____ (c) nights (graveyard)

4. What time of day do you prefer to go to work if you work the day shift and work:

   1) 12 hours per day?

   ____ 6 AM ____ 7 AM ____ 8 AM ____ 11:30 AM ____ other

   2) 8 hours per day?

   ____ 6 AM ____ 7 AM ____ 8 AM ____ 9 AM ____ other

5. When working shift work do you prefer:

   _____ (a) The shift to rotate at short intervals such as one to three days?
   _____ (b) The shifts to rotate at some long interval such as two weeks or longer?
   _____ (c) The shift that you are assigned to be held constant throughout the duration of the mission?

PART III: SCHEDULES

The support of long duration (greater than 3 weeks) space operations requires 24 hour controller support. This support requires scheduling the controller in shifts. The following is a list of proposed controller shift schedules. Please evaluate each schedule in light of the factors presented in Part I.

1. Shift Schedule One
   If you work this shift schedule as a prime mission support team member, you would work four days, have three days off, work three days, then have four days off. The cycle would

then be repeated. Each working day will be 12 hours long plus crew change-over time. After you have worked two complete cycles you would change shifts; that is, if you were working days, you would begin working nights. If you had been working nights for the past two cycles, you would start working normal days (5 days - 8 hr. per day) doing routine office work. While doing office work for the next four weeks you may be called upon to substitute for someone who cannot work. You would return to mission support working days at the end of the office duty cycle.

2. Shift Schedule Two
Working this schedule as a prime mission support team member you would work four days, have two days off, work four days followed by two days off. If you have been working days you would next work four nights, have two complete days off, work four nights followed by two days off. After you have completed the night shift cycle, you would begin working normal days (5 days - 8 hrs/day) doing routine office work for six weeks. The teams working normal days (office work) will be required to work two days on mission support while the prime teams are off. This is a rotating duty where all teams have equal amount of the two day duty. Each shift in support of the mission is 12 hours long plus team change-over time. While working in the office you may be called upon to substitute for someone who cannot work. You will return to mission support, working days, when your office duty cycle is complete.

3. Shift Schedule Three
If you work this shift as a mission support team member, you will work three days and have three days off. You would work four groups of three day shift cycles before changing to the night shift. If you have been working days you would start working nights. If you were working nights, you would return to the office working normal days (5 days - 8 hrs. per day) for four weeks. During the time you are working in the office, you may be called upon to substitute for someone who cannot work their mission support shift. Completion of the office duty cycle will return you to mission support working days. Each mission support shift is 12 hours long, plus team change-over time.

4. Shift Schedule Four
If you work this mission support schedule, you will work two days, two swings (afternoon shift), two nights (graveyard shifts), followed by three days off. After completing your three days off, you would return to the office for three days (working normal 8 hour days each day). Each shift in support of the mission activities is 8 hours long plus team change-over time. When you are in the office you may be required to substitute for someone who cannot work their mission support shift. At the completion of the office duty you will return to mission support working the day shift.

5. Shift Schedule Five
Working this mission support shift, you will work four days, have four days off, work four days, followed by another four days off. After two groups of day shifts have been worked you will rotate to the swing shift. Two groups of four swing shifts will be worked before rotating to the night shift. Upon completion of two groups of four night shifts, you will rotate back to working the day shift. Each shift is 8 hours long plus team change-over time. Working this shift schedule you will be required to perform normal office duties (8 hours per day) to insure that a minimum 40 hour week is accomplished. This office duty will only be performed after having a minimum of two complete days off. You may also be required to substitute for others who cannot work their mission support shift. This shift cycle (working four shifts with four off) will continue throughout the mission.

After studying the proposed mission support schedules, and referencing the scheduling factors and your personal desires, please rank the schedules. Rank each of the shift schedules by assigning a value of from 5 to 1. Assign a value of 5 if in your opinion that schedule best incorporates those scheduling variables and best suits your desires (the shift you prefer to work). A value of 1 indicates that schedule system that you least prefer to work and does not incorporate the scheduling variables as well as the others.

______ Shift Schedule One

______ Shift Schedule Two

______ Shift Schedule Three

______ Shift Schedule Four

______ Shift Schedule Five

Vita

Carroll E. Hopkins was born [redacted] in [redacted] He graduated from high school in [redacted] in 1956, then attended Phoenix College from which he received an Associates of Arts Degree in 1958. In 1961 he graduated from Arizona State University, with a Bachelor of Science Degree in Mechanical Engineering. The same year he was commissioned in the United States Air Force. He was assigned to an Atlas F missile combat crew as a Deputy Missile Combat Crew Commander at Walker AFB, New Mexico until 1965. After six months at Vandenberg AFB, California in the 4392nd Civil Engineering Squadron, he was transferred to the Manned Spacecraft Center. From 1965 until 1971 he worked as a flight controller in both the Gemini and Apollo programs. In 1971 he was assigned to the Air Force Institute of Technology to study for a Master of Science Degree in Systems Management.

Permanent address: [redacted]

This thesis was typed by Mrs. [redacted]