N 72 - 16016

NASA TECHNICAL
MEMORANDUM

NASA TM X-58067
October 1971

CASE FILE
COPY

BEHAVIORAL, PSYCHIATRIC, AND SOCIOLOGICAL PROBLEMS OF LONG-DURATION SPACE MISSIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

NASA TM X-58067

BEHAVIORAL, PSYCHIATRIC, AND SOCIOLOGICAL PROBLEMS OF LONG-DURATION SPACE MISSIONS

Nick A. Kanas
UCLA School of Medicine
Los Angeles, California

William E. Fedderson
Manned Spacecraft Center
Houston, Texas

ABSTRACT

In an attempt to isolate behavioral, psychiatric, and sociological problems expected on long-duration space missions, a literature search was conducted at the NASA Manned Spacecraft Center, Houston, Texas. Primary sources include short-term space flights, submarine tours, Antarctic expeditions, isolation-chamber tests, space-flight simulators, and hypodynamia studies. Various stressors are discussed including weightlessness and low sensory input; circadian rhythms (including sleep); confinement, isolation, and monotony; and purely psychiatric and sociological considerations. Important aspects of crew selection are also mentioned. An attempt is made to discuss these factors with regard to a prototype mission to Mars. However, it is concluded that more experimentation under actual space conditions are necessary before such a mission should be attempted.

CONTENTS

TABLES

FIGURES

BEHAVIORAL, PSYCHIATRIC, AND SOCIOLOGICAL PROBLEMS OF LONG-DURATION SPACE MISSIONS

By Nick A. Kanas* and William E. Fedderson
Manned Spacecraft Center

SUMMARY

The results obtained from a comprehensive search of existing literature are presented in this paper. The search was instigated to examine the experimental results of all available studies concerning psychological and sociological factors associated with the problems, known and anticipated, that will affect crewmembers on long-duration space missions. Studies of Antarctic expeditions, submarine patrols, space simulators, and confinement and isolation conditions have exposed and defined many of the problem areas. These problems have not been solved within the state of the art, and further work is necessary.

INTRODUCTION

"There is an old saying that you cannot teach a hungry child; you cannot teach an unhappy child either, or a worried one, and you cannot expect peak performance, or even rational behavior, from an adult who is bordering on panic or frenzy or despair" (ref. 1).

The year 1971 marks the 10th anniversary of Yuri Gagarin's suborbital space flight and the second year since Neil Armstrong and Edwin Aldrin first set foot on the Moon. The U. S. manned space program has concerned itself with the engineering technology required to place a man on the Moon, with the medical requirements for survival being an important allied part. However, basic biological research has played only a secondary role, and the social sciences have been comparatively ignored. The U.S.S.R. program has accomplished more in the biological realm but has, likewise, produced little social science data. The reasons for this are obvious: the longest flight lasted 18 days (Soyuz 9), and the greatest number of men in a capsule has been three. The workloads have been generally heavy with clearly defined tasks and goals, and all the men have been highly motivated test pilots accustomed to stress and danger. Because no serious behavioral or psychiatric problem reported by either the Russians or the Americans has interfered with performance or mission success, one may conclude erroneously that the social sciences do not belong in space! This is possibly true for short-term

*University of California School of Medicine, Los Angeles, California.

missions but may not be true for a long-duration mission involving 2 years and 8 to 12 men, a workload admixed with much free time, a goal not to be attained before several months, and a mixture of pilots and scientists with different backgrounds and interests. Behavioral and psychiatric factors of the men involved in long-duration space missions are extremely important and must be investigated in future flights. Kubis and McLaughlin (ref. 2) also express this need. "It is well known that energies can be mobilized, stress can be adapted to, and discomfort can be tolerated for short periods of time. But under conditions of continuous long term mobilization of effort against unrelenting stresses, there may well be a degradation of the resistance and adaptability of the astronaut despite the superb conditioning which he has acquired in training."

Is manned space flight necessary? The Soviet successes with lunar robots and the abundance of data acquired by both U.S.S.R. and U.S. deep-space probes have shown that nonmanned flights do contribute to space programs. However, machines are limited. For example, no photoelectric cell has ever been devised that can improve upon the versatility of the human eye (ref. 3); likewise, no computer has man's ability to react, evaluate, and act upon unprogramed inputs. Kubis and McLaughlin estimate (ref. 2) that half of the pre-Apollo space missions would have failed were it not for astronaut reaction to emergency situations. They state that "The success of a space mission is intrinsically dependent on the information-processing, decisionmaking, and highly adaptive capabilities of the astronaut who is required not only to manage and control the spacecraft and its systems, but also, in an emergency, to insert himself as an intelligent override within those automatic but not perfectly reliable systems." Modern cybernetics recognizes the advantages of the man-machine combination in providing redundancies contingent upon each other to increase the chances of mission success. Some advantages and disadvantages of man and machine in such systems are given in table I.

Finally, men derive satisfaction in conquering the unknown (the "because it is there" drive of mountain climbers). Man, master of both his fate and his machines, grows by conquering his environment and by taming his frontiers, and space is a new frontier. All people shared excitement and unity when Neil Armstrong first stepped on the Moon. Thus, man belongs in space, and, for this reason, the psychosocial characteristics of the species in this environment deserve study.

Many problems inherent to long-duration space missions would be alleviated with the perfection of techniques in anabiosis, consisting of induced hibernation and deep hypothermia. Anabiosis, by slowing down metabolic processes, would diminish the effects of psychological and social factors because the men would spend much of the time in a state of suspended animation. However, several practical problems exist that would preclude anabiosis being used on the first long-duration space missions. Also, although many psychosocial problems would be eliminated, new ones may result from the procedure itself. Finally, under these conditions, man is no longer a part of the man-machine process, and many of the advantages he brings to such a mission would be gone. Therefore, a closed ecosystem approach will probably be enforced, with the men awake and interacting much of the time.

A trip to Mars is, perhaps, the most practical and realistic example of a long-duration space mission. Hyatt (ref. 4) estimates the length of such a trip at 500 days, assuming moderate energy expenditure, with a visiting time of 25 days. Price et al. (ref. 5) describe a Mars mission, with a Venus flyby, that would last 450 to 510 days. They propose a Mars landing, lasting from 1 to 60 days, which would use a Mars excursion module. The mission activities can be classified under four headings: operational, scientific, human support, and maintenance. The 10-man crew would live in the center section of the space vehicle with facilities for work, recreation, hygiene, and dining located around the perimeter. Both of the preceding sources describe a trip involving one spacecraft. Some proposals involve more than one vehicle. Sharpe (ref. 3) discusses this idea in terms of the redundancy concept: "The process of redundancy can be carried even further to increase the probability of a successful mission on very long-range projects such as a voyage to Mars. We should launch more than one vehicle so that they can travel like the Nina, Pinta, and Santa Maria during a far more hazardous exploration in the 15th century (sic), which ended successfully when two out of the three ships returned safely."

The important aspect of these proposals is that the estimated time to Mars is approximately 8 months. During this time, men must interact under conditions of weightlessness, monotony, isolation, possible danger, and an abundance of free time. After a "breather" on Mars, they must then face the same conditions during their return to Earth. No space mission to date has provided enough information to truly analyze any of these factors. The U. S. Skylab missions of 28 and 56 days, to be launched early in this decade, will provide some answers concerning men working for nearly 2 months in a weightless environment. This, however, represents only one-fourth of the total trip time to Mars. Obviously, a space station or lunar laboratory would be much better, but at present these structures are still "on the drawing boards." Therefore, data must be obtained from short-duration space missions, long-duration space simulators located on Earth, and various social systems that have characteristics common to long-duration space missions. Hopefully, by extrapolation, some meaningful trends may be exposed, although these must be taken as extrapolated probabilities, not fact.

Sells (ref. 6) has done an interesting study of 11 social systems he regards as pertinent to long-duration space flight. He first developed 56 characteristics of such flights, then scored his social systems on each characteristic according to a scale of 2 (highly similar), 1 (moderately similar), and 0 (dissimilar or unrelated). The results are presented in table II. A large break appears between the first five systems and the next six, implying that systems 1 to 5 provide the best data for extrapolation to long space missions. Short-duration space flights, space simulators, weightlessness, and the recent hypodynamia studies, which are not included in table II, would undoubtedly alter the ranking. Sells' systems do not include many important variables and none of the systems even nearly approach an ideal score of 112, showing that they are at best only approximations to the actual missions.

With regard to systems that Sells omitted, similar faults may be found. A comparison of these sources of information is given in table III, which indicates that these other systems do not truly represent an accurate picture of long-duration space missions. One report (ref. 7) helps to put the picture in proper perspective: "... no 'simulation experiments' land based, submerged, or even a short or long term orbital laboratory can serve as an absolute predictor of future long-range missions. Simulation studies can only provide relative or trend data."

STRESS AND ITS MEASUREMENT

"Be careful and slow to form an estimate of a man's value until he has been observed under stress. To a great extent the men who were on their feet, working to save themselves and the ship, when the long dive was over, were not the normal leaders of the crew. The people who lasted out were those of a more phlegmatic disposition who didn't bother too much when things were running smoothly. The worriers and the hurriers had all crapped out, leaving the plodders to bring home the ship" (ref. 8).

Stress and Stressors

The concept of stress means different things to different disciplines. Stress may connote either a cause or an effect. For example, rotating in a centrifuge may be considered as a stress; likewise, the physiological mechanisms causing a person to black out at high g-loads are also considered as a stress. Therefore, a stress will be defined as any change in an organism produced by a stressor (e.g., blacking out). A stressor is some condition(s) affecting an organism (e.g., rotating in a centrifuge).

There are four types of stressors: physical, physiological, psychological, and social. The U.S. manned space program has largely concerned itself with the first and second types, for these have been of major concern so far. However, the advent of long-duration missions requires that the latter two types of stressors be considered. Dunlap (ref. 9) has stated that "the long duration of a Mars mission, the great distance the crew will be from the vicinity of Earth, the vastness and hostility of outer space, and man's lack of knowledge about outer space are factors which make it unwise to extrapolate from our current experiences and predict that psychological and social stressors will not seriously affect the probability of mission success." At the 21st Congress of the International Astronautical Federation, Charles A. Berry stated (ref. 10) that problems concerning confinement and group interaction will be a critical factor in the crew's ability to work and get along together.

It is important to realize that all types of stressors may affect the behavior of the crewmen. For example, Yuganov et al. (ref. 11) found that, in simulated space flights lasting as long as 60 days, background noises of a 75-decibel intensity produced tinnitus, headaches, lack of sleep, and fatigue. Dunlap states (ref. 9) that "the presence of environmental stressors, such as weightlessness, ionizing radiation, and atmospheric contaminants, can lower the threshold of tolerance to psychological and sociological stressors." In one simulation study, a moderate increase of cabin carbon dioxide (as much as 3 percent) was found to increase alertness and performance (ref. 12), but a review of submarine literature has shown that higher-than-ambient carbon dioxide levels can cause headaches (ref. 13). Physical and physiological stressors that affect man's behavior and state of mind are acceleration, vibration, lighting, temperature, radiation, magnetic fields, noise, weightlessness, atmosphere, food, liquids, waste removal, instrument display, disruption of circadian rhythms, and lack of sleep. Physical and physiological stressors are not minimized, but this report will assume that they will be resolved to tolerable limits by the time a long-duration space mission is undertaken.

The psychological and social stressors, the main concern of this report, are low sensory input, lack of motivation, confinement, isolation, monotony, free time, unconscious conflicts, blocked drives, dangers and emergencies, interpersonal relationships, crew size, and crew structure.

Measurement of Psychological and Social Stress

Psychological and social stressor effects are, in general, measured by psychophysiological, psychological, and social tests. The psychophysiological tests measure emotion, arousal, or excitation. According to Ruff (ref. 14), the tests are based on three concepts. The first of these is the idea that the "fight or flight" reaction to an emergency is mediated through the sympathetic nervous system. For example, responses involving fear are associated with epinephrine release and those of anger are associated with norepinephrine secretion. The second concept, the "general adaptation syndrome," is that stressors such as cold and infection cause adrenal corticosteroid secretion through the action of pituitary adrenocorticotropic hormone. The third idea is that stressors cause cortical arousal by way of the ascending reticular activating system in the brain stem and its thalamic extensions. Wang (ref. 15) and Burch (ref. 16) have confirmed this concept and shown that the galvanic skin response is also a good indicator of cortical arousal. Some representative psychophysiological tests and typical psychic correlates are given in table IV.

Several of these tests have been used on manned space missions. For example, on the Gemini VII and IX missions, urinary catecholamines, heart rate, and respiratory rate were measured as an indication of short- and long-term stress. On the Gemini VII mission, Frank Borman was connected to an electroencephalograph (EEG) transmitter, and data were collected concerning his general activity patterns and sleep state. Russian scientists have used these same tests.

It has been found that the psychophysiological tests occasionally give varying results. For example, Lacey and Lacey (ref. 17) tested several subjects on a variety of stressors and found that each subject was overactive in some physiological responses, average in others, and underactive in still others. They found (ref. 17) that "these patterns of response tend to be reproduced from one stressor episode to another." Therefore, any one physiological measure may not be a good indicator of stress in a particular individual. Consequently, when individuals are compared in an experiment involving one stress measure, the differences observed may be due to individual idiosyncracies and not to the experimental variables. In addition, Ruff (ref. 14) points out the importance of considering what a particular stressor means symbolically to an individual. He states (ref. 14) that external dangers may be met with immediate, uncomplicated responses but that "when danger is internal, symbolic, and anticipated, a variety of psychological defense mechanisms are called into play.... The result may be a breakdown in performance that would be unpredicted if the total meaning of an unusual environment were not considered." As an example, using heart rate, Ruff (ref. 14) cites the following report: "Lacey (1959) has shown that if a subject is required to note and detect what is going on in the environment, cardiac deceleration is the rule. Where he must concentrate on internal symbolic manipulations or is exposed to stimuli in which mechanisms to reduce environmental intake would be useful, cardiac acceleration is the rule." Thus, it appears that psychophysiological tests measuring external stressors must also take into account internal stressors rooted in the personality of the subject.

Psychological tests often give a good picture of internal stressors. They are especially useful to describe a person's reasoning ability, general intelligence, personality, emotional state, and unconscious drives. A classification of these tests is given in table V.

Both psychological and psychophysiological tests have given varying results to the same stressors because they are very subjective and difficult to interpret, especially the personality tests. However, when used in conjunction with more objective data, more meaningful interpretations can be made (ref. 14): "Performance and physiological variables are well-suited for serving as criteria of stress and for measuring its magnitude, but they are usually nonspecific.... Personality variables, on the other hand, tell us what kind of stress, but seldom indicate its degree. By combining both categories of tests, we can learn something about the nature and degree of stress — both as imposed by the environment and as perceived by the subject." In fact, personality tests can also reveal conditions not externally present. For example, in a space simulator study by Flinn et al. (ref. 18), these tests, plus diary information, revealed that the subjects harbored extremely hostile feelings despite behaving in a calm, businesslike manner.

Before leaving the subject of psychological tests, a problem that exists with any sort of test should be noted. Ebersole states, (ref. 13) "It is my opinion, after five years of sea duty in submarines, that in such an isolated group the use of interviews, projection technics and gadget tests so perturb the subjects that the findings are without validity.... The use of formal psychologic testing may convince the group that there is a limit to its endurance about which to be concerned." Therefore, any type of experimental constraint may introduce a bias, which is a concern in psychosocial testing, and the experimenter must caution against a too aggressive experimental approach. A good experiment is one in which the subject forgets that he is being experimented upon.

The social tests (measures of group behavior) are few in number. One reason for this, no doubt, is the difficulty in devising a test that can account for all the variables present in a group interaction. The following is a listing of some of these tests: (1) direct observation, (2) Bales Interaction Process Analysis (BIPA), (3) Rankin Scales, and (4) Interpersonal Projection Test (Donald Glad).

One of these tests that has been used in some simulator studies (refs. 18 and 19) is the BIPA. Using this method, every observed verbal and nonverbal interaction between the members of a group is classified according to the categories listed in table VI. All interactions are tabulated within each category, and a profile is prepared that indicates the interaction pattern for the group. Flinn et al. (ref. 18) and Hagen (ref. 19) used this test in evaluating the interaction of four pairs of subjects who spent 14 to 30 days in the School of Aviation Medicine (SAM) two-man Space Cabin Simulator (SCS). The results were compared with an average profile from 21 other small-group studies reported in the literature. The comparison is shown in figure 1. The experimental profile differed greatly from the "control" because the more formal, task-neutral categories were much higher and the positive and negative categories much lower. In fact, Hagen found that interactions in categories 5 to 8 accounted for 83 percent of the total, and that the changes from the control in categories 1, 3, 10, and 11 were statistically significant. These results indicate that the men limited their interactions to those useful in completing the mission. Also, no evidence of extreme friendliness or hostility existed between the men. However, the data reveal some interesting trends. For example, the number of interactions scored as giving opinion increased with time, whereas those giving information decreased. No relationship was evident between giving information and asking for information and asking for opinion (ref. 19). Finally, figure 1 shows that giving opinions and information is much more common than asking for opinions and information.

The men's diaries and poststudy debriefings indicated that the men held covert hostilities toward one another not manifested overtly for the sake of the mission. Although the men underwent extensive psychological and psychiatric testing before the missions, they were paired off essentially at random. However, the hostilities that resulted could be predicted from these tests. To quote from Flinn et al. (ref. 18), "In each flight, some feelings of resentment have occurred due to differing behavioral characteristics of the two subjects which were readily identified in the preflight assessment. For example, a taciturn individual may be irritated by the continual conversation of a talkative crew-mate, while the latter feels rebuffed when his comments are ignored ... seemingly innocuous habits and mannerisms may eventually become irritating." The men failed to recognize the source of their hostile feeling, and they often displaced their anger to the outside monitoring personnel. Again from Flinn et al. (p. 614): "Often the subjects have failed to realize the extent or force of irritation displayed by their crewmate. For example, Subject A may assume that his crewmate is short tempered and irritable because of his annoyance with monitors outside the chamber, while actually Subject B's growing irritation is the result of dislike or disgust toward some mannerism of Subject A himself."

Combining this information with the Bales Interaction Process Analysis, a complete picture of the men's internal feelings and external behavior results (ref. 18): "In the space cabin study, the more neutral categories in the middle ... dominate the profile, while the extreme, more emotionally tinged categories are not well represented. This was consistent with subjective observations during the flight that the relationship between the subjects was quite formal and polite. They consciously refrained from expressing very much negative feeling for fear of disrupting their relationship. Much of the negative feeling expressed was displaced and directed toward monitoring personnel outside the chamber." In addition, the peculiar trends mentioned previously became clear (ref. 19): "The most obvious interpretation of this phenomenon is that it represents evidence of increasing psychic distance between the subjects, and the loss of sensitivity to the other's feelings and thoughts. It seems to reflect the general increase in covert hostility the subjects felt about each other during this time."

The results of this experiment demonstrate the utility of the Bales Interaction Process Analysis in evaluating group interactions. However, an objective test like this, which gives quantitative information only about stress, must be used in conjunction with more subjective psychological tests. Thus, a more complete picture would emerge, and both the behavioral "what" and psychic "why" become evident. The experiment also demonstrates the predictive value of psychological and psychiatric tests.

Conclusions on Stress and Its Measurement

The physical and physiological stressors affecting man in space will probably be well controlled by the time of a Mars mission; consequently, this report will be concerned with psychological and social stressors. However, because of their importance to behavior, sleep and circadian rhythms and weightlessness will be discussed further. Many methods, including psychophysiological, psychological, and social tests, have been developed to measure stress in man. No single test can divulge a complete picture of "what is going on." One must combine subjective and objective tests, using the strengths of each. The combination of the Bales Interaction Process Analysis with various psychological and psychiatric tests, diaries, and postflight debriefings has been used successfully to describe the two-man interactions observed and the underlying motives and emotions felt by the men in space cabin simulators. A fairly complete picture of the group dynamics involved is presented and is a promising combination for future study.

WEIGHTLESSNESS AND LOW SENSORY INPUT

"Deprived of sensory input, the mind is cut adrift and regresses inexorably into that Sargasso Sea of the primary process, where time disappears, where there is no order, quantity, direction, or rationality, where vivid, multi-colored hallucinations swirl and befuddle the senses" (ref. 1).

Weightlessness

Weightlessness cannot be studied for any length of time on Earth. True weightlessness can be produced for as long as a minute in aircraft flying Keplerian trajectories, but minimum information concerning long-duration space missions can be obtained from such a short time period. The U.S. space program uses water-immersion techniques to simulate weightlessness; however, Henry (ref. 20) has described one serious disadvantage to this approach: "A man may try to initiate weightlessness by floating in water. Although the water exerts an upward buoyant force on his body in such a case, any heavy object within his body is pulled down onto the wall of its containing cavity by the force of gravity. Thus, a steel ball swallowed by a man in a weightless state will drift about freely within his stomach, but if swallowed while he is floating in water, the ball continues to press on the stomach wall. The tiny otoliths in the horizontal utricle and vertical saccule of the labyrinth of the ear are like this steel ball. In the weightless state the otoliths float free." A more accurate picture of the effects of this phenomenon on a human being is available only from space experiences. However, in space capsules, many factors are interacting (weightlessness, confinement, danger, etc.), and an observed effect is difficult to attribute to any single cause. The U.S. and U.S.S.R. reports on the physiological effects of orbital and lunar flights (refs. 21 to 25) show that weightless conditions have a definite effect on the human body. Some of these are (1) muscle atrophy (including the heart); (2) weight loss; (3) moderate cardiovascular deconditioning; (4) moderate loss of exercise capacity; (5) minimal loss of bone density, calcium mobilization, and formation of urinary stones; (6) loss of catecholamines and aldosterone in the urine; (7) moderate loss of red blood cell mass; (8) depression of blood clotting ability; and (9) catarrhal and urinary infections from opportunistic invaders because of general lowered immune response.

However, the U.S. program to date has found no serious decrement in performance because of any of these factors. Charles A. Berry (ref. 21) concludes that "the crews have adapted extremely well to the weightless environment, have found the environment pleasant, and used the environment to assist them in accomplishing inflight activities."

Weightless conditions likewise have had a minimal effect on the neuropsychological functioning of the crews. Visual acuity tests conducted during the Gemini V and IX missions and measurements of otolith functioning, preflight and postflight, have shown no apparent decrement (ref. 2). Some disorientation has been noted as a result of suppression of vestibular and kinesthetic sensations, but the men have been able to compensate adequately by using visual and tactile cues (refs. 20 and 26). Electroencephalographic recordings of Frank Borman during the Gemini VII mission showed a high preponderance of theta waves (4 to 7 Hz), which have been interpreted as demonstrating an adaptation to the weightless condition (refs. 27 and 28). Also, some disruption of sleep occurred on this mission. One U.S.S.R. cosmonaut has experienced severe nausea in flight — Gherman Titov during the Vostok 2 mission. Boris Yegorov noted some feelings of being upside down, occasional dizziness, and anorexia during the Voskhod 1 flight. Several U.S. astronauts have experienced head stuffiness during the first 24 hours that has not been accompanied by skin flushing, reddening of the eyes, or a pounding pulse (refs. 3 and 25). Nausea and mild disorientation have been reported by several Americans in space. Andrian Nikoleyev experienced no problems with the Kraepelin mental arithmetic test or with distinguishing geometrical designs (ref. 24). No U.S. astronaut has experienced hallucinations, delusions, depersonalization, or any other psychiatric problem. However, several U.S.S.R. cosmonauts have reported an initial fear caused by a sense of falling down that was followed by feelings of joy, gaiety, and euphoria. Simonov (ref. 29) interprets this feeling of joy: "This emotion is a result of the comparison of expected danger (falling down is usually associated with danger — stroke, death, etc.) with the experienced safety of the state of weightlessness. The person comes to the latter conclusion several seconds after the development of weightlessness." Both U.S. and U.S.S.R. pilots have described extravehicular activity as a pleasant, almost euphoric experience with no resulting problems in orientation or emotion. Cosmonaut A. Leonov (ref. 20) summarizes the impression: "As for the so-called psychological barrier that was supposed to be insurmountable by man preparing to confront the cosmic abyss alone, I not only did not sense any barrier, but even forgot that there could be one."

Despite a generally rosy picture painted by artist-spacemen, there is some indication on the longer flights that physiological and psychological breakdown was occurring as a result of weightlessness. Following the 18-day, two-man Soyuz 9 mission, the cosmonauts reported difficulty adapting to one-g conditions. Both men experienced problems with posture and gait for several days, had the feeling that they were in a centrifuge "under the effect of two — or slightly more — g's" for as long as a week, and experienced sleeping difficulties for 5 days (ref. 30). During the flight, Andrian Nikolayev lost nearly 6 pounds, and both men experienced muscle atrophy and heavy calcium losses from their bones (ref. 31). He concludes (ref. 30); "... apparently, manned flights of several months' duration will require development of special measures and means to prepare the organisms (sic) of cosmonauts to withstand re-entry g-loads and to facilitate readaptation to the earth gravity conditions.... Probably, for interplanetary flights, spacecraft should be provided with artificial gravitation facilities."

The U.S. Gemini VII crew experienced difficulty sleeping, averaging only 5.3 hours per night and less than 5 hours per night on each of the last 4 nights. Both men felt fatigued and, during the last 2 days of the mission, exhibited irritability and loss of patience (ref. 23). There was no observable decrement in performance, but the men were obviously under increased psychological stress during the later days of the flight.

Hypodynamia Studies

During 1968, U.S.S.R. scientists concluded a series of five hypodynamia experiments. Sixteen healthy male subjects, between 21 and 23, were confined in bed for 70 days. The five series are summarized as follows:

Series I: Strict bedrest (four subjects)

Series II: Strict bedrest with mixed medication (securinine, caffeine, and amphetamine given on a definite schedule) (three subjects)

Series III: Bedrest with mild physical activity allowed (three subjects)

Series IV: Bedrest with moderate physical activity (three subjects)

Series V: Bedrest with complex physical activity (three subjects)

The subjects were given physiological and psychological tests before and after the experiment, and in some cases at 10-day intervals. The psychological tests measured task performance, emotional stability, memory, mental efficiency, and intelligence. In addition, the subjects were observed clinically throughout the study. The results of these studies are presented in references 32 to 34.

Physiologically, the subjects experienced little difficulty during the first 2 weeks, with the exception of mild pallor, muscle weakness, and pain around the waist. Later, several functional problems developed. Sorokin et al. (ref. 34) describe some of these problems, which were (1) muscle atrophy and decreased tone (most subjects); (2) weight loss (14 subjects); (3) joint pains (all subjects at end); (4) cardiovascular difficulties (systolic murmur, pains over the heart, palpitations) (five subjects); (5) tachycardia and increased blood pressure (average of all subjects, but especially groups 1 and 2); (6) decreased exercise tolerance (one subject); (7) decreased clotting ability (five subjects); (8) catarrhal and urinary infections caused by lowered immune response (six subjects); and (9) gastrointestinal complaints (spastic colon, constipation, anorexia) (most subjects).

Many obvious similarities are apparent when these results are compared with those produced during weightless conditions. The degree of symptomatology in the U.S.S.R. studies was much greater (including two cases of appendicitis and one subject being dropped from the experiment for psychological reasons); however, the subject's test duration was four times as long as the duration of space flights of the past. An interesting idea arises from the preceding comparison: do the weightlessness findings resemble those of the hypodynamia studies because astronauts and cosmonauts are largely confined to their seats, or do weightlessness and hypodynamia share some common characteristics? Although the former idea is in part true, the latter concept leads to more fruitful discussion.

The psychological and psychiatric results of these hypodynamia studies are interesting. The subjects generally performed various tests with no decrement observed. Also, no decrement was noted in intelligence quotient, memory, attention stability, or problem solving. However, some subjects did not do as well on the time-interval tests, often giving premature reactions. Also, the subjects scored lower in tests measuring emotional stability, especially two subjects who were considered to have inadequate emotional stability and "weak inhibitory processes" before the study.

The series I subjects were observed clinically to be irritable at times, and all expressed a desire to terminate the experiment. In fact, one did. After 45 days two subjects experienced mood swings accompanied by irritability and neurotic reactions, exhibiting a negative attitude toward certain tests and toward personnel. One subject evidenced severe psychiatric disturbances: headaches, nausea, dizziness, inability to think, depression, and lassitude.

The series II subjects also showed mood swings and had difficulty sleeping. The subjects in series III and IV, however, experienced only minimal emotional problems. Bogachenko (ref. 32) summarizes these results in the following way: "Thus, manifest changes in psychic state arose during hypodynamia in the series I subjects, who were strictly confined to bed, and in the individuals who received the mixed medication (series II). These disturbances were less pronounced among the volunteers who were allowed physical exertion in series III, and practically absent in series IV and V, where a more complicated physical load was imposed."

Similar results were observed in another set of U.S.S.R. hypodynamia experiments by Purakhin and Petukhov (ref. 35). In this study, six males between 20 and 35 underwent 62 days of bedrest. Group 1 (three subjects) was allowed to participate in physical work (bicycle ergometer, rubber stretchers, static exercises), while group II (three subjects) spent the entire time in bed. This study was concerned mainly with neurological changes, and the results are summarized in table VII.

In this study, definite neurological and emotional responses were observed from prolonged bedrest. In addition, exercise helped to decrease the symptomatology. Also interesting was the finding of theta waves (4 to 7 Hz) in this experiment, the same waves that were present in increased quantity during the Frank Borman study of the Gemini VII mission.

The hypodynamia studies present some interesting conclusions. First, as noted in the previous section, clinical observations definitely play a role in supplementing and clarifying the results of psychological testing. Second, the need for exercise in maintaining physiological and psychological well-being must not be minimized. Third, prolonged inactivity causes increasing emotional problems, as has been implied during the Gemini VII mission; however, performance is only slightly affected. Fourth, prolonged bedrest produces definite physiological and neurological changes. Finally, there are striking similarities between hypodynamia and weightless conditions.

Purakhin and Petukhov (ref. 35) give an interesting neurological explanation for the results of the hypodynamia studies. "A decrease in work capacity, changes in behavior and the rhythm of sleep, paradoxical reactions during examination (dropping off to sleep when exposed to stimuli during electroencephalographic examination), and 'explosiveness' in behavior all indicate a decrease in the tone of the cerebral cortex and impairment in the excitation and inhibition process. The appearance of slow waves on the EEG and a decrease in the rate of formation of cortical time shifts confirm this. The reason for the changes described above is a constant restraint of customary actions and suppression of emotions, resulting in an overstraining of the inhibitory process, which is the basic cause of neurasthenia." The cerebral cortex exhibits a well-known inhibitory influence on the spinal cord; should this be broken (e.g., by an upper motor neuron lesion), general hyperreflexia results. In effect, Purakhin and Petukhov state that decreased sensory input from prolonged hypodynamia causes a general decrease in cortical tone, which results in a functional upper motor neuron lesion by inhibiting the cortical inhibitory process. The addition of exercise, however, increases the total stimulation to the brain, which helps to maintain cortical tone and, in turn, preserves the inhibitory process and causes a decrease in symptomatology.

Weightlessness and Hypodynamia

Goshen (ref. 36) speculates that man's upright posture requires numerous proprioceptive and muscular adjustments, which in turn give him a high degree of incoming sensory stimulation. When man is placed in a position where he does not have to battle gravity (such as horizontally), he loses many of these inputs, and lethargy, sleep, or pathological responses may occur. This mechanism of sleep is certainly not new, but hypodynamia experiments confirm Goshen's ideas regarding pathological deficits. Extending this concept to the weightless state, where man has to battle gravity even less than when horizontal on the Earth, it seems reasonable to view weightlessness as simply another condition of reduced sensory stimulation. In fact, it is this "essence" which weightlessness and hypodynamia share in common. Of course, each of these conditions possesses mutually exclusive characteristics, but both can be placed on a "sensory stimulation scale" and be quantified. The problem, however, is that man is bombarded by a variety of stimuli that help to maintain his cerebral tone through the reticular activating system, and the effect of these stimuli is additive. Hypodynamia alone causes some pathological responses, whereas hypodynamia plus occasional activity is less severe. The combination of weightlessness and hypodynamia would be expected to cause more severe responses than either alone.

In space flights to date, all space pilots have been kept extremely busy so that their level of sensory stimulation has been high despite the presence of weightlessness. Eberhard (ref. 37) has stated that the crew of long-duration missions will have more than 10 hours of free time each day, much of which will be spent doing low-stimulating work such as monitoring data. Consequently, unless other sources of sensory stimulation can be found, levels of sensory input will be low and may approximate those in the hypodynamia studies.

Sensory Isolation

Total sensory isolation would probably result in even more psychological difficulties than either weightlessness or hypodynamia alone. This has been confirmed in numerous studies. Goldberger and Holt (ref. 38) report on a study in which 14 college students were placed in a room for 8 hours under conditions of minimal and constant sensory input. The subjects were on their backs, their limbs cushioned in cuffs, their eyes covered with Ping-Pong ball halves, and their ears in headphones producing a constant background sound. Three subjects terminated the experiment early; the results of the other 11 subjects are as follows.

1. Affective problems: apathy, restlessness, tension, anger, anxiety (all subjects)

2. Increased imagery: auditory and visual hallucinations (nine subjects)

3. Time-sense disturbances: subjects reported that time seemed to drag during the experiment, but afterward 10 subjects underestimated the time they were in the room

4. Depersonalization: ego disruption (three subjects)

5. Defects of body image: sense of motion, increased weight of hand (three subjects)

Many of these effects are characteristic of primary-process thinking, yet none of the 11 subjects showed complete regression to this mode of thought.

Flaherty et al. (ref. 39) state the results of four volunteers who each spent 36 hours in a small altitude chamber that simulated orbital flight. Although the subjects were not nearly as sensory deprived as those in the previous experiment, they had no visual contact with the outside; and, except for 10-minute progress reports every 90 minutes, they had no audio contact with the outside. The results are as follows.

Subject A, a 30-year-old high school graduate, completed the study. The subject thought he heard a radio playing and various "mystery" sounds at the 25th hour. Shortly after this, the subject perceived a deep hole opening up beyond his feet.

Subject D, a 23-year-old college graduate, completed the study. The subject perceived monitor meters as "Indian faces" during the latter half of the experiment. As he fought sleep, he hypnagogically imagined himself back at the barracks talking with friends.

Subject B, a 23-year-old high school graduate, did not complete the study. After 7 hours, he complained of poor focus on the monitors, then of blurred vision. He terminated the study because of visual problems.

Subject C, a 23-year-old professionally trained man, did not complete the study. After 22 hours, he stated that the monitor was smoking and turning brown. Despite reassurance that there was no fire, he became severely agitated and anxious, and the study was terminated.

The two subjects who did not finish the study had personality problems, verified by comparison of presimulation and postsimulation psychiatric examination, which were intensified under the conditions of the experiment. All four subjects experienced perceptual difficulties under conditions of low sensory input.

Simmons et al. (ref. 40) report on eight subjects who spent 30 hours in the SAM one-man Space Cabin Simulator. After 18 hours, more than one-half of the subjects experienced visual, auditory, and proprioceptive aberrations attributed to sensory deprivation and fatigue.

Interesting anecdotal information exists that is pertinent to low-sensory stimulation. Mikushkin (ref. 41) reports on the experiences of speleologists who have spent from 63 to 130 days in isolation under conditions of weak, artificial light and low sound level. Comparing diary reports with actual time spent, all the men underestimated their duration of stay in the caves by 25 to 60 days. Weybrew (ref. 42) states that a review of literature concerning mariners sailing alone and shipwreck survivors indicates that (1) isolation causes severe perceptual changes and (2) if isolation is extended, controls over antisocial impulses may disappear. He states also that labatory studies have shown that hallucinations, delusions, depersonalization, an inability to concentrate, increased slowing of occipital EEG waves, increased regressive behavior, increased hostile feelings, and preoccupation with food and sex are produced in a man alone in isolation. Finally, some studies have described the curious break-off phenomenon that has occurred in 35 percent of pilots flying under monotonous conditions at high altitudes. This phenomenon has been described as a feeling of separation from the Earth and has been characterized (ref. 13) by "dazed feelings, confusion, faulty perception and judgment, and either anxiety or a peculiar exhilaration."

Three cats restricted to a box for 20 to 30 days were studied by Kogan (ref. 43) for effects of immobilization and prolonged fixation. He found cardiac disturbances in all three animals (bigeminal rhythm, paroxysmal atrial tachycardia) and a decrease in the amplitude of the EEG waves, with a poorer reaction in alpha-rhythm response to a sound irritant. He concludes that the conditions of the study (particularly the prolonged-fixation aspect) caused "considerable changes in nervous and cardiac activity." Therefore, sensory isolation data reveal the presence of extreme neuropsychological disturbances. Dunlap (ref. 9) summarizes this: "In experiments with adult humans, this sensory input underload has resulted in general personality disruption, perceptual distortion, deterioration in cognitive functions, loss of accuracy in tactual, spatial, and time orientation, and visual, auditory, and somesthetic hallucinations."

A Hypothesis

From results of weightlessness, hypodynamia, and sensory isolation studies, the following hypothesis may be made: conditions of weightlessness, hypodynamia, and sensory isolation may be placed on a continuum measuring total sensory stimulation to the subject under study (fig. 2). Each of these conditions produces psychophysiological stress, varying in degree according to the total amount of sensory stimulation. Combining the conditions produces a decrease in total sensory stimulation that, in turn, intensifies the resulting psychophysiological stress.

The neurological basis for this hypothesis lies in the ability of sensory input to maintain proper physiological cerebral-cortical tone. Lowered sensory input decreases this tone, which would cause neurological and psychic changes. Sensory overload would also be expected to produce abnormal cerebral tone, resulting in aberrations perhaps similar to those seen in an underload. In addition, there are probably purely psychic "inputs" that have an effect on cerebral tone.

Weightlessness and the Astronaut

The preceding hypothesis may be used to explain the apparent negligible effect of weightlessness on astronauts to date. During an orbital flight, the men are kept busy monitoring instruments, communicating with the ground, conducting experiments, handling emergencies, performing for television, et cetera. Despite the weightless condition, the total sensory input is adequate to prevent psychological problems.

However, conditions on a long-duration mission will be different. Although there will still be many activities, they will become routine as the time scale is expanded. Much of the astronaut's time will be spent monitoring instruments, which Davies (ref. 44) describes as being of very low sensory input. In addition, the men will have more than 10 hours a day free time (according to Eberhard (ref. 37)). The mission goals will be 8 months away, and even the most highly motivated man will probably suffer loss of motivation. Some of the men will be scientists whose primary talents will not be used until the goal is reached. Finally, the space capsule will be confining and monotonous. The additive effect of all these factors will be one of low sensory stimulation and cortical arousal. Superimposed on this will be a state of weightlessness. Something can be done about the other factors, but what can be done about the weightless state?

Artificial Gravity

Nikolayev (ref. 30) suggests the use of "artificial gravitation facilities" for interplanetary flight. This is not a new idea, and Goshen (ref. 36) describes the most practical approach: "To provide artificial gravity would require ... a very large wheel-like structure rotating about its central axis, with crew located at the periphery where centrifugal force would serve as a gravity substitute." Many people become motion sick in such rotating systems because of rotational forces on the vestibular system, particularly on the semicircular canals. Guedry (ref. 45) and Graybiel et al. (ref. 46) observed subjects in a rotating room and found that they exhibited a variety of symptoms, ranging from nystagmus and unusual sensations to nausea, when they moved their heads in any direction other than parallel to the axis of rotation. However, as the subjects became habituated to the effects, the symptoms disappeared. Within a few hours, most of the men experienced no difficulties. Interestingly enough, following habituation to the rotating conditions, the men experienced similar symptoms when the room was stopped in its rotation, and it took them a few hours to become readjusted to the nonrotating state. Thus, from these studies, one could conclude that man can tolerate a rotating system for a long period of time.

Of more important concern are the technological difficulties and cost in creating such a system. Goshen (ref. 36) states that "if artificial gravity were provided for, the state of the art would have to make substantial progress before design decisions could be put into effect." Thus, barring any radical fund allocations or engineering developments, the first long-duration space crews will probably have to function under weightless conditions, despite the advantages of artificial gravity.

Exercise

Exercise is advocated to minimize the effects of weightlessness. Korobkov (ref. 47) emphasizes the positive role exercise plays in space. He believes that exercise causes better stability of the conditioned reflex and higher central nervous system tone because of improved sympathetico-adrenal functions and reticular activation. He lists four effects of exercise: better adaptability to stress and emergency situations, better psychological conditioning, better physiological conditioning, and more rapid recovery to one-g postflight conditions. He cites evidence from a 40-day bedrest study that athletes exhibited higher performance and better endurance than untrained persons. He also states that, in centrifuge rotations, resistance was found to be better in subjects given "exercises used in the training of gymnasts, wrestlers, acrobats, weightlifters, and mountain climbers." Davies (ref. 44) states that mild exercises improves performance on vigilance tests: "An increase in sensory variation, whether provided externally, as in conversation, or internally by proprioceptive feedback to the brain from the body's joints and muscles, as in mild exercise, probably increases the level of arousal of the central nervous system and in this way promotes better performance."

Finally, the results from the Apollo missions indicate that 12 of 15 crewmen tested experienced decrement in exercise capacity as measured by a bicycle ergometer postflight, but recovered after 36 hours on Earth (ref. 21). Therefore, a regular routine of exercise is a "must" on long-duration space missions.

Conclusions on Weightlessness and Low Sensory Input

Weightlessness can be visualized as a condition of low sensory input. In this way, it may be placed on a continuum with other states of sensory deprivation, such as hypodynamia and single-man isolation. The lower the total sensory input, the more severe are the physiological, neurological, and psychological aberrations that result. Also, the effects of sensory-deprived states are additive, and weightlessness added to a low-sensory-input condition would produce a more profound effect than the latter alone.

The high-level sensory stimulation of heavy workloads has minimized astronaut and cosmonaut reactions to weightless conditions. However, on long-duration missions, more monotonous conditions will exist, and necessary corrections must be made. Practical considerations indicate that weightlessness probably will be present and must be seriously considered. Exercise is a good method to counteract the deleterious effects of weightlessness.

CIRCADIAN RHYTHMS AND SLEEP

"In interplanetary space flight beyond the earth's gravisphere ... is constant sunshine and a velvet black sky, day and night at the same time. In this zone with sharp contrast — rich photic periodicities or no photic periodicities at all, the astronaut is still bound to a temporal pattern of sleep, rest and activity which he inherited from his life on earth with its regular circadian cycle" (ref. 48).

Circadian Rhythms

During evolution, plants and animals became physiologically adapted to periodic environmental changes associated with rotation of the Earth. Most of these adaptations vary with a 24-hour rhythm; hence, the name circadian rhythm. Examples of circadian rhythms include sleep/wakefulness, body temperature, heart rate, urinary excretion, and numerous other physiological functions. A more complete list is described by Rummel (ref. 49). Most of these rhythms are endogenous but may be influenced by a variety of exogenous synchronizing factors called "Zeitgebers." Although the most important Zeitgeber is light, cosmic rays and the Earth's electromagnetic field may be factors. Morey (ref. 48) believes that these latter factors may be even more important in space conditions because of the constancy of light. A magnetic storm might be significant. The exact mechanism by which Zeitgebers influence body rhythms is not known, but the pineal gland has been implicated (ref. 48). Mikushkin (ref. 41) emphasizes the role of the endocrine glands and autonomic nervous system. Finally, Folk (ref. 50) describes three theories of circadian rhythm development, the most likely of which states that each rhythm is genetically determined by centuries of evolution.

Disruption of circadian rhythm is called desynchronization. The most obvious example of this occurs in travelers flying across several time zones. Symptoms include malaise, insomnia, appetite loss, inability to work, and nervous stress. Increasing the intensity of light generally shortens the circadian rhythm in man; likewise, low light intensity increases these time intervals. This phenomenon provides a possible explanation for the apparent increase in time perception observed by speleologists under conditions of weak illumination (ref. 41).

Circadian Rhythms and Performance

Attempts have been made in several studies to analyze the effect of circadian rhythmicity on performance. Flinn et al. (ref. 51) demonstrated the existence of a diurnal variation in performance in the SAM one-man Space Cabin Simulator. Three subjects who started at different times showed a performance decrement at approximately the same time the following morning. Frazier et al. (ref. 52) report that three subjects who spent 14 days confined to a chamber revealed period shifts and showed task performance deterioration in systems monitoring, visual reaction time, communications, and imbalance matching. The results indicated that circadian rhythmicity was often found to be a major source of performance variation. The 15-day Lockheed study (ref. 53) revealed performance peaks between 7 and 10 p.m. during the first 5 days, with the worst performance occurring during the early morning hours. During subsequent days, there was a time shift toward later hours; and, during the last few days, the subjects performed best shortly after midnight. However, the author suggests an interesting explanation for this result: "... the study began at 0930 hours which was approximately 3-1/2 hours after waking. During the course of the study, however, the work period which began at 0930 became a reference point for the beginning of another day, and corresponded psychologically more closely to the subjects' normal hour of arising. In this sense, the subjects' 'day' shifted to a new time zone."

Finally, Chiles et al. (ref. 54) report a study in which the subjects were shown previous performance curves during a similar experiment and were encouraged to put extra effort into performance whenever they sensed a lowering of their "sharpness." The results showed no significant diurnal variation. The authors concluded that "when subjects are tested around the clock ... they exhibit circadian periodicities in their performance .... The magnitude of these fluctuations can be substantially reduced by instructing subjects to consciously attempt to raise their performance during 'low' periods." Morey (ref. 48) describes the effects of motivation in modifying the circadian rhythmicity of performance: "For animals, the physical factors (light, temperature, etc.) are of principal significance in the re-arrangement of the diurnal regime; for humans the psychic activity, the will power to accomplish the day's schedule and the ability to reorganize rapidly in relations to a change in a situation are essential."

Thus, performance as measured on standard tests shows circadian rhythmicity. The best performance occurs between 7 and 10 p.m.; the worst between 2 and 8 a.m. Without the effect of a strong Zeitgeber, these times shift toward later hours in subsequent days. Performance rhythmicity will disappear when knowledge of the performance cycles is coupled with high motivation.

Circadian Rhythms in Space

Circadian rhythms have been observed in space. On Gemini VII, Frank Borman's heart rate was observed to drop regularly during the Kennedy Space Center night (ref. 3). In addition, heart-rate rhythms have been observed to increase steadily in periodicity with time (ref. 55). Interesting information regarding rhythms was obtained during the Gemini missions (ref. 23). The men of Gemini IV had great difficulty sleeping. The longest consecutive sleep period was 4 hours, and the command pilot slept less than 8 hours altogether. The sleep schedules on this flight were staggered, and it was believed that noises caused by the onduty member kept the other awake. On Gemini V, the sleep periods were programed to coincide with the Kennedy Space Center night; however, they were still staggered, one man sleeping from 6 to 12 p.m. and the other from 12 p.m. to 6 a.m. Again, the onduty member kept the other from sleeping. However, there was a tendency for both men to sleep during the 12 p.m. to 6 a.m. period. There was no tendency to sleep during the earlier 6 hours. Therefore, the sleep-wake rhythm the men had on Earth seemed to manifest itself in space. To verify this, the Gemini VII crew's sleep time was not staggered and corresponded to that of the men at Cape Kennedy. The crew slept much better; however, their sleep was still not as good as on Earth.

A similar sequence occurred during the Apollo missions (ref. 21). On Apollo 7, the sleep periods were staggered, and the crew reported unsatisfactory sleep periods. One man fell asleep during one watch and took 5 milligrams of Dexedrine to keep awake during another. Similar problems occurred during the Apollo 8 mission, and it was believed that "crew performance was slightly degraded, and minor procedural errors were committed" (ref. 21). During Apollo 9, however, the men slept simultaneously at a time following their normal circadian rhythms. The results are summarized as follows: "A definite improvement over the previous two missions in both quantity and quality of sleep was noted, and a lack of postflight fatigue was evident during the recovery-day physical examination" (ref. 21). A similar policy was followed on the Apollo 10 and 11 missions, with good results. During the latter mission, however, the crew reported difficulty sleeping while in the cold, noisy, cramped conditions of the lunar module.

Therefore, circadian rhythms occur in space in a manner similar to that on Earth, provided an appropriate Zeitgeber is present. This means that spacemen can simulate conditions on Earth by controlling such factors as light intensity and sleep-wake regimes. Periodicities may be lengthened or shortened by decreasing or increasing Zeitgebers (light intensity, for example). Of course, certain Zeitgebers may play a more important role in space than on Earth. Also, circadian rhythms in space have not been observed over long periods of time. These problems have been summarized by Morey (ref. 48): "An astronaut will be subjected to an environment entirely different from the one to which he has become adapted by heredity. The 24 hour rhythm may free run causing external and internal desynchronization. It may be necessary to install special cues to prevent such asynchrony. He may be subjected to Zeitgebers which are not present on earth such as high magnetic fields, differing UV radiation and cosmic showers as well as marked variations in light-dark cycles .... The determination of all Zeitgebers (synchronizers) that can affect an astronaut is a necessary condition prior to the start of long term flights. The constant monitoring of astronauts in short-term flight is mandatory in order to predict long term effects."

Work/Rest Cycles

The Apollo astronauts generally scheduled 12 hours of work, 8 hours of sleep, and 4 hours of relaxation each day (ref. 21). However, their days were busy and interesting. For more routine, long-term space-mission conditions, shorter work/rest cycles may be preferred (refs. 53, 54, and 56). Chiles et al. (ref. 54) found in their studies that "with tasks that are not intrinsically interesting (such as those used in these studies) the briefer work periods (e.g., 4 hrs) are preferred, and subjects generally predicted that duty periods longer than 4 hours would lead to decrements over any prolonged period of testing." Naturally, these work/rest schedules would have to be modified somewhat to fit into the sleep/awake rhythm for the crew.

Andrezheyuk et al. (ref. 57) report on three test subjects involved in two 15-day isolation-chamber experiments. The first study placed the men on staggered 16/8-hour work/rest schedules. In the second study, the men were placed on a 12/6-hour work/rest schedule in an attempt to enforce an 18-hour circadian pattern. The authors found that the men adapted to the first condition (the man who was awake "at night" habituated himself within a few days). However, the second routine was more difficult for all the men (ref. 57): "There was an increase in number of mistakes and in the time required for the concentration tests, a deterioration in the accuracy of reproduction and decrease in the amount of material remembered, an increase in the latency of response, and decrease in muscular strength and endurance. All these changes were more pronounced in the second experiment than in the first." In addition, the men were drowsy when awake and slept poorly. Biochemical tests confirmed evidence of strain caused by desynchronization. Therefore, it appears that trying to enforce an 18-hour cycle on man has a much greater deleterious effect than simply staggering his normal 24-hour period.

Despite the circadian advantages of similar sleep-awake cycles for the men, a staggered schedule has been proposed. Thus, a man would be awake at all times to handle any emergency situation. Seminara and Shavelson (ref. 58) confined four subjects in a simulated lunar shelter for 5 days. The performance of the subjects when they had just been awakened and when they had been awake for some time was compared. Significant ($p < 0.05$) performance decrements were recorded on four tests of subjects just awakened. Results indicate that the first 3 minutes are the most critical, but that decrements occur until 10 minutes after waking. Also, continued confinement seemed to degrade this effect even more. They conclude (ref. 58): "The data supported the view that the simultaneous sleep schedule is not advisable where the crew is required to perform critical actions within three minutes subsequent to sleep arousal. If the simultaneous sleep schedule is dictated by other considerations, emergency system responses must be automated, whenever possible, to minimize the safety penalty (in) arousal performance."

Apparently, many factors must be considered regarding the work/rest/sleep cycle of a crew on a long-duration space mission. A 16/8-hour awake/sleep cycle that corresponded to the crew's cycle on Earth would be ideal. The awake time could be divided into 4/4-hour work/rest units. These cycles could be governed by several known Zeitgebers, such as light, cabin temperature, and time. However, simultaneous cycles are prevented by practical considerations, which require one crewman to be awake at all times to monitor key instruments, and a significant problem would occur if the crewmen were on simultaneous schedules (ref. 58). Therefore, some sort of staggered scheduling will be necessary. Naturally, this will put strain on the crew, but Andrezheyuk et al. (ref. 57) show that cycles of approximately 24 hours require little adapting. Additional study on the long-term effects of these cycles is necessary, however.

Sleep

Sleep-wakefulness is considered a circadian process even though it does not follow a classical 24-hour maximum-minimum wave pattern. Man usually sleeps 7 to 8 hours at a time each day corresponding to darkness hours, when most other physiological rhythms are at low levels. Sleep itself is periodic and is divided into four stages, which are detected by the observation of slow or fast waves on an EEG. The cycle of the four stages is repeated, five to six times a night. Following the first cycle, a new stage, called rapid eye movement (REM) or paradoxical sleep, occurs. It is characterized by fast, low-amplitude EEG waves, movement of the eyes, relaxation of the neck muscles, and dreaming. As the night progresses, REM sleep increases in length with each cycle and gradually replaces stage 1 sleep. The sleep cycle in general, though averaging 90 minutes a cycle, steadily increases in duration as the night progresses so that the last cycle is the longest. This type of pattern is reminiscent of the free-running circadian rhythms.

The literature reveals that difficulty in sleeping is a minor problem aboard most modern submarines, with the exception of the 11-day Nautilus mission in 1956 (ref. 59), when muscle tension and insomnia were reported. During the 83-day Triton cruise in 1960 (ref. 42), irritability, tension, and insomnia were reported among habitual smokers during a smoking curfew. No sleeping problems were reported during the 30-day Nautilus cruise in 1958 (ref. 59), the 60-day Seawolf cruise in 1960 (ref. 13), or the 60-day isolation study aboard the U.S.S. Haddock (ref. 59). Serxner (ref. 61) recently found no sleep disturbances and no differences in the nature or frequency of dreams in the evaluation of the crews of two Polaris submarine patrols.

In contrast, Natani et al. (ref. 62) report that insomnia and sleep disturbances accompanied early Antarctic exploring parties (Amundsen, Byrd, Scott) and were prevalent on Antarctic expeditions during the International Geophysical Year. An experiment was conducted using EEG, electrooculograph (EOG), and electromyograph (EMG) measurements on four subjects who spent 9 months in Antarctica. Although the mean duration of sleep did not vary, the quality changed, and the men suffered from a virulent form of insomnia known as the polar "Big Eye." A decline in REM sleep from 27.9 to 23.9 percent was noted. The amount of stage 3 sleep decreased, and stage 4 sleep disappeared; in fact, the latter was not recovered during followup. Natani et al. postulate that the loss of stage 4 sleep is an adaptational response to the high-altitude conditions and that "slow-wave sleep may be curtailed to avoid decreased levels of arterial oxygen found to be physiologically associated with slow-wave sleep" (ref. 62). They report an experiment by Agnew et al. which indicates that subjects deprived of stage 4 sleep "became physically uncomfortable, withdrawn, less aggressive, and began to manifest increasing concern over their vague physical complaints and changes in bodily feelings, suggesting a depressive and hypochondriacal reaction with progression of the stage 4 deprivation" (ref. 62).

These conclusions have been verified by other Antarctic researchers. Shurley et al. (ref. 63) found that 32 subjects observed during a typical week at a South Pole station averaged 7.55 hours sleep per night. Rasmussen and Haythorn (ref. 64) found several incidences of disruption of sleep cycles and restlessness at one Antarctic station. In a survey of several Antarctic stations, Gunderson (ref. 65) observed that insomnia increased 28 percent in Navy personnel and 4.4 percent in civilians during the winter months from 1964 to 1966.

The Russian hypodynamia studies found several sleep aberrations. Sorokin et al. (ref. 34) state that after the first few nights "the subjects found it difficult to go to sleep at night, and many of them slept fitfully, with frequent awakenings and nightmares. The sleep disturbances were more pronounced durnng (sic) the first and second weeks of the hypodynamia, but they persisted in one degree or another over the entire period of confinement to bed."

Finally, Cramer and Flinn (ref. 66) report on the results of eight 17- to 30-day-duration experiments using the SAM two-man Space Cabin Simulator: "Most of our crews eventually adjusted their sleep patterns to this somewhat choppy schedule in which sleep opportunities were limited to two- or three-hour blocks except for one 5-hour period every other day." The subjects adjusted in 5 to 21 days. However, most found the sleep less refreshing than usual and noticed a decreased threshold to fatigue during the day with "little reserve to bolster them in the face of unexpected demands." Finally, the authors noted a relationship between mood, attitude, and efficiency and the number of hours slept.

Sleeping in Space

Some of the more rhythmic aspects of sleep during the Gemini and Apollo mission were mentioned earlier in this document. This section will describe some of the EEG characteristics of sleeping in space. During the Gemini VII mission, Frank Borman was connected to an EEG transmitter and 55 hours of data were received before the system failed. Borman slept poorly during his first night in space (a fact reported by several astronauts), but during the second night, he had four normal sleep cycles of approximately 90 minutes each. However, because an EOG hookup was not made, it could not be determined if he experienced REM sleep, although Maulsby (ref. 67) states that some wave patterns characteristic of paradoxical sleep were observed on the EEG recording. In addition, other data revealed that both Gemini VII men felt fatigued during the mission and averaged only 5.3 hours of sleep a night and less than 5 hours a night for the last 4 nights (ref. 23).

Borman's EEG data revealed another interesting finding: a high preponderance of theta waves (4 to 7 Hz) (refs. 27, 28, 67, and 68). Walter et al. (ref. 68) state that the EEG records of 200 astronaut candidates revealed increased theta activity in the parieto-occipital leads during vigilance testing and in the temporal leads during visual discrimination. Adey et al. (ref. 28) state that "gradation in theta-band power densities was observed from low levels in laboratory tasts (sic), to intermediate levels in Gemini flight simulators, with highest levels as a consistent feature of the flight records." Adey et al. (ref. 27) interpret this as a compensatory orienting response to novel experiences and, in the case of weightlessness, to reduced sensory and vestibular inputs. Increased theta activity was noted in cosmonauts Nikolayev (refs. 25 and 27) and Tereshkova (ref. 67) and has been reported in the U.S.S.R. hypodynamia studies.

Literature on sleep both on Earth and in space contains much intriguing information that cannot be fully explained. However, the following tentative conclusions can be made.

1. Sleeping difficulties have occurred in submarines, Antarctic expeditions, hypodynamic studies, space cabin simulators, and orbital flight.

2. Under Antarctic conditions, the quality of sleep seems to be affected by a decrease in slow-wave and paradoxical sleep (ref. 63).

3. In space (refs. 27, 28, 67, and 68) and in hypodynamia (ref. 35), an increase in slow-wave activity during waking conditions affects sleep quality.

4. The quantity of sleep decreases in space but not under Antarctic conditions, and insomnia is reported under both conditions.

Additional study is necessary, particularly during weightlessness.

Conclusions on Circadian Rhythm and Sleep

Circadian rhythms exist in space and must be considered in planning long-duration space flights. Performance has circadian periodicity that can be affected and controlled by a knowledge of its characteristics and associated motivation. The sleep-awake rhythm occurred during orbital and lunar flight, and recognition of its importance has resulted in astronauts using space schedules similar to Earth schedules. However, staggered schedules are proposed as better for long-term flight, and more research is needed on this subject.

Sleep difficulties ranging from muscle tension and fatigue to insomnia have been reported both on Earth and in space. In a weightless state, the total amount of sleep decreases, and the presence of REM sleep is questionable. Antarctic studies have shown decreased slow-wave activity during sleep, and the Gemini VII flight and reports from the U.S.S.R. imply the existence of increased slow-wave activity during the awake state, possibly representing an orientation response. Additional study is certainly necessary.

CONFINEMENT, ISOLATION, AND MONOTONY

"Anxiety, irritability, sleep disturbances, and to a lesser extent, depression and hostility, seem to be the most characteristic features of prolonged confinement and isolation. On the other hand, there is the puzzling outcome of ordinary tasks being performed without significant deterioration. The picture, then, is one of generalized anxiety without performance decrement" (ref. 2).

Antarctic Data

For several years after the International Geophysical Year, Rasmussen and Haythorn (ref. 64) conducted a study assessing the wintering-over periods of men of five U.S. Antarctic stations. During this time, not one man was hospitalized for psychiatric reasons. However, several behavioral problems were noted. For example, table VIII presents the results from one small station reported by the U.S. Navy Medical Neuropsychological Research Unit in San Diego. In general, the symptoms seem to be a function of time; however, the sleep pattern of the men in this study adapted to the environment after 8 months.

In another study, conducted during the same time period, Gunderson (ref. 65) reports on several U.S. Antarctic stations. He found a higher incidence of psychiatric problems among naval personnel stationed in the Antarctic than in naval personnel elsewhere (3 percent to 1 percent). In addition, he found that from 1964 to 1966, the number of cases of insomnia, depression, anxiety, and hostility increased as much as 40 percent during the wintering-over months for naval personnel. The increases were much less for the civilian population. Gunderson also found that the motivation of the men was related to their work.

Pope and Rogers (ref. 69) made a study of 13 scientists who spent 10 days walking on snowshoes in Alaska under dangerous conditions. He found that the men who performed best listed scientific motives, above adventure and fellowship, as being most important. The monotony of the trek caused apathy among the men, but those who could concentrate on the scientific aspects of the mission performed best. An interesting correlation with body type exists. Those men who were short, fat, and broad were initially depressed but improved greatly after the sixth day. In contrast, the men who were tall and wiry were in good spirits initially but deteriorated and became apathetic after the sixth day. There was no overt friction, fighting, or development of subgroups, which Pope and Rogers (ref. 69) attributed to the fact that a psychiatrist was present who "permitted the ventilation of many hostilities without their becoming apparent to the other members of the group." One man, however, developed psychiatric problems and required emergency psychotherapy.

Smith (ref. 70) reported on a seven-man Antarctic expedition. He found that the men responded to monotony and boredom in five ways: widespread daydreaming, sensitivity to and being critical of those on the outside (e.g., the crew of a supply plane), a desire for change, even destructive change (e.g., breakdown of one of the trucks), erroneous interpretation of familiar sounds, and a tendency to choose those physically remote as companions for a future trip.

Submarine Data

In one of the first Nautilus missions, Weybrew (ref. 59) reports that the men showed good adaptation from the sixth to the eighth day, but that after this time muscle tension, insomnia, headaches, and lowered motivation gradually increased. The mission was terminated after 11 days, so no further conclusions could be made. During the historic transpolar cruise in 1958, the Nautilus was submerged for 1 month. Kinsey (ref. 71) vividly describes the conditions aboard this cruise. The men were provided with good food, washing and bathing facilities, music from a jukebox and a hi-fi tape recorder, a variety of reading material ranging from "Playboy" to technical books, movies, card games, chess tournaments, and several contests that provided opportunities for discussion and creative thought. In addition, the emergence of self-appointed jokers, physical horseplay, and a "scandal sheet" provided tension release and humor. Generally speaking, the morale was kept extremely high, and few difficulties were experienced. Undoubtedly, the historic nature of the cruise helped to keep motivation high.

During the 83-day cruise of the Triton in 1960, 40 men filled out a daily questionnaire composed of 50 behavior statements such as "tense," "happy," "can't concentrate," et cetera, which they scored from 0 ("not at all like me") to 9 ("exactly like me"). These factors were covaried with six atmospheric variables (levels of oxygen, hydrogen, carbon dioxide, carbon monoxide, Freon, and barometric pressure). Some interesting results were reported on analyzing the questionnaires (refs. 42 and 72). After 10 days, personal motivation and group morale declined steadily, and homesickness increased. Morale was found to be highest during free-time periods and lowest during weekly "field days" (when a complete cleanup of the ship was made). Morale also was high when a landfall was approached and during the last 2 weeks of the cruise. Morale was quite low during an imposed smoking curfew. On any given day, approximately 25 percent of the men reported headaches. Tension, irritability, and sleeping difficulties increased as the mission progressed but never became a serious problem. However, time perception gradually became less accurate. Three persons experienced anxiety reactions requiring medication, and one man showed obsessive thinking and delusions. No one reported any hallucinations. Kubis and McLaughlin (ref. 2) summarize these results: "The effect of prolonged submergence is indicated by an increase in tension, headaches, and sleep difficulties. In a study of morale over a 79-day period, during which the submerged atomic submarine Triton circumnavigated the world, there was a definite increase in feelings described as irritable, annoyed, disinterested, feel like giving up, bored stiff, uncomfortable, and frustrated." Despite all these difficulties, the men's performance was adequate and the mission was completed.

During the 60-day mission of the Seawolf, no formal testing was performed but the conditions were similar to those aboard the Nautilus. The men were kept busy and highly motivated, and there was no evidence of psychological or psychiatric illness. Ebersole (ref. 13) reports an interesting form of tension release called "pinging." In this game, one sailor (the pinger) teases another (the pingee) about some tender subject. If he could incite an angry reaction, he won the game. Ebersole also describes "channel fever," a mild insomnia and loss of appetite that occurred at the end of the patrol as a result of the anxiety generated by anticipation of the landing. He summarizes the experience (ref. 13): "The general opinion of the division officers at the conclusion of the patrol was that there had been a slight negative decrement in overall alertness and reaction time, <u>but that this would be insignificant in relation to combat performance</u>."

Weybrew (ref. 59) reports on Operation Hideout, a 60-day confinement of 22 men aboard the U.S.S. Haddock. Although the men were isolated, no attempt was made to simulate actual operating conditions. It was found that psychomotor efficiency decreased slightly after the first week, and coordination decreased after the second.

Other conclusions are as follows (ref. 59): "Motivation declined gradually; tension increased somewhat; anxiety moderated but was high throughout; the quality of sleep declined early in the study but improved; and the overall alertness of the group declined."

Serxner (ref. 61) served as medical officer aboard two cruises of a Polaris submarine and reports that 5 percent of the men were treated for psychological or psychiatric problems. These consisted of minor anxiety reactions (insomnia, headaches, somatic concerns, anxiety attacks), depressive reactions (anorexia and weight loss, unsatisfied dependency needs), and one full-blown psychotic episode, which will be described later. A strong activity program aboard the submarine prevented inactivity from becoming a stressor, but separation from family was significant. Pinups, vulgar talk, and preoccupation with sexual thoughts gave evidence to sexual release. As observed previously, Serxner also notes (ref. 61) that "certain of the men take it upon themselves to be entertainers or to 'raise the morale' of their watch section (or of the whole crew), often through highly imaginative joking." He also noted some personality conflicts.

Weybrew (ref. 72) has reviewed the submarine literature and makes several points. As many as 20 percent of submariners describe confinement as the worst aspect of submarine life, despite the rarity of true claustrophobic reactions. Because of the conditions, the environment is not truly sensory deprived; however, during World War II, severe neurotic and psychotic behavior was observed during the "running silent" that occurred at the time of a depth-charge attack. However, the danger and the heat present in the submarine probably combined with the sensory deprivation to cause these reactions. Time perspective seems to be related to overall group morale and day-night cycle elimination. A common morale booster is marking off the days until the mission ends. The men usually rank high in both social and conformity motivation. Subgroups tend to form based upon rating specialties (cooks, enginemen, etc.). These often become cliquish and are a basis for identity. In fact, a good identity and role concept are necessary for high morale and effectiveness. Finally, leadership is an important factor in maintaining high morale.

The 30-day Ben Franklin submersible study (ref. 73) evidenced a trend toward withdrawal and an increased need for privacy of the six-man crew as time progressed. Halfway through the mission, disagreements occurred with the surface crew over procedural matters. Depression and evident loss of a "feeling of well being" developed, and crew proficiency was adversely affected.

Reviewing the submarine and Antarctic data, several problems occurred that seem to be time dependent. However, performance generally remained sufficiently adequate to complete the mission. Flinn et al. (ref. 18) have also observed this fact: "Closely monitored groups exposed to restrictive conditions, on an experimental basis in a submarine environment ... have demonstrated significant levels of interpersonal friction, monotony, and lowered morale and motivation. Despite these problems, performance has generally remained at high levels, and gives cause for optimism about the psychological adaptability of man under severe confinement."

Space Simulator Data

Some of the interpersonal results observed during the School of Aviation Medicine two-man Space Cabin Simulator tests have been previously mentioned. Psychological testing, diaries, clinical observation, and the Bales Interaction Process Analysis revealed much tension between the men. However, by displacement to the outside monitors and by repressing feelings, the men overtly "got along" and were able to complete the mission. Cramer and Flinn (ref. 66) state that "despite considerable amounts of underlying friction and hostility with individuals relatively unsuited to each other, mission goals are sufficiently important to prevent the eruption of significant overt friction that would seriously impair working relationships."

Contrary to observations made in the one-man experiments, those in the SAM two-man studies revealed no gross perceptual distortions or psychological aberrations. About one-half of the men, however, experienced minor transient perceptual problems, but the presence of another crewmate helped greatly to consensually evaluate this perception as illusory. Monotony was a significant stressor in these experiments. Time seemed to drag for the men, and clock watching and marking off the days were popular activities. The men handled their time by reminiscence and fantasy, reading, or catnapping. According to Cramer and Flinn (ref. 66), this monotony is a serious problem: "Monotony while on duty was universally present and poses perhaps the most significant psychologic threat to successful space flight. Many pilots are activity-oriented people who are accustomed to coping with life aggressively rather than reflection and contemplation." A proposed solution is the selection of men who are easily able to fantasize. Finally, under the confining conditions, the men expressed a desire to perform physical activity (such as bowling), and tension-release mechanisms were common.

In a Lockheed 15-day simulator study, two crews of five and six men each were subjected to extensive performance and psychophysiological tests (ref. 53). Some decrement in performance occurred as time progressed and was probably the result of boredom and decreasing motivation. However, all the men maintained "acceptable test levels" throughout the studies. Decreased arousal levels also were evident and were possibly caused by the lowered motivations and monotony. Similar results were found in a North American Aviation three-man, 17-day simulator test (ref. 40).

Ruff et al. (ref. 74) report on a series of five-man, 5-day confinement studies. They found that for such a short time, performance and morale were good. However, projective tests revealed a tendency toward regressive behavior, some ego impairment, and hostile feelings. Thus, overt behavior alone is not always indicative of the entire situation.

Dushkov et al. (ref. 75) describe some U.S.S.R. simulation studies involving a total of 80 subjects confined from 12 hours to 70 days. The conditions were as follows: "All had in common the simulation of certain spaceflight factors, namely, limited space and limited movements (hypodynamia), relative isolation from the social environment, solitude (or living as part of a small group of 2 or 3 persons), uncomfortable position, monotony and sameness of the surroundings, unusual food and, finally, peculiar living conditions (discomfort) and activity (mainly tracking)."

During the first 10 days, a deterioration of mental efficiency occurred, together with inadequate associations and lengthening of latency of responses. However, these stabilized soon after and gradually returned to base-line levels. A gradual decrease in emotional stability and an increase in fatigue became evident as the studies progressed. Finally, hormonal and physiological data revealed the presence of stress in most studies (especially the longer ones).

Gerathewohl (ref. 12) reports on a space cabin simulator study involving three subjects. To measure performance, the subjects underwent Kraepelin's Work Performance Test, essentially a continuous addition test that is very sensitive to motivation and attitude. Generally, the subjects' scores improved with time, showing that learning was not impaired. However, although the total number of correct additions increased, so did the number of errors and corrections. The subjects became more irritable as time progressed, although outright hostility did not interfere with the mission. An interesting facet of this study was the morale boost provided by the Kraepelin test. The subjects looked forward to it as a daily break in an otherwise monotonous routine, and they participated in a spirit of competition and fun.

Finally, Burnazyan et al. (ref. 76) describe a yearlong isolation study of three subjects in a closed ecosystem, where water, atmosphere, and part of the food were synthesized by the simulator. The men in this study had been tested before and were found to be psychologically compatible. Generally, they tolerated the conditions well, performing all their functions adequately and maintaining the various life-support systems. There were no psychological problems, and the men showed a great deal of mutual understanding and cooperation.

Generalizations

The studies show some interesting trends. Conditions of confinement, isolation, and monotony induce behavioral and psychiatric problems. In addition, interpersonal stresses begin to develop, and spontaneous compensatory actions develop to relieve these (e.g., expressing hostility toward outside monitors or supply planes). Despite these problems, which increase in severity and frequency with time, performance levels remain high enough to accomplish most mission tasks. This appears to be a function of motivation; if the men are motivated enough, they can put up with a variety of stressors for the sake of completing the mission. Thus, on a long-duration space mission, keeping the morale and motivation of the men at high levels is extremely important. The alternatives are described by Wise (ref. 77): "A decline in adjustment to, or tolerance of space flight occurs with time in well adjusted persons. This will be evidenced by loss of interest in tasks, the environment and in the mission. The flight will lose purpose and meaning. Depression, lack of incentive, emotional exhaustion and increasing irritability will occur."

Stages of Reaction to Isolation

Rohrer (ref. 78) has reviewed Antarctic and submarine literature and evolved three stages of reaction to conditions of isolation. Other authors (refs. 9, 64, and 69) have concurred.

The first stage is a period of heightened anxiety, which occurs during the first few days, and is a function of the degree of danger that each individual perceives. Rohrer believes that this stage predisposes to psychotic episodes. He cites one study (ref. 79) in which all the men evacuated from the Antarctic regions for psychiatric reasons developed psychotic episodes within 1 week of "getting on the ice." Rohrer states that work is a method used in the Antarctic and on submarines to reduce anxiety.

The second stage is the period of depression. This stage occupies the greatest block of time and occurs as the men settle down and begin routine duties. There is a steady increase in the total amount of depression. Rohrer concludes this is caused by repression resulting from a reduction in social roles caused by the isolation. He states (ref. 78): "Under conditions of isolation, about the only social role that an individual has is that connected with his occupation. The temporary loss of such social roles as 'husband,' 'brother,' 'father,' 'club member,' and all of the other various roles that he occupies in normal society is a keenly felt deprivation."

The final stage is the period of anticipation. This occurs at the end of the mission. Rohrer describes it (ref. 78) as follows: "It is characterized by increased affect expression, and differs from the other periods in that much anticipatory behavior occurs. Also, it is at this time that there is a great likelihood of the occurrence of aggressive behavior. This is a function of a lessening of the repressive processes that occur during the period of depression." It is at this time that overt hostility may become apparent, and the men generally behave in an adolescent manner. Working habits are not as precise as before, and a greater amount of error is evidenced.

These stages have great meaning for a long-duration space mission, for they describe some of the problems to be expected at various periods of the flight. Of particular interest is the last period, in which a decrement of work was noted. Perhaps the most crucial part of a long space flight will be the end, when the complex procedures of orbiting and landing must be performed. The men must be at their best performance at this time, for a mistake could be crucial. Thus, further study must be made to find ways to keep the crew alert and mission oriented at this important time.

Monitoring Activity

One of the most important jobs of the crew on a long-duration space mission will be monitoring activities. Gurovskiy (ref. 80) divides these into two types: observing instruments under conditions of automatic control and observing instruments under conditions involving a large number of rapidly appearing signals (e.g., docking, landing, etc.). The latter condition involves a possible case of sensory overload, and the former is an example of sensory underload.

Routine monitoring of instruments will be a boring job indeed. The men will have to devote considerable attention to a task that is devoid of good sensory stimulation. The work/rest studies described previously have shown that duty periods longer than

4 hours were considered by the men to be intolerable. Also, on submarine cruises there was a tendency toward reduced alertness and a general reduction in excitation level as the cruise progressed (ref. 72). Methods must be found to reduce the monotony of monitoring duties.

Davies (ref. 44) attempts to link graphically the relationship between level of arousal and performance (fig. 3). Citing the works of Hebb and Silverman as support, he states (ref. 44): "Many investigators have put forward the hypothesis that the relationship between arousal level and efficiency takes the form of an inverted U, such that peak efficiency for any individual corresponds to a certain level of arousal." High levels of arousal (noise alone) or low levels of arousal (sleep deprivation alone) cause a decrement in performance; however, a summation of factors giving a high and a low level of arousal (e.g., sleep deprivation plus noise) combine to give moderate arousal levels, with a concomitant high level of performance. (An interesting parallel exists between Davies' hypothesis and the one developed in the section on weightlessness and low sensory input. In effect, both are dealing with proper cortical tone as a function of sensory input, but Davies' hypothesis deals more with performance than psychic aberrations.)

An interesting variable, the effect of personality on performance, is included in figure 3. Davies (ref. 44) states: "In a number of studies, the efficiency of extroverts has been found to decline at a faster rate than that of introverts ... the performance of ambiverts resembles that of extroverts rather than that of introverts." Studies conducted by Davies indicate that under quiet conditions, the performance of extroverts on vigilance tests deteriorates rapidly, although introverts are not affected; however, when a loud noise is present, no deterioration is observed with extroverts, and introverts show either no or a slight decrement. Davies (ref. 44) also reports on a study by Corcoran which shows that introverts perform better than extroverts under conditions of low motivation, and the opposite is true under high-motivating conditions. Finally, Corcoran has found that extroverts get worse while introverts improve under conditions of sleep deprivation. Davies attempts to fit these observations to the arousal concept shown in figure 3: "under 'normal' conditions extroverts can be thought of as being less highly aroused than introverts, and that they may therefore require somewhat higher levels of stimulation to function at the same level of efficiency as introverts can reach without such stimulation." This information shows that under quiet, low-motivating, sleep-deprived conditions, introverts perform monotonous vigilance activities better than extroverts. Extroverts perform better at activities that are socially oriented.

Feedback is another important factor in monitoring activities. Weybrew (ref. 42) reports on a study in which the subjects, placed in an isolated room, were asked to respond to a pointer, moving in a circle at 1 rpm, by pressing a button at each 90° of arc. A response was scored as positive if the button was pressed within 3° of each 90° mark. There were two groups of subjects: the control group, which had feedback data informing them if they were pressing the button on target, and the experimental group, which had no feedback information. Palmar conductance was measured on both groups as an index of general excitation level. The control group experienced a higher general arousal, reported less fatigue symptoms, and scored better than the experimental group. Davies (ref. 44) reports on a similar study made by Mackworth in which the subjects observed a rotating black pointer on a white background and were to report whenever the pointer moved twice its usual distance per unit time. The following decrement in performance was observed: after one-half hour, 85 percent of the signals were observed correctly; after 1 hour, 74 percent; and after 2 hours, 72 percent. However, this deterioration trend ceased when the subjects were informed of their progress. In addition, 30-minute rest breaks and 10 milligrams of Benzedrine every half hour eliminated the decremental effect. Thus, feedback information appears to improve performance on vigilance tasks. Davies (ref. 44) suggests three mechanisms to explain this occurrence. First, a knowledge of results provides information about signal characteristics, permitting a time orientation of signal sequences. Thus, an operator learns to anticipate likely signal occurrence. Second, feedback acts as an incentive to motivate the operator, acting as a positive (or negative) reinforcer. Finally, a knowledge of progress keeps an operator at an optimal arousal level, being another form of sensory input under otherwise low input conditions.

These studies reveal possible solutions to the boredom resulting from the monotony of monitoring activity. An operator should be on short work/rest schedules. The personality of the operator should be taken into account — introverts generally do better under the conditions to be expected on a long-duration space flight. In addition, figure 3 shows that an optimal level of arousal is necessary for best performance; therefore, attention should be focused on the total amount of sensory input received by the operator to keep his arousal at its most efficient level. Finally, feedback should be included to inform an operator of how well he is performing his task.

Leisure Time

A study conducted by Shurley et al. (ref. 63) to determine how men at the South Pole spend their time indicated that 8.6 hours a day were spent in leisure-time activities. Nowlis (ref. 81) states that 20 percent of the total time aboard the Tektite II underwater-research facility was spent in leisure activity, and he estimates that longer missions should average a minimum of 25 percent. Eberhard (ref. 37) believes that on long-duration space missions, the total leisure time will be much greater: "Off-duty time may exceed 10 hours per day during deep space periods of the mission. This is the cause of unscheduled free time because of: (1) an excess of time (2.2 hours) allocated for sleep and (2) an inadequate opportunity for work (5.5 hours in excess)." Thus, a great amount of time will probably be spent off duty, and the prevention of boredom is essential.

Literature on Antarctic and submarine personnel shows that free time is used in a variety of ways. Shurley et al. (ref. 63) state that some of the most popular activities included talking (4.5 hr/day), games (1.35 hr/day), reading (1.35 hr/day), and movies (1.2 hr/day). During the Nautilus and Seawolf submarine cruises, reading, music, films, and hobbycraft occupied a great amount of time. Nowlis (ref. 81) states that audio cassettes, books, television tapes, and games were used during the Tektite II mission, and that lack of variety was the most common complaint. An interesting personality correlate emerged during the mission: the Cattell Factor F (Surgency — impulsiveness, enthusiasm, liveliness) correlated 0.554 ($p < 0.02$) with the total time spent in leisure pursuits. Gunderson (ref. 65) discovered that, surprisingly, the most stable people on an Antarctic expedition had neutral feelings toward popular recreational activities such as music, card playing, and photography; however, most of the men studied were either scientists or technicians, and Gunderson believed that they spent their leisure time in pursuits related to their jobs.

Men in the Antarctic environment do not utilize their free time as effectively as do men in submarines (ref. 77). Antarctic personnel prefer talking or light reading; submariners use free time for self-improvement or reading technical material that will help them advance in grade (refs. 13 and 71). Fraser believes this is due to the high morale found aboard submarines and concludes that (ref. 60) "creative use of leisure may be both a function of morale and a factor in maintaining high morale."

Eddowes (ref. 82) surveyed 80 men working at the Westinghouse Air Arm Division concerning favorite leisure-time activity. The results of the survey are presented in tables IX and X. In this study, age (from 19 to 56) and education (high school to Ph. D.) varied more than would be expected in a space-mission crew, and none of the men had flight experience. Nevertheless, the choices shown in tables IX and X are very similar to the most popular activities on board a submarine or in the Antarctic. In a space capsule, a microfilm library, a tape library, a television hookup with Earth, reusable supplies for handicraft and manual activities, and simple exercise facilities could satisfy many preferences and still be practical. However, Eberhard (ref. 37) points out two important principles concerning choice of activities: "Selection of discretionary activities must take into account personal preference of crew members and the influence of long duration confinement on these preferences .... In considering educational activities, previous habit patterns relative to education is a better predictor than lofty goals crew members might anticipate for their confinement period." The idiosyncracies of a crew must be the final guide to leisure-time activities. In addition, Gunderson (ref. 65) suggests that "job-oriented" men might find more happiness in activities related to their job than in purely recreational pursuits.

Fraser (ref. 60) considers music a valuable asset both as recreation and as an adjunct to working activities. He states that music "has been found of particular value in reducing the boredom associated with routine and monotonous activities." Davies (ref. 44) reports "it was found that music, compared to a quiet condition, significantly improved reaction time to signals while having no effect on the number of signals which were correctly detected." During the Nautilus transpolar cruise, Kinsey (ref. 71) reports that music was piped almost constantly to three stations aboard the submarine. In producing a rationale for this, he states: "The almost continuous use of this type of auditory stimulation may have had its source in the reduced sensory stimulation of the submarine's confined environment."

Eberhard (ref. 37), in his monumental study of off-duty time concludes that men in confinement seem to prefer work to free time and jealously guard (and hesitate to give up) their work activities. Although the total amount of free time may exceed 10 hr/day, he believes that 5 hours should be an upper limit "in view of reduced activity possibilities in space." He states that talking, reading fiction, and watching movies and television are the most popular activities of confined groups, whereas painting, playing cards, chess, and checkers are relatively infrequently preferred. However, Eberhard believes that the activities should consider the personal preferences of the men. He makes an interesting observation: "The discretionary activity value of eating should not be overlooked since men in confinement take almost twice as long to eat." Finally, he recommends a 5- or 5-1/2-day workweek and three off-duty time periods per day for a long-duration space mission.

Conclusions on Confinement, Isolation, and Monotony

Confinement, isolation, and monotony are three important stressors that will accompany a crew on any long-duration space mission. A review of the Antarctic, submarine, and space-simulation literature shows that behavioral, interpersonal, and psychiatric problems occur more frequently when these conditions are present. However, performance levels are high enough for mission success, provided the men are highly motivated.

Several studies have confirmed Rohrer's (ref. 78) three stages of reaction to isolation: the period of heightened anxiety, the period of depression, and the period of anticipation. The third stage is particularly important for a long-duration space flight, because the observed decrement in performance, the hostility, and the adolescent behavior that is characteristics of this stage is not compatible with the required complex landing activities.

The monotonous activity of monitoring instruments can be minimized by providing short work/rest schedules, considering the personality of the operator (introverts do better at vigilance tasks if under low sensory-input conditions), keeping the arousal level of the operator high by varying the totality of sensory inputs, and providing monitoring feedback.

Leisure time may also contribute to the monotony if not properly used. Although the personal preferences of the crew must be considered, existing literature indicates possible practical activities to be included on a space mission. Music especially is valuable as a primary off-duty activity and as an accompaniment to work. Other popular activities include reading, talking, and watching television and movies. The value of job-oriented leisure pursuits should not be minimized; in fact, scientists and technicians may prefer these to the more standard activities.

PSYCHIATRIC CONSIDERATIONS

"Experience in the Second World War demonstrated that ... every man has his breaking point .... Psychoanalytically, it may be said that the ego succumbs whenever the combined forces attacking it, be they physical, psychological, or both, are more than it can bear. The concept of the ego can be of value here because it is known that the ego has large areas that are wholly unconscious, and these may be critical in determining the point of breakdown (ref. 1).

A Theory of Personality

Sigmund Freud developed one of the most complete and influential theories of personality. Although modified somewhat in the past 50 years, the basic tenets of his theory still remain sound and are cornerstones for psychoanalysis and psychiatry; even modern psychology, with its behavioral slant, acknowledges the importance of such Freudian concepts as the unconscious, the defense mechanisms, and the drives.

Freud's ideas were based on careful clinical observations and constitute a concise way of explaining the difficult subject of personality. He constructed his theory around the concept of psychic energy. Originally invested in the aggressive and libidinal drives, this psychic energy became the chief power source for the machinery of the personality. As personality grows, it gradually becomes differentiated into three component parts. The first is the id, which describes all personality functions concerned with the basic drives: life, sex, aggression, death, etc. Developing from the id (and "capturing" a part of its energy) is the ego, the "I" of the personality, the part most concerned with the realities of life. The last is the superego, which represents the child's version of the morals of his parents. Throughout life, these three aspects of the personality interact with the environment and with each other in a fluid, dynamic way, with psychic energy (largely controlled by the ego in the mature person) "fueling the fire." Contrary to the primitive, unrealistic mode of operation of the id (primary process thinking), which seeks immediate gratification of all drives no matter what the circumstances (the pleasure principle), the ego operates in an orderly, rational manner, taking the drives and social mores and comparing these with the environment before acting (secondary process thinking). The ego processes are not actually antidrive; they attempt to satisfy id demands but only if social customs and the environment realistically allow this to occur.

The id, ego, and superego represent the "structure" of the personality. However, personality can be divided in another way, which Solomon and Patch (ref. 83) call its topography. They summarize this division in the following way.

"1. The conscious includes those parts of mental life of which the individual is readily aware at any given moment. It includes most, but not all, of the ego.

2. The preconscious includes those parts of mental life which can be brought into consciousness with concentration and effort. It lies principally in the ego.

3. The unconscious is unknown to the individual (totally outside of awareness). Its contents may remain permanently unknown, or parts of it may at times pass into the preconscious and from there be called up into the conscious. According to psychoanalytic theory, the contents of the unconscious, primarily id and superego, are of great significance in determining behavior and thought. The part of the ego which produces the mental mechanism of defense and symptom formation is unconscious."

Unconscious ideas, possessing psychic energy, strive toward conscious realization. However, many of these possess threatening content, both emotionally and conceptually. To protect itself, the ego develops a complicated system of defense mechanisms, the purpose of which is to prevent threatening ideas from becoming conscious. However, the ego is not entirely successful in containing these powerful forces. Dreams and slips-of-the-tongue represent ways in which these concepts escape from the unconscious, albeit in a form so altered that they are not a threat. Occasionally, however, when the ego defenses are weakened or when the unconscious force is too great, the unconscious idea threatens to explode into consciousness. This is perceived by the ego as anxiety, or a fear that the unconscious drive will get out of control. In desperation, the ego attempts to control this drive by any means at its disposal, and the result constitutes the symptoms of a neurosis. When the ego completely breaks down (or has not truly formed), a psychosis is present, and the irrational, primary process thinking runs rampant.

An Illustrative Example

A practical example of how dynamic theory and therapy can be applied is the sensory isolation experiment (ref. 39) outlined previously. Two of the four subjects who participated in this study did not complete the simulation. Subject B, a 23-year-old high school graduate, complained of blurring vision after 7 hours. Despite reassurance, he became very anxious, stating (ref. 39): "It's more than my eyes. I've got to get out of here. I just can't take it anymore. I'm sorry." The study was terminated at that point.

This behavior appears bizarre and irrational. However, Flaherty et al. (ref. 39) state: "This subject had volunteered for the flight as a maneuver in his lifelong battle with feelings of inadequacy and inferiority. He had fantasied being the center of much attention and admiration .... With the lack of support which he experienced, his basic feelings of inadequacy emerged. He pictured the long hours stretching ahead, and felt his performance was certain to be inferior and humiliating despite his efforts. At this point he began his attempts to terminate the flight by claiming equipment failure and somatic symptoms and finally by admitting intolerable anxiety. In so doing, he was using the technic evident in so many other facets of his life — that of provoking failure on his own responsibility to avoid intolerable feelings of inadequacy. In this manner he had avoided competition in school by quitting rather than failing."

Subject B had severe feelings of inadequacy, perceived as a threat by his ego, which he kept more or less unconscious by using compulsive interaction with others and the praise ensuing therefrom as a main defense mechanism. This served him well in real life, but in isolation this ego defense was weakened. His unconscious feelings began to reach consciousness, and his ego perceived this danger as anxiety. Finally, in desperation, he fantasied somatic problems and then made an anxious appeal to terminate the study.

What would have been the result if this man were part of the first mission to Mars? Careful personality screening obviously must be done on all applicants for such a flight. Buyanov and Terent'yev (ref. 24) state: "Spaceflight makes great demands on man's nervous system and psychological status. Persons with functional nervous disorders of any etiology cannot adapt well to the unfavorable living conditions."

The Magnitude of the Problem

Confinement, isolation, and monotony produce stress and cause an increase in psychiatric problems. Gunderson (ref. 65) reports the incidence of such problems in the Navy is normally 1 percent; however, he found that in the Antarctic, Navy personnel attain a 3-percent level. Serxner (ref. 61) reported 5 percent of the men on two Polaris cruises were treated for psychological or psychiatric problems. On the 83-day Triton cruise, four of the crew experienced anxiety reactions or obsessive thinking (ref. 42). Finally, Pope and Rogers (ref. 69) reported depression a common reaction in their Antarctic study. In fact, most of the studies examined reveal behavioral or sleep disorders present under confining conditions, which could indicate an underlying personality weakness.

Ruff et al. (ref. 74) report on subjects who have undergone sensory and social isolation ranging from 3 hours to 7 days. In this short time, they have isolated a characteristic pattern of adjustment expressed in terms of personality variables. Phase I consists of initial anxiety followed by relief of anxiety "as defense mechanisms become effective." Phase II is a time of exaggeration of customary defense mechanisms and is described by Ruff et al. as follows. "An obsessive-compulsive person ... adopts a repetitive pattern of thought or activity. The passive-agressive individual may view the experiment as a battle and try to 'beat' the experimenters." During Phase III, anxiety reappears and defenses become more primitive. Unconscious material threatens to erupt, and thinking becomes disorganized.

The stages of Ruff et al. and Rohrer (ref. 78) are almost identical except that Ruff et al. do not mention the occurrence of depression during Phase II. Phase I in both schemata is nearly the same. The primitive mode of thinking and threatened eruption of unconscious material described by Ruff et al. may well be the cause of the hostility, aggressiveness, and performance breakdown characterized by Rohrer's period of anticipation.

Reaction to Danger

Danger is another stressor that can lead to psychiatric difficulties. Danger situations are especially important because they involve both the intellect and the emotions, and the latter must not interfere with the former during these times. Response to danger situations varies. For example, Cramer and Flinn (ref. 66) report on an unprogramed fire that occurred in the SAM two-man Space Cabin Simulator: "During the fire ... one subject became very anxious and ineffective, whereas his partner took calm and appropriate action." Danger may thus uncover an underlying psychiatric problem.

Smith (ref. 70) describes the reactions of a seven-man group to danger conditions in the Antarctic and reported two distinct phases. The first phase lasted approximately a day and was composed of three stages: (1) an initial inability to perceive the danger (the men traveled as if there were no threat and took no safety precautions); (2) a complete attention to obstacles, but with efforts being chaotic and unorganized and safety precautions hurried and impractical; and (3) a general cessation of activities.

Smith's second phase began the second day the group was in danger. Whereas the first phase was chaotic, irrational, and anxious, the second was almost the direct opposite; the men realized the danger they were in, traveled slowly and carefully, and took safety precautions. Their efforts were no longer chaotic and disorganized. The men apparently "buttressed up" their defense mechanisms against the anxiety of the first phase and were able to act rationally and calmly.

Before the expedition, Smith had made three hypotheses regarding the reaction to danger. One of these was borne out (ref. 70): "... while experiencing danger, there was a noticeable decrease in verbal interaction and an increase in irritability, shown by sharp, brief, personal exchanges." Smith had believed that men would show extreme depression just before and after entering the known danger area, but that did not occur.

Hartman and Flinn (ref. 84) report on a review of anecdotal literature that non-adaptive behavior can occur during catastrophes and acute stress. This may lead to group disintegration. However, when the men are highly trained and the crew structure is clearly defined, this possibility is unlikely. Hartman and Flinn have determined three potential problem areas: (1) possible panic situations, (2) situations with an unstable reward structure that may lead to uncooperative behavior, and (3) potentially unstable situations.

Tension Reduction

The "pinging" activity described aboard the submarine Seawolf and the aggressive behavior, preoccupation with sexual thoughts, and joking that is observed on many submarine and Antarctic missions demonstrate the need for tension reduction and the release of libidinal and agressive psychic energy. Cramer and Flinn (ref. 66) also noticed this on the SAM two-man Space Cabin Simulator: "Tension reduction mechanisms were very prominent throughout every flight; one common example was by means of sudden verbal exclamation, loud shouts, cries, or shrieks. In addition, frequent swearing was noted and seemed to serve this purpose .... Another form of gratification of needs was fantasy and dream content which generally were wishfulfilling in nature." This is compatible with dynamic theory, which states that a particular tension, if not relieved in its most direct way, will find another outlet for its energy; this is the process of sublimation. The frustrated lover who burns off his sexual tensions in the form of work is an example of sublimation.

Men are apparently able to find successful means to release tension under conditions of long-duration confinement. Sexual tensions are an important practical example. Cramer and Flinn (ref. 66) found that, while all the men had sexual fantasies, it took 10 to 14 days before these became frequent. Before this time, the men were able to sublimate their erotic feelings into the mission. The sexual fantasies apparently developed as sublimation became less effective. In addition, three men experienced nocturnal emissions.

Freud postulated the presence of numerous erogenous zones throughout the body. For example, the mouth is a primary source of pleasure and tension reduction in the nursing infant. Although their importance declines with maturation, these erogenous zones appear ever ready for gratification; indeed, they may assume primary importance if other means of release are blocked. This concept is substantiated in the confinement literature.

Ruff et al. (ref. 74) found an increased interest in food by two of three groups studied under isolated conditions. They attributed this interest to drive reduction. "When cut off from many of their usual outlets, these subjects emphasized eating and activities associated with food. Plans to use algae for a (sic) nutrition, should thus take into account the advisability of making the product as tasty as possible." Eberhard (ref. 37) cautions that "the discretionary activity value of eating should not be overlooked since men in confinement take almost twice as long to eat." Finally, Rohrer (ref. 78) summarizes: "With the rather intense repression of sex impulses that occurs in isolated small groups of the same sex, there is a corresponding increase in the importance of oral gratification ... weight gains are reported by nearly all, and food preparation is more important than it is in normal society. Correspondingly, the social status of the cook in these isolated small groups reaches heights unknown to a cook in our more complex society." Ferguson (ref. 73) reported that as the Ben Franklin mission progressed, food provided a topic for conversation and allowed "sublimation of psychological stress."

The question of direct sexual release on a long-duration space mission must be considered. Practical considerations (such as weight and expense) preclude men taking their wives on the first space flights. It is possible that a woman, qualified from a scientific viewpoint, might be persuaded to donate her time and energies for the sake of improving crew morale; however, such a situation might create interpersonal tensions far more dynamic than the sexual tensions it would release. Other means of sexual release (masturbation, homosexuality) would be discouraged because of the confined quarters and the lack of privacy on such a mission. Thus, it appears that methods involving sublimation are more practical than these more direct alternatives.

Separation Reactions of Married Women

The situation of their families at home is important to men under conditions of long confinement. Pearlman (ref. 85) reports on 485 women patients who represented 9 percent of the wives on a submarine base. Most of these women had feelings of anger and despair caused by long separations but they tolerated separation well, despite disliking it. However, they were unable to develop mature associations with their husbands because of repeated separations. Consequently, many of the women required counseling for marital problems following the return of their husbands. These women experienced "The Submariners' Wives Syndrome."

Isay (ref. 86) named this syndrome during his study of 432 wives on a submarine base. He found that 61 percent possessed this syndrome, which he defines as "the depressive illness of the large number of these wives, who became symptomatic shortly before, or after, the return of their husbands from sea patrol" (refs. 86 and 87). Isay believes this is an unconscious reproach to the husband generated by repressed anger and despair. It is manifested by sexual withdrawal, marital conflicts, sleep disturbances, and uncontrollable weeping.

Men training for a long space flight will frequently be away from home for varying periods of time, and the actual flight itself will involve many months; therefore, the need to recognize the "Submariners' Wives Syndrome" is obvious.

Predicting Action from Personality

It is impossible to predict a man's exact reactions to stress situations over a prolonged period. However, numerous studies indicate that psychological tests are valuable tools to outline probable reaction patterns to known stressors. These tests aid in identifying individuals who possess possible psychological weaknesses.

The Tektite II crew was carefully screened using a variety of personality tests (Cattell 16 PF, MMPI, etc. ref. 87). The responses were compared with observed behavior.

More than 50 correlations were found, which were significant at $p < 0.02$, and several more at $p < 0.05$. Some examples are shown in table XI.

Pope and Rogers (ref. 69) conducted extensive psychological and psychiatric tests on 13 scientists who participated in a 10-day snowshoe hike in Alaska. Some of the scientists possessed poor self-concepts, unconscious conflicts, and irrational fears. These traits all correlated with the low success rating during the mission. Gunderson (ref. 65) reports similar results: "Ratings by psychologists and psychiatrists on negative personality traits, such as aggressive, excitable, impulsive, and hostile, and ratings on positive traits, such as emotional control, conforming, and tactful, tended to correlate in the expected direction with emotional adjustment in Antarctica for both Navy and Civilian groups."

Ruff et al. (ref. 74) used various projective tests (Blacky Test, draw-a-person test, sentence completion test) to determine evidence of regression, primary-process thinking, transient ego impairment, and underlying hostile and aggressive feelings of subjects in space simulators, despite adequate performance. Haythorn and Altman (ref. 88) found that conformity, tolerance, and following rules and regulations correlated with good adjustment to isolation.

Volunteers for submarine duty are carefully screened using various psychological and psychiatric tests (refs. 42 and 72) before being accepted for submarine service. All U. S. and U. S. S. R. space pilots receive a barrage of psychological and psychiatric tests. The original seven U.S. astronauts underwent 3 hours of psychiatric evaluation, 6-1/2 hours of psychological testing, and several hours of performance stress testing (ref. 89). The cosmonauts have also undergone a variety of similar testing procedures (ref. 10). Gagarin and Lebedev (ref. 90) even classify many of the cosmonauts as to personality types (choleric, sanguine, phlegmatic, and melancholy) and have correlated these with behavior. These procedures have been apparently successful, since performance of space pilots has been excellent.

There is no highly reliable, complete personality test that all testers will interpret in the same way. However, as data on personality are accumulated, correlations are studied, and after-the-fact conclusions are made, a "perfect" test for a long-term space flight may result.

Psychotherapy in Space

Despite special precautions, psychiatric problems may develop during a space mission. If, on a long-duration space mission, a crewmember should have a psychotic break, restraint would be difficult and evacuation for hospital treatment would be impossible. This dilemma faced Serxner when a Polaris submarine crewman experienced an acute paranoid-schizophrenic break 5 weeks into the mission (ref. 61). Serxner kept the man under control and functioning using a combination of drugs, supportive therapy, and the help of the crew. In addition, the effect on the crew was held to a minimum and they performed satisfactorily. Flinn et al. (ref. 91) report on the successful use of phenothiazines, over a 2-year period, to control psychiatric patients who were air evacuated.

Weightlessness is one variable not yet fully studied psychiatrically. Not only might this condition aggravate any mental problems, but its effect on a patient using psychiatric drugs is unknown. U.S.S.R. studies (ref. 92) show that many common central-nervous system stimulants do not increase the working capacity of the human body under difficult circumstances; in fact, they may act adversely during periods of anoxemia. Parin et al. (ref. 92) state, "It may be expected that the abrupt reduction in the volume of information will induce in the astronauts a tendency toward inhibition, depression with distortion or weakening of the action of drugs exciting the central nervous system and strengthening of those depressing it." Thus, further study in space pharmacology is needed to resolve problems of drug effectiveness and drug dosage.

Since a psychiatrist might not be with the first few long-duration space missions, preparation must be made prior to a mission to prepare for psychiatric problems. A physician or social scientist aboard, along with the rest of the crew, should be well-versed in psychotherapeutic techniques. Flinn (ref. 93) has categorized the various states of altered awareness found most commonly in pilots. Those applicable to long-term space flights are: (1) states related to impoverished environment (e.g., lowered proficiency), (2) anxiety states (e.g., depersonalization), (3) states related to fatigue and drowsiness (e.g., sleep), (4) states related to sensory input overload (e.g., panic), (5) states related to narrowed attention (e.g., instrument fascination), (6) states related to underlying psychopathology (e.g., dissociative reaction), and (7) states related to temporal lobe epilepsy (e.g., frequent deja vu experiences). Other techniques may be used to alleviate psychiatric stresses. One practical suggestion made by Solomon (ref. 1) is: "Prophylactically, during the course of space travel, every effort should be made to keep the voyager not only in constant communication with his scientific monitors on earth, but with close members of his family and friends."

Regular psychotherapy, using television, with a psychiatrist on Earth may help to resolve problems before they become serious. Pope and Rogers (ref. 69) state the presence of a psychiatrist on their mission permitted the men to vent their hostilities before they became serious.

Dunlap (ref. 9) describes the advantage of sensitivity training for recognizing and handling interpersonal stresses. Flinn et al. (ref. 18) and Hagen (ref. 19) recommend a diary for good surrogate therapy.

Hypnosis is proposed as a method to relieve anxiety and other painful states. Sharpe (ref. 3) has proposed eight applications for hypnosis.

1. Selecting candidates for astronaut training

2. Creating an illusion of realism during astronaut training

3. Focusing attention on critical tasks during periods of psychophysiological stress

4. Reducing the metabolic rate of the crew to reduce in turn the amount of oxygen, food, and water required

5. Reducing fear and anxiety among astronauts during very long voyages

6. Reducing boredom by compressing off-duty time and creating the illusion of stimuli to occupy time

7. Training astronauts to induce self-hypnosis so that they can go to sleep on schedule and awake refreshed

8. Maintaining uncomfortable positions for long periods of time

Unfortunately, hypnotic susceptibility varies with personality and is not successful on all people.

A final technique is the cyborg, or cybernetic organism (ref. 9). This fascinating man/machine concept, not probable in the near future, would use a small sensing arrangement to detect certain chemical or hormonal products secreted as a result of stress. An osmotic pump would release drugs in the proper concentration and the proper rate to counteract the stress effects; to calm or arouse man, as the case may be. This devise could be small enough to implant under the skin.

Conclusions on Psychiatric Considerations

The dynamic theory of personality developed by Freud emphasizes several concepts which must be considered during a long-term space mission: unconscious drives and motivations, the preservation of ego defenses, and the control of anxiety. The literature indicates that incidence of psychiatric problems increases with prolonged confinement, isolation, and monotony.

This personality theory may be applied in several specific areas. Smith divides group reaction to danger, where the response appears a function of the personality, into two stages. Literature indicates that men in confinement reduce tension by a number of indirect means (expression of psychic energy associated with drives): "pinging," aggressive behavior, preoccupation with sexual thoughts, joking, sexual fantasy, and increased interest in food. Finally, "The Submariners' Wives Syndrome," a type of depression caused by unconscious anger and despair, affects men who are frequently away from home.

Personality tests have some value in defining probable reaction patterns to known stressors and in screening individuals with serious psychological weaknesses. However, there is no single personality test with high reliability that can be interpreted in the same way by all testers. Clinical observations and interviewing techniques must be used with personality tests.

Should psychiatric problems occur during a long-duration space mission, the following therapeutic measures may be used: the presence of a crewman trained in psychotherapy and psychopharmacology, television with Earth to facilitate conversation with family or a psychiatrist, use of sensitivity training techniques, hypnosis, and, possibly the cyborg.

SOCIOLOGICAL CONSIDERATIONS

"In isolation, interpersonal conflict becomes exaggerated, and there is less chance to go outside to blow off steam, or escape from the difficulties of adjustment. In these circumstances, irritations are likely to accumulate to the point of explosion. Such frictions are reported in histories of isolated groups almost without exception. In many instances, such conflicts have resulted in breaking up the group — even murder" (ref. 88).

Sociological Stressors

Problems of group dynamics may occur during long-term space missions lasting many months and involving eight to 12 men. The New York Times (Oct. 7, 1970) made the following statement. "On past missions, with crews of no more than three and voyages of 18 days or less, the formation of cliques and other aspects of what psychologists called 'group dynamics' were not a problem. But Dr. Charles A. Berry, who is responsible for the health of American astronauts, said the coming extended flights with crews of 10 and 12 would bring group dynamics into play."

It is important to isolate the various social stressors which affect the dynamics of a group. They may be divided into five types (modified from Dunlap (ref. 9)): small size of the group, organized versus informal structure, proper leadership, reduction of available social roles, and relationship between the crew and outside monitors.

Group Size

One group problem is the restricted number of interpersonal contacts. Dunlap states that the smaller the group, the lower the probability that interpersonal needs will be satisfied. Wise echoes this concern: "... small crews tend toward fatigue, overloading, reduced social contacts, etc." (ref. 77).

Bales and Borgotta (ref. 94), conducted a study of group size and social interaction observing two- to seven-man groups and analyzing individual interactions using the Bales Interaction Process Analysis (BIPA). The groups were male students who did not know each other before the study. The group members were given a five-page presentation of facts about a hypothetical problem and discussed, during four group sessions, a course of action. During the discussions, evaluations were made using the BIPA. Three types of effects were expected: effects which vary with group size, effects uniquely associated with a group of a given size, and effects associated with group division into subgroups.

Table XII presents scores of three variables. The following conclusions are the result of a careful study of the experiment and reflect the interpretation by this author of the Bales and Borgotta data.

1. As group size increases, the members become more organized and efficient in the way data are presented. Membership polarizes with greater tendency for leaders and followers to emerge.

2. Two-man groups show much tension caused by inability to form a majority. Consequently, the men differentiate away from each other but in a complementary way, throughout the mission, in order to maintain peace and relative stability.

3. Three-man groups show great variety caused by changing majorities. Relative active or passive behavior is expressed by the isolated member.

4. Seven-man groups (the largest group in this study) show great stability, primarily as a result of passivity of the great number of followers. Larger groups should show even more stability.

5. Even-numbered groups may form equal-numbered subgroups which may deadlock. Individuals in each subgroup tend to low variance with one another. High variance occurs around "giving suggestion" and "giving orientation" with time due to efforts of the members to resolve the deadlock.

6. The fact that variation is less over a time span than at individual sessions, suggests that time causes stability of observed patterns.

Examination of the preceding conclusions produces the following predictions.

1. Two-man groups would encounter some of the problems noted in the SAM 2-man studies.

2. Three-man groups are very unstable, despite the success of the Apollo flights (the formality and lack of free time of the Apollo missions may have served to stabilize the group).

3. Even-numbered groups tend to form equal-numbered subgroups.

4. The larger the group, the greater the tendency for leader-follower relationships to emerge, the greater the stability, and, in odd-numbered groups, the less likely deadlocks are to form.

Therefore, given a possible crew size of eight to 12 men, the ideal number would be 11.

Group Structure

Most groups have a formally assigned organizational structure. However, in time, an informal functioning structure often develops. Smith (ref. 70) identifies two stages in the formation of this informal group structure. The first stage, the task-activity stage, takes about a week to form and is job oriented. The second stage, the interpersonal stage, develops after 3-1/2 weeks. Weybrew (ref. 72) emphasizes the first stage. He states that in submarines subgroups form based upon specialities, and that these may even become cliques. However, he sees this as important for identity and proper role visualization, and states (ref. 72): "Crews that tend to have low discrepancy between self-perceived roles and roles ascribed by the organization charts tend to be rated higher in morale than those with high discrepancy scores." However, Wise (ref. 77) is pessimistic about these subgroups: "Cliques will tend to form of individuals sharing common skills, interests, social and interpersonal needs. Cliques disrupt group cohesion and tend to reject individuals incompatible with them." Dunlap (ref. 9) also believes that, if the informal structure deviates too much from the formal one, a great deal of stress may develop.

Most of the existing studies deal with groups much larger than eight to 12 men, and, although subgroups can form in such a small crew, it is unlikely that frank cliques will develop. The men will be specialists, with things in common, such as intelligence, a common goal, and similar training experiences. A more serious danger than cliques would be the real or perceived isolation of one individual. Rohrer (ref. 79) describes this effect. "The behavioral syndrome produced by the exclusion from the isolated group I have labeled the 'Long Eye'.... This is the 'silent treatment'.... In from six to ten days the 'Long Eye' phenomenon is produced. It consists of various combinations of sleeplessness, spontaneous bursts of crying, hallucinations, and a giving up of the usual habits of living, such as washing, eating, drinking coffee, and the like. Persons experiencing the 'Long Eye' are apparently oblivious to external stimulation and are described variously as lying in their bunks, staring into space, or moving aimlessly about.... Sometimes the phenomenon is accompanied by a repetitive, obsessive carrying out of rather simple acts.... As soon as the person is permitted to return to, and interact with the group, the symptoms disappear."

Leadership

The leader-follower relationship appears important to group stability. However, Wise (ref. 77) cautions against having too many leaders and not enough followers. In addition, he states that "... authority relationships tend to become less effective over time." Nevertheless, with a strong command structure and a respected commander, the leader would probably still possess some authority, for he would serve two important purposes: on a long-duration space mission, much of the authority invested in the ground command would be transferred to him, and he would represent a neutral and supportive balance to any friction that might result, especially where two equal-numbered subgroups form.

Dunlap recognizes sources of "power" which may detract from a leader's influence, such as personal attraction, personal competence, reputation, friendship, and previous power structures (ref. 9). In addition, he considers two roles of a leader: goal achievement and adaptation to external demands (this requires a person who is task-oriented, instrumental, and directive), and internal integration and expression of emotional tensions (the man must be group oriented, expressive, and sociable). Dunlap states (ref. 9): "These two different leadership roles can be filled by the same man, but more often are not. Frequently, two different men will cooperate in the leadership function, one as the task specialist who gets the job done, and the other as the socio-emotional specialist who keeps the group happy and integrated."

Reduction of Social Roles

A man has many earthly roles not applicable in space: father, husband, club member, et cetera. Dunlap (ref. 9) points out that in the space environment, "the work role becomes more highly valued than normally and its prerogatives are jealously guarded." Eberhard (ref. 37) agrees, stating that not only are meaningful work opportunities preferable to excess off-duty time, but that "... men in confined space with little work to perform are unwilling to share their workload with others whose work opportunities may have been reduced."

Preservation of social roles in space could require a TV link with Earth. The crew could talk with family and close friends, thereby perpetuating their involvement in accustomed roles.

Relationship with the Ground Personnel

Two aspects of the relationship between the flight crew and the ground personnel are important. First, a crew often handles interpersonal friction by displacing their hostility to outside personnel. The outside monitors must be made to accept and understand this as a necessary therapeutic fact. Second, personal conflicts between the crew and the ground personnel before a mission may affect the former's interactions during the mission. Dunlap (ref. 9) states: "... even the voice characteristics of an outside monitor has been a source of irritation."

Interpersonal Compatibility

The selection of crewmen who are compatible will minimize many stressor effects. Rasmussen and Haythorn (ref. 64) state: "When enforced interaction occurs over a prolonged period of time, among a small group of highly skilled and trained men, mission effectiveness will suffer unless the group is personally compatible."

A study by Haythorn and Altman (ref. 88) involved 36 sailors, selected to meet varying conditions of compatibility along four personality dimensions: need for achievement (goal-orientation), need for dominance (self-orientation), need for affiliation (association with others), and need for dogmatism (authoritarianism). The men were scored by a variety of tests and ratings, then paired. Some pairs, the experimental group, were confined for 10 days. The other pairs did the same tasks but were free to leave the isolation chambers. These were the control group. The experimental and control pairs were matched for personality dimensions. The men were observed through a one-way mirror, and their actions were graded on territoriality, disclosure, performance, and personality interaction and social behavior. The results are presented in table XIII. A closer examination of the data reveals even more information. In the isolate condition (experimental group), four pairs experienced a great deal of trouble (arguing, fighting, etc.). Analysis of the individuals in these pairs, along two of the four personality dimensions measured, revealed that three pairs had members both of whom were high in dominance and two pairs had members who had contrasting needs for achievement. All four pairs showed great territoriality during the experiment. In contrast, the matched pairs in the nonisolate condition (control group) performed well together and experienced no arguments. This study indicates: "the stresses of isolation are considerably affected by the relations between personality types" (ref. 88) (and conversely, isolation serves to potentiate personality differences) and a knowledge of personality variables helps to predict how men will interact under stress.

Hartman and Flinn (ref. 84) report on three four-man simulated space flights; one lasting for 2 weeks, and two for 6 weeks. Although antagonisms developed, the men were motivated enough to complete the mission, and the personalities of the men largely determined the degree of antagonism expressed. "Passive and compliant subjects generally got along well with others and each other; occasional irritations with more outspoken and assertive crew mates were mild and transient. However, stronger antagonisms have been between immature and aggressive subjects."

Burnazyan et al. describe a yearlong confinement study of three subjects in a closed ecosystem. The men were tested before the experiment began (paired verbal association test, sociometric test) and found to be psychologically "compatible." Burnazyan et al. (ref. 76) state: "The testees demonstrated quite harmonious work on psychological models of group interdependent activity, similar trends of emotional-autonomic manifestations under the effects of functional loads, and a good understanding of one another when exchanging information by speech, by emotional-expressive movements, etc."

Interpersonal compatibility and a knowledge of the personalities of the men involved are very important in protecting against social stressors. A perfect test has yet to be devised. Mann (ref. 95) reviewed the literature from 1900 to 1957 and isolated over 500 personality variables which he combined into seven categories: intelligence, adjustment, extroversion-introversion, dominance, masculinity-feminity, conservatism, and interpersonal sensitivity. He also categorized six status and behavior variables describing an individual's functioning in a group: leadership, popularity, total activity rate, task activity, social-emotional activity, and conformity. The relationships between personality variables, group status, and behavior variables are presented in table XIV.

The table XIV results for task activity have not been corrected for total activity rate. Mann found that when such a correction was made, negative correlations resulted between this variable and intelligence, adjustment, and masculinity. Also, conformity scores are self-ratings. Note the importance of intelligence, adjustment, and extroversion to the six group variables, and the unexplainable poor showing of interpersonal sensitivity. Predicting group behavior should result from proper use of these data. To date, this has not been done satisfactorily.

Preventing Interpersonal Strife

One of the best ways to prevent conflict in space is to ensure that the group members are as compatible as possible. A proper group size, a firm command structure with a respected leader, proper visualization of roles, a good relationship with the Earth personnel, and, of course, high motivation with a common unity of purpose are important. Dunlap (ref. 9) cites a study involving a four-man crew of college students who were confined in the Douglas Space Cabin Simulator. They participated in sensitivity training before the experiment. "Sensitivity training accelerated the acquaintanceship process, exposed potential sources of interpersonal friction, provided understanding of interpersonal problems, and imparted techniques for controlling frictions that do arise. To date, the same group has made four different runs of 12, 30, 3, and 18 days each without any serious interpersonal frictions developing."

Conclusions on Sociological Considerations

Sociological stressors that would act on a crew during long-duration missions demonstrate that the largest odd-numbered crew would be the most stable; hence 11 men would be ideal in the 8- to 12-man range. An informal structure develops within the group in 1- to 3-1/2 weeks, based first upon jobs then upon interpersonal considerations. Although cliques may develop, a more important danger may be the real or perceived isolation of a particular individual (the "Long Eye" phenomenon). Leadership is a powerful stabilizing force serving both task-oriented and socioemotional functions, a difficult feat for one man. The lack of social roles in space is another problem. Television communication with family and friends on Earth, however, may help to dampen this effect. Sound crew and ground personnel relationship is crucial. Finally, crew sensitivity training can be effective.

CREW SELECTION

"... we must prepare for increased requirements, larger pools of candidates, a drop in the experience level and perhaps the quality of the candidates, with a corresponding increase in the importance of psychological and psychiatric evaluations" (ref. 84).

Jobs in Space

Price et al. (ref. 5) conducted a study of the activities that will be required on a trip to Mars, with a Venus flyby, and established four activity types: operational, scientific, human support, and maintenance. Some of the scientific jobs are shown in table XV. Recognizing the principle of cross-training, Price et al. have isolated crew tasks as follows: microbiologist-biochemist, physical scientist, deputy physical scientist, geologist, medical-psychological monitor and biological technician, physical science technician, electronics engineer (and vehicle controller), electronics engineer (and commander), physical scientist (and navigator), and medical-psychological monitor and physiologist.

Hartman and Flinn divide long-duration activities into five categories: piloting, maintenance, observational (scientist-astronaut), systems testing and operations (engineer-astronaut), and exploration. They (ref. 84) emphasize the principle of cross-training, but warn: "Cross-training will be a part of all crew preparation. To assume, however, that an all-pilot pool of astronauts can successfully handle all missions is to take an unnecessary risk of marginal-mission success and impose unnecessary requirements for cross-training." These authors have made a survey of sources evaluating long-duration space missions and have prepared a matrix (table XVI) comparing number of crewmen with duration of mission in days.

Finally, Gurovskiy (ref. 80) breaks down long-duration space flight crew activities into four types: (1) monitoring instruments; (2) servicing life-support systems, repairing instruments, growing plants, et cetera; (3) activity serving personal needs; for example, food preparation and maintaining sanitary conditions; and (4) activity connected with the fulfillment of inflight scientific observations; for example, extravehicular activity, planetary exploration, et cetera.

Eberhard (ref. 37) points out two problems resulting from mission activity that dictate crew selection. First, crew size is based upon the various "heavy work phases" of the mission, but these phases will occupy less than 1 percent of total mission time. Second, long-duration missions require highly skilled people for a relatively short time. Hartman and Flinn (ref. 84) state: "The crucial phases of fly by missions normally take only a day and for most of the Mars exploration studies, the time spent on the Martian surface is normally less than 45 days." Other than the physical-scientist technician and the navigator, only 35 to 40 percent of the available work time is scheduled for the crew. Eberhard suggests three solutions: change the activities necessary for mission success, cross-train the crew and rotate jobs, and plan carefully for free time.

Pilots Versus Scientists

Two general types of activity will be necessary: piloting (and engineering) and scientific (and medical). Past space missions were largely operational, piloting functions. Thus, men were selected who were outer-directed, action-oriented, confident in their skills, and satisfied when challenged. Cramer and Flinn (ref. 66) state: "A not uncommon underlying psychologic motivation for flying ... is a need to prove one's ability to master challenging or threatening situations. Later some pilots handle their concern about the dangers of flying through the development of an attitude of invulnerability and the feeling that they can handle any situation without help." However, longer space missions may require other qualities. For example, introverts perform better on vigilance tasks under low sensory-input conditions than extroverts. Also, Fraser (ref. 60) states that much free time requires men who see leisure as an opportunity, and are challenged by it; he believes also that men who are extremely job-oriented may not be able to do this. According to him, scientist-astronauts have an advantage. "Those characteristics which caused him to select a scientific career, amplified by his training, are such that his leisure time and his work time tend to overlap diffusely, or that in his leisure time he continues to pursue activities which will develop other areas of compelling interest." The findings of Gunderson (ref. 65) and Pope and Rogers (ref. 69) confirm this. Flinn et al. (ref. 18) point out a great need for the men to be able to fantasize and to find happiness with "inner satisfactions."

Gunderson (ref. 65) conducted a study of five U. S. Antarctic stations and found a greater incidence of psychological disorders among the Navy servicemen there than among the population at large. In addition, he found a striking difference in symptomatology between the Navy and civilian personnel during the wintering-over period. His data, converted from absolute numbers to percentages, are shown in table XVII. At the end of the wintering period, the total Navy cases more than doubled those of the civilians. Most of the civilians were either scientists or technicians. Gunderson (ref. 65) states: "Overall, Navy personnel evidence more symptomatic distress than did the civilian scientists and technicians, suggesting that occupation or work role was a significant factor in determining the amount of emotional stress experienced in this environment." The civilians experienced more anxiety symptoms than the Navy personnel; perhaps the latter were better able to control this problem because of more experience with hazard-fraught situations.

Gunderson speculates that the work role influenced his finding. Changes in self-esteem and group status are related to the perceived importance of one's job. The civilians saw their job as important throughout the winter months because of constant need for their efforts, whereas the lack of activity during these times reduced the need for the Navy personnel. Also, Navy men require more immediate rewards than scientists who are used to waiting months or years for professional rewards.

However, pilots and service personnel are not to be excluded from long-duration space missions. Piloting functions are necessary for such a flight. Cool-headed men accustomed to danger, who are confident in themselves, make good leaders. In addition, the data in table XIV show the importance of extroversion to proper group status and behavior. Therefore, both piloting and scientific qualities are necessary for mission success and may exist in the same individual (for example, confidence and extroversion coexisting with curiosity and ability to introspect). Compatibility in many personality variables, coupled with a good command structure, a common goal, respect for each other's worth, et cetera, still enables pilots and scientists to coexist for long periods of time. Much work remains to isolate the most important variables and verify that they are possessed in a complementary fashion by the individuals.

Women in Space

There has been only one woman in space, Valentina Tereshkova, during the 3-day Vostok 6 flight (ref. 96). All cosmonauts, men and women, were trained identically by the U. S. S. R. The men had to be jet pilots, whereas the women belonged to the same parachute club. During training, the women seemed to adapt faster to weightlessness than the men, and there was no difference between the sexes concerning the effects of prolonged sensory deprivation, although takeoff and landing stress seems to be worse in the women during ovulation. Phases of the menstrual cycle under weightless conditions are not significantly important.

Women have accompanied men on a few polar explorations, but no sociological data are available from these expeditions. Cameron (ref. 97) made a study of 98 air hostesses regarding several physiological and psychological complaints and included a 6-year followup. He found deterioration in both physiological and psychological dimensions. The physiological functions, however, improved after the women stopped flying, whereas the psychological parameters continued their downward course. He concluded that the physiological observation reflected the hostesses' working environment, (interference with circadian rhythm, long periods of standing, etc.), whereas the psychological effect was due to the psychological makeup of the population (ref. 97). Concerning menstrual functions, one quarter of the women showed deterioration (irregularity, dysmenorrhea) during their first year as jet hostesses with gradual improvement back to "normal" with increasing flying experience. There was no evidence of infertility or increased liability to miscarriage (ref. 97).

Information regarding women during periods of stress is scanty. This lack, plus previously mentioned problems, will make it difficult for a woman to be a member of the first long-duration space missions. However, it is just as unlikely to think that women cannot adapt to space. Initial exploration parties are historically composed of men, for various cultural and social reasons. Once space exploration by men has been successfully accomplished, then women will follow. In preparation for this, more information should be compiled regarding the physiology and psychology of women under stressful situations.

Mixed-Nationality Space Crews

Discussions have occurred concerning a mixed-nationality space venture. At the 21st Congress of the International Astronautical Federation (I. A. F.) held at Constance, West Germany, the keynote speaker predicted an international space station within 10 years. At the same meeting, Y. A. Senkevich, one of two U. S. S. R. scientists aboard the Thor Heyerdahl transatlantic raft, stated that "confrontation with common problems and dangers soon broke down the barriers rooted in nationality" (New York Times, Oct. 7, 1970). However, he stressed that a good commander in such a situation is important. Also at the I. A. F. meeting, a joint U. S. -U. S. S. R. docking mission for future space rescue was discussed; in addition, the U. S. S. R. agreed, for the first time, to send four representatives to the federation's space-rescue study committee to be held in Brussels the next year. At a press conference at Houston-MSC on October 22, 1970, Nikolayev and Sevastyanov stated that the U. S. S. R. has definite plans to orbit a space station and would favor a mixed crew, provided all members of the station learned English and Russian.

Three good reasons for a joint effort are: improving prospects for peace, combining brainpower and talent of all nations, and reducing costs and unnecessary duplication. However, several problems involved are: politics and secrecy, language and custom differences (e.g., food), incompatible equipment (e.g., docking parts), attitudes toward females, acceptance of command structure, off-duty activities, and role of scientists versus pilots.

V. S. Vereschetin (ref. 10) presents 12 legal questions that would concern a space station joint effort: (1) agreement on legal terms and definitions that will include foreign astronauts in a space station crew; (2) right of ownership of the space station; (3) registration of the station, because registration indicates the state of jurisdiction;

(4) agreement on rescue and return; (5) liability in case of damage; (6) legal codes for financing, procurement, data receipt and reduction and profits; (7) jurisdiction of a crew of different nationalities; (8) agreement on a standard docking mechanism for rescue; (9) agreement that the vehicle would carry no weapons; (10) right of visit by all states; (11) definition of the objective of the station; and (12) definition of the relations among the participating countries.

The problems are many and international cooperation is apriori before a joint space effort can be consummated. Certainly, a space station composed of allied nationalities is a probable first venture.

Astronaut Selection

At the beginning of the U.S. Manned Space Program, candidates for astronaut training had to fulfill eight criteria (ref. 3): less than 40 years of age, less than 5 feet 11 inches in height, excellent physical condition, Bachelor degree (or equivalent), graduate from a test pilot school, 1500 hours of flight time, qualified jet pilot, and citizen of the United States.

A battery of stress, physiological, and psychological tests were given prospective astronauts at Wright Air Development Center in 1959. According to Link (ref. 98): "the psychological tests administered at WADC had two objectives: to determine personality and motivation, and to determine intelligence and special aptitudes." Some of these tests are itemized in table XVIII. These tests required 6-1/2 hours to complete. The men averaged nine IQ points higher than 200 flying personnel, scored higher than college norms in achievement, dominance, endurance, need for deference, and need for change. The candidates showed good aptitude, and demonstrated themes of achievement and autonomy with the positive attainment of a goal on the T. A. T.

In addition, the men had 3 hours of psychiatric evaluation. Flinn et al. (ref. 89) describe the goals: "In general, considerable weight was given to the candidates' overt behavioral and personality characteristics, with relatively less weight being given to emotional conflicts which seemed unrelated to job performance and effectiveness. Our definition of normal and 'adaptable' tends to be operationally oriented." The men were evaluated on seven characteristics: ability to perform during psychiatric and physiological stress, high motivation, persistence, high energy level, aggression in pursuit of job-oriented goals, enthusiastic approach to work, and ability to work with others.

These tests, in addition to physiological, medical, and stress studies, resulted in the selection of the seven original Mercury astronauts. Since that time, the selection procedure has remained essentially the same, although some of the criteria (height less than 5 feet 11 inches, requirement for test pilot training) were waived for the scientist-astronauts.

At the 21st I. A. F. meeting, O. G. Gazenko (ref. 10) stated that the U. S. S. R. approaches the selection process according to five principles: effectiveness of the group in a multiman crew, use of known psychological testing methods, study of the nature of group activity, recognition of the social backgrounds of crewmembers, and readiness of each member to perform his task.

The Russians are seriously emphasizing the psychosocial nature of their candidates for space flight. Gagarin and Lebedev (ref. 90) support this in their book. Buyanov and Terent'yev (ref. 24) list seven approach guidelines for functional and psychological problems of long-duration space flights: identify candidates who can solve problems with maximal efficiency, evaluate "microsymptoms" with the aid of careful case study, detect latent epilepsy or unusual response to stimuli, determine resistance to decompression, observe for borderline psychopathological personality traits, detect psychological incompatilibity, and determine central nervous system (CNS) reserves for high-level performance under complicated environmental conditions. Many of these techniques will certainly be useful in selecting crews for long-duration space missions, especially if some of the principles mentioned in previous chapters are considered. Both psychological testing and interview techniques will have to be applied. Some of the important personality traits are shown in table XIX. The men should have demonstrated that they are capable of favorable response to the various stressors described in this report. Without a doubt, further testing and study along these lines is necessary to ensure future mission success. In the words of Dunlap (ref. 9): "While there are many practical actions which can be taken to anticipate possible psychological and sociological stressors and reduce their impact, still there is a great need for research at the basic science level before we can say with confidence that such stressors will be no problem on a Mars mission."

Conclusions on Crew Selection

Jobs to be done on a long-duration space mission can be divided into four types: operational, maintenance, scientific, and human support. Thus, two broad disciplines must be represented among the crew: piloting and engineering, and scientific-medical. In the past, space flights have been largely operational in purpose; hence, piloting activities have been predominant. However, on a long-duration exploration mission, both pilots and scientists must coexist, for personality traits characteristic of each will be needed.

Although the idea of including women and people of other nationalities on the first long-duration missions has been discussed, it is unlikely that this will occur, inasmuch as numerous cultural, social, and political problems complicate the matter. What is needed is further study, and a space station would be an ideal training ground.

Numerous psychological, psychiatric, physiological, and stress adaptability considerations were used in selecting the U.S. and U.S.S.R. space pilots. The U.S.S.R. has begun seriously to consider social factors. Although several precedents have been set, it is obvious that in the psychosocial sphere, long-duration missions are sufficiently different from shorter flights to warrant further study.

CONCLUDING REMARKS

Man has always been aware that certain psychiatric and sociological problems existed under abnormal conditions of confinement and isolation. Recently, with the advent of space missions, the need to identify, define, and solve these problems has become a necessity. The added factor of weightlessness complicates the situation.

Long-duration missions, a Mars mission, for example, will be possible only when the solutions to all psychiatric and sociological problems are within the state of the art.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, October 13, 1971
914-50-CD-95-72

TABLE I. - ADVANTAGES AND DISADVANTAGES OF MAN AND MACHINE IN MAN-MACHINE SYSTEMS

[From reference 3]

Man	Machine
Can acquire incidental data and report unexpected events	Unable to detect or sense phenomena beyond design limits
Cannot be jammed by electromagnetic radiations	Can be disrupted or degraded by electromagnetic radiation, especially in the radio-frequency range
Can detect primary signals masked in extraneous noise	Difficulty in detecting primary signals in a noisy environment
Relatively slow and inaccurate in mathematical computations	High-speed mathematical computation with great accuracy
Long-term storage of large amounts of of information with variable recall time	Short-term storage of limited amounts of information with very fast recall time
Performance deteriorates with time; requires rest for optimum performance	Performance is not time dependent; requires periodic inspection and maintenance
Sensitive to various stressors of space flight and environment	Can be designed for optimum performance under most space conditions
Lightweight and low power consumption	Weight increases with complexity of tasks and reliability required; modest to high power consumption
Emotional and easily bored; nonexpendable	Expendable and has no feelings
Large available supply but requires long programing and training time	Must be designed and manufactured to order
Can communicate both subjective and objective experiences	Can communicate only information for which it is specifically instrumented
Significant time lag in response to stimuli	Responds almost instantaneously to signals

TABLE II. - A RANKING OF SOCIAL SYSTEMS SIMILAR TO LONG-DURATION SPACE MISSIONS (MODIFIED FROM SELLS)

[From reference 6]

System	Rank	Similarity score
Submarines	1	79
Exploration parties	2	68
Naval ships	3	61
Bomber crews	4	60
Remote duty stations	5	59
POW situations	6	39
Professional athletic teams	7	37
Mental hospital wards	8	23
Prison society	9	20
Industrial work groups	10	16
Shipwrecks and disasters	11	11

TABLE III. - A COMPARISON OF LONG- AND SHORT-DURATION SPACE MISSIONS, SPACE SIMULATORS, AND HYPODYNAMIA

Factor	Long-duration mission	Short-duration mission	Space simulator	Hypo-dynamia
Weightlessness	Present	Present	Absent	Absent
Crew size	8 to 12	1 to 3	Varied	Varied
Duration	17 months	Less than 3 weeks	Less than 12 months	Less than 3 months
Danger	Present	Present	May be present	Absent
Rescue	Unlikely	Unlikely	Possible	Possible
Confinement	Present	Present	Present	Present
Free time	Present	Absent	Present	Present

TABLE IV. - PSYCHOPHYSIOLOGICAL TESTS AND PSYCHIC CORRELATES

Test	Psychic correlate[a]
Catecholamines (urine or blood)	Increased norepinephrine — anger Increased epinephrine — fear
ACTH or adrenal corticosteroid levels (urine or blood)	Increased levels in stress
Protein-bound iodine (serum)	Increase related to anxiety
Skin resistance	Decrease with arousal
Heart rate	Usually increase in stress
Blood pressure	Variable
Respiratory rate	Increase in fear or anger
Electromyogram	Related to motivation
Electroencephalogram	Alertness related to frequency

[a]Reference 14.

TABLE V. - PSYCHOLOGICAL TESTS

Test type	Stressor
Perceptual	Threshold
	Flicker fusion
	Perceptual speed
	Perceptual retention
	Attention
	Discrimination
Cognitive	Problem solving
	Concept formation
	Conditioning and learning
Motor	Steadiness
	Tracking
	Coordination
Perceptual-motor	Reaction time
Personality	Direct observation and interviewing
	Self-ratings (e.g., MMPI, Edwards Personal Preference Schedule)
	Projective tests (e.g., Rorschach, TAT)

TABLE VI. - BALES INTERACTION PROCESS ANALYSIS CATEGORIES

Category	Observed interaction
Positive reactions	1. Showing solidarity
	2. Showing tension release
	3. Showing agreement
Problem-solving attempts (task neutral area)	4. Giving suggestion
	5. Giving opinion
	6. Giving orientation (or information)
Questions (task neutral area)	7. Asking for orientation (or information)
	8. Asking for opinion
	9. Asking for suggestion
Negative reactions	10. Showing disagreement
	11. Showing tension
	12. Showing antagonism

TABLE VII. - NEUROLOGICAL RESPONSE TO HYPODYNAMIA

Factor	1 to 2 weeks	3 to 9 weeks	Recovery
Neurologic exam	Asthenic reactions (brisk tendon reflexes, problems with coordination, nystagmus, pathological reflexes)	Aggravation of asthenic reactions (especially Group II)	Improved, but gait disturbances and muscle pain took 2 to 7 days
Behavior	Nervousness, increased hostility, sleep disruption (not refreshing, superficial, bad dreams), somnolence during the day	Nervousness, increased hostility, sleep disruption (not refreshing, superficial, bad dreams), somnolence during the day	Improved
Autonomic nervous system	Tachycardia, increased heart rate, diaphoresis, tremor, vascular dystonia	Aggravation of symptoms (especially Group II)	Improved
Work capacity	Decreased, with accompanying decrease in desire to study, academic subjects	Decreased, with accompanying decrease in desire to study academic subjects	Improved
Electroencephalograph	No change	Shift toward slower frequencies (4 to 7 Hz) and decreased formation of cortical time shifts to indifferent stimulus	Improved

TABLE VIII. - FREQUENCY OF CHANGES IN INDIVIDUAL'S CONDUCT AND EMOTIONS

[From reference 64]

Behavior	1 to 4 months	5 to 8 months	9 to 12 months
Disruption of sleep cycle	2	15	3
Apathetic, indifferent	1	5	1
Tense, restless	3	8	19
Complaining, whining	0	1	3
Irritable, hypertensive	6	9	13
Suspicious, mistrustful	0	7	16
Uncooperative	1	2	13

TABLE IX. - RANK ORDER OF LEISURE-TIME ACTIVITIES

[From reference 82]

Rank	Activity	Relative frequency (F/N)
1	Reading	0.725
2	Television	.300
3	Musical activities	.275
4	Manual activities	.213
5	Playing bridge	.163
6	Educational activities	.150
7	Miscellaneous work	.125
8	Social activities	.125
9	Travel and driving	.100
10	Family activities	.100
11	Photography	.100
12	Sports	.088
13	Hunting and fishing	.088
14	Gardening	.075
15	Chess	.063
16	Others	.277

TABLE X. - RANK ORDER OF EQUIPMENT DESIRED FOR A HYPOTHETICAL SPACE JOURNEY

[From reference 82]

Rank	Equipment	Relative frequency (F/N)
1	Books	0.925
2	Playing cards	.613
3	Chess	.525
4	Musical instruments	.425
5	Record equipment	.413
6	Handicraft equipment	.313
7	Art supplies	.288
8	Writing supplies	.275
9	Athletic equipment	.263
10	Puzzles and games	.250
11	Photographic supplies	.225
12	Flowers and pets	.063
13	Sex responses	.063
14	Food and drug responses	.003

TABLE XI. - CORRELATIONS BETWEEN PERSONALITY FACTORS AND OBSERVED BEHAVIOR ABOARD TEKTITE II (ALL SIGNIFICANT AT $P < 0.01$)

Factor	Observed behavior	Correlation
Outgoingness (Cattell)	Amount of gregariousness	0.575
Stability (Cattell)	Percent time awake	-.628
Suspicious (Cattell)	Likability as a teammate	-.597
Tender-minded (Cattell)	Likability as a teammate	.589
Apprehensiveness (Cattell)	Amount of work	.617
Aggression	Rating of enthusiasm	-.610
Social affection	Attitude toward topside	-.718

TABLE XII. - A COMPARISON OF SCORES FROM THE BALES INTERACTION PROCESS ANALYSIS WITH THREE GROUP VARIABLES

Bales factor	Increasing group size	Two-man groups	Even-numbered groups
Showing solidarity	↑	--	↑
Showing tension release	↑↑	--	--
Showing agreement	↓↓	--	↓
Giving suggestion	↑↑	↑	--
Giving opinion	↓↓	↓	--
Giving orientation	↑↑	↑	--
Asking for orientation	--	↑↑	--
Asking for opinion	↓↓	↑	--
Asking for suggestion	--	--	↓↓
Showing disagreement	--	↓↓	↑↑
Showing tension	↓↓	↑↑	--
Showing antagonism	--	↓↓	↑↑

Note: -- neither high nor low

↑ high, but not significant

↓ low, but not significant

↑↑ high, significant at 0.05 level

↓↓ low, significant at 0.05 level

TABLE XIII. - TWO-MAN GROUPS IN ISOLATION AND NONISOLATION CONDITIONS

Dimension	Isolates	Nonisolates
Territoriality (one-way mirror)	Established preference for beds with little intrusion into the other's sleeping area	Tendency was minimal at first with slight increase with time
Disclosure (questionnaire)	Confided a great deal initially but gradually drew apart into "territories"	Confided less initially but gradually came closer together
Performance (questionnaire, performance scores)	Experienced stress but still performed very well	Experienced less stress but performance much poorer
Interaction (one-way mirror, questionnaire)	Much personal conflict and hostility	Less conflict and hostility

TABLE XIV. - CORRELATIONS BETWEEN PERSONALITY VARIABLES AND GROUP STATUS AND BEHAVIOR VARIABLES

	Group status and behavior variable					
Personality variable	Leadership	Popularity	Total activity rate	Task activity	Social-emotional activity	Conformity
Intelligence	+	+	+	+	+	o
Adjustment	+	+	+	+	+	+
Extroversion	+	+	+	+	o	+
Dominance	+	+	o	+	o	-
Masculinity	+	o	o	+	o	o
Conservatism	-	+	o	+	o	+
Interpersonal sensitivity	+	+	o	+	o	o

Note: + positive correlation

- negative correlation

o no correlation (neither very high or very low)

TABLE XV. - TYPES OF SCIENTIFIC ACTIVITIES ON A PROPOSED MARS MISSION WITH VENUS FLYBY

[From reference 5]

Functions / Phases	Exobiology			Physical science										Physiology					Performance times
	Landing-decision data collection	Disembark-decision data collection	Exploration of Martian surface	Topology and geography of Mars	Geology of Mars	Man's long-term existence on Mars	Exoatmosphere of Mars	Shape and motion of Mars	Topology and geography of Mars' moons	Corroboration of space data	Topology and geography of Venus	Exoatmosphere of Venus	Shape and motion of Venus	Circulatory system	Respiratory system	Nervous system	Endocrine and metabolic system	Body fluid system	
Earth launch																			0
Earth orbit										X									50
Earth-Venus flight								X		X	X	X	X	X	X	X	X	X	2616
Venus flyby											X	X	X						156
Venus-Mars flight	X	X					X	X		X	X	X	X	X	X	X	X	X	4089
Mars orbit	X			X	X	X	X		X	X									271
Mars landing																			0
Mars exploration	X	X	X	X	X	X	X			X									2558
Mars lift-off																			0
Mars orbit									X										147
Mars-Earth flight			X	X		X	X	X	X	X				X	X	X	X	X	4256
Earth orbit										X									0
Earth reentry																			0

TABLE XVI. - A MATRIX COMPARING NUMBER OF CREWMEN WITH DURATION OF MISSION

[From reference 84]

Number of crewmen	Number of days				
	3 to 7	10 to 20	23 to 50	60 to 90	100 +
2 to 5	Gemini and Apollo	Advanced Apollo	Early space laboratory tests	Possible Apollo emergency mode	Deep-space explorations
5 to 10	Unlikely	Space laboratory tests	Space laboratories	Space laboratories	Mars missions, etc.
10 to 20	Training facility	Major lunar explorations	Lunar construction program	Space systems operations	Planetary exploration programs
20 plus	Unlikely	Unlikely	Unlikely	Lunar systems operations	Lunar and planetary colonies

TABLE XVII. - EMOTIONAL SYMPTOMS IN THE ANTARCTIC (1964 to 1966) —

CHANGE IN FREQUENCY OF EACH BETWEEN BEGINNING

AND END OF WINTER MONTHS

Symptom	Increase, percent	
	Navy men	Civilians
Insomnia	28	4.4
Depression	15	[a]2
Anxiety	28	42
Hostility	39	21

[a]Decrease.

TABLE XVIII. - PSYCHOLOGICAL TESTS ADMINISTERED TO THE PROJECT MERCURY CANDIDATES

[From reference 98]

Personality and motivation	Intelligence and aptitude
Rorschach	Wechsler Adult Scale
TAT[a]	Miller Analogies
Draw-a-person	Raven Progressive Matrices
Sentence completion	Doppelt Mathematical Reasoning Scale
Self-inventories	
Officer effectiveness inventory	Engineering Analogies
	Mechanical Comprehension
Personal-preference schedule	Air Force Officer Qualification Test
Preference evaluation	Aviation Qualification Test (USN)
Determination of authoritarian attitudes	Space Memory
Peer ratings	Spatial Orientation
Answer to question "Who am I?"	Gottschaldt Hidden Figures
	Guilford-Zimmerman Spatial Visualization

[a]Thematic apperception test.

TABLE XIX. - IMPORTANT PERSONALITY TRAITS FOR LONG-DURATION SPACE MISSIONS

[From reference 20]

Favorable	Unfavorable
Youth	Increased age
Single	Marriage, if wife opposes flying
Good family history	Poor family history (tuberculosis, nervous and mental diseases, etc.)
Few and only minor diseases — especially those with few complications and sequelae	Numerous and severe diseases of childhood — especially nervous diseases and defects, severe infections in adult life and nervous or mental breakdowns
No operations, or serious injuries, or serious stresses	Operations — which may have left permanent impairment
High school and college education with good scholarship throughout	Inadequate education with poor scholarship
Unusual ability in athletics	Little or no athletic training
Evidence of manual dexterity, good at billiards, tennis, sailing, golf, violin, piano, horseback riding	No evidence of manual dexterity
Active, successful civil life	Sedentary civil occupation with poor or moderate success
Liking for normal amusements — no evidence of excesses and dissipations	No interest in amusements
Extreme moderation in use, or complete abstinence from tobacco and alcohol	Excesses in tobacco, alcohol, and sexual life
Good appetite and digestion	Poor appetite and digestion

TABLE XIX. - IMPORTANT PERSONALITY TRAITS FOR LONG-DURATION SPACE MISSIONS - Concluded

[From reference 20]

Favorable	Unfavorable
Normal sleep and absence of dreams, normal sexual tendencies	Insomnia and frequent unpleasant or terrifying dreams, especially of an occupational type, abnormal sexual tendencies or perversions
Good, active, sympathetic cooperation of family in all that pertains to flying	Anxiety concerning or active opposition to flying on part of family, especially mother and wife
Normal reactions throughout physical examination and satisfactory physical examination	Unsatisfactory physical examination
Personality showing: Temperament: cheerful, stable, self-reliant, aggressive, modest, frank, fond of people, satisfied, punctilious, serious, good cooperation in work and in examination, good sportsmanship, moderate tension, enthusiastic, adaptable	Personality showing: Temperament: depressed, unstable, submissive, pacific, vain, withholding, secretive, loquacious, likes to be alone, hypercritical of conditions, careless, frivolous, poor cooperation, irritable, poor sportsmanship (under adverse circumstances querulous and complaining), exceedingly high tension, lost enthusiasm

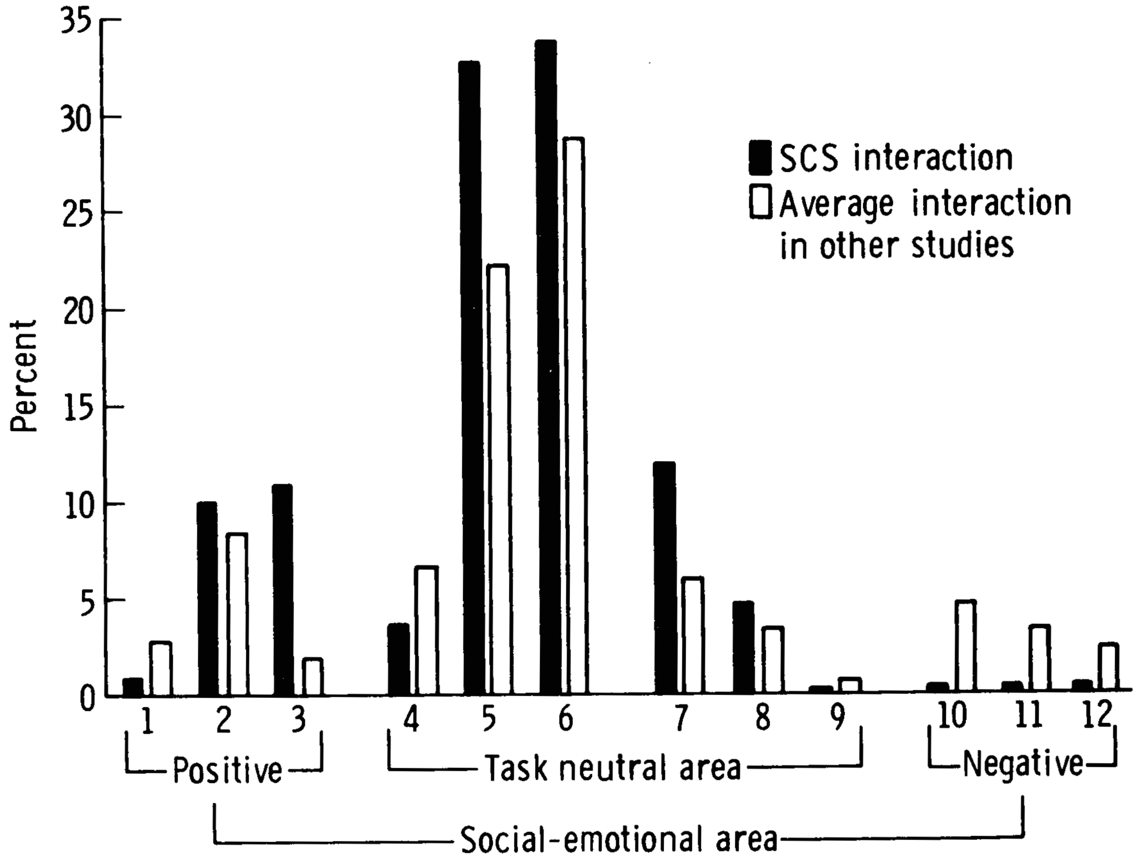


Figure 1. - Comparison of interactions in the Space Cabin Simulator with average interaction in 21 other studies (ref. 18).

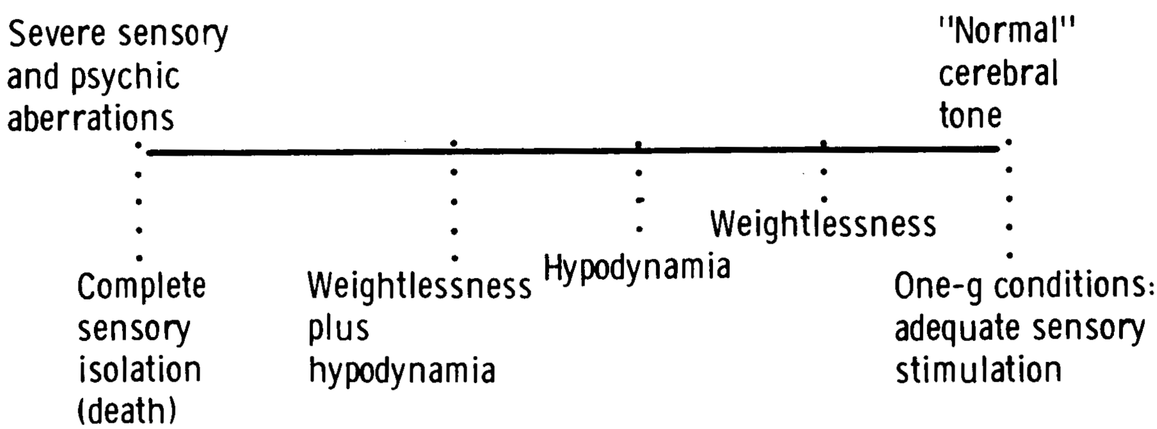
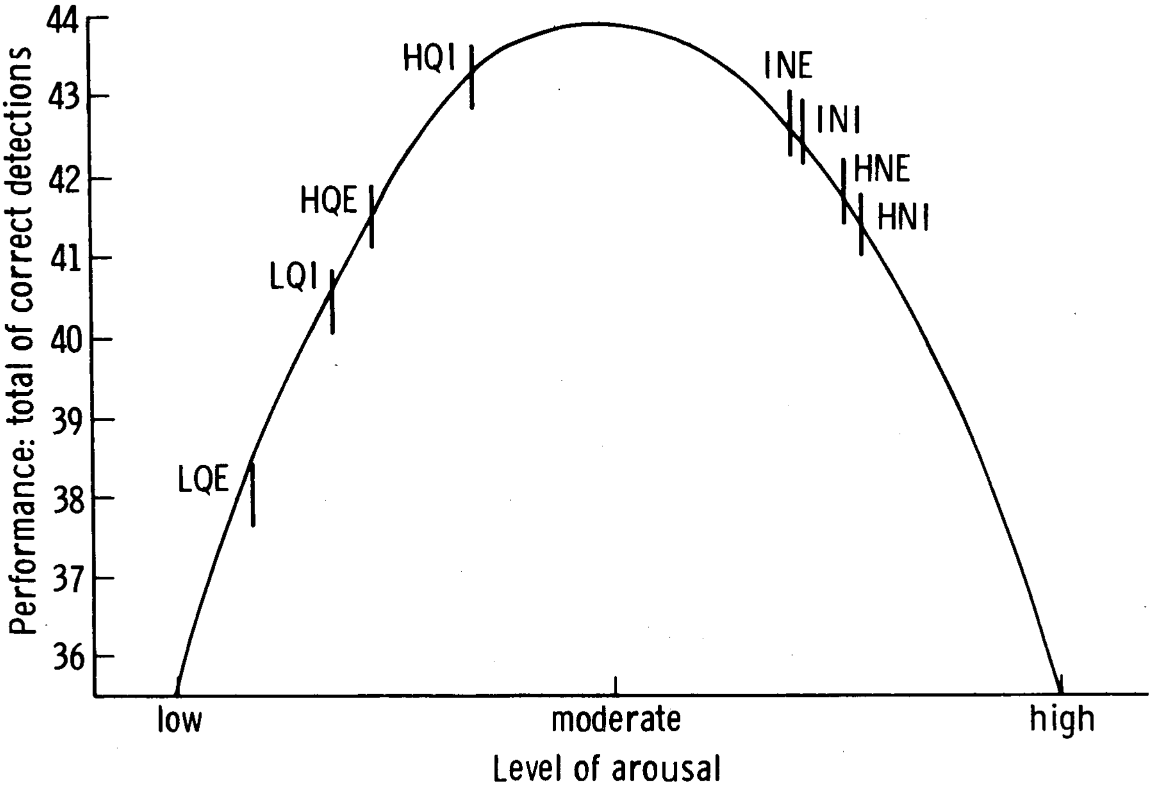


Figure 2. - A sensory-stimulation scale.



Note: Relation between efficient performance and level of arousal is given by an inverted U-curve in which the peak of efficiency corresponds to a certain level of arousal, which varies from person to person. Extroverts seem to require a higher level of arousal to reach the same efficiency as introverts, and it is generally assumed that arousal in vigilance tasks is increased by a high-signal frequency and a high-noise level. Thus people can be placed in a rough order representing an increasing level of arousal. When these levels are plotted against the efficiency of the subjects, measured in monotonous tasks, they fit the inverted U-curve. L represents a low-signal frequency, H a high-signal frequency, while Q is quiet, and N is noise. I refers to introverts and E to extroverts.

Figure 3. - Relationship between level of arousal and performance.

REFERENCES

1. Solomon, P.: Motivation and Emotional Reactions in Early Space Flights. Symposium on Psychophysiological Aspects of Space Flight. B. E. Flaherty, ed., Columbia Univ. Press, 1961, pp. 272-277.

2. Kubis, J. F.; and McLaughlin, E. J.: Psychological Aspects of Space Flight. Translations of the New York Academy of Science, Series II, vol. 30, no. 2, Dec. 1967, pp. 320-330.

3. Sharpe, M. R.: Living in Space, The Astronaut and his Environment. Doubleday and Co., Inc., 1969.

4. Hyatt, A.: Planning For The Future Goals of NASA. Proceedings of the NASA-University Conference on the Science and Technology of Space Exploration, Vol. 1, NASA SP-11, 1962, pp. 15-24.

5. Price H. E. et al.: A Final Report of a Study of Crew Functions and Vehicle Habitability Requirements For Long-Duration Manned Space Flights. Vol. 1. Serendipity Associates (Chatsworth, Calif.), 1965.

6. Sells, S. B.: A Model For The Social System For the Multiman Extended-Duration Space Ship. Paper presented at the AIAA/AAS Stepping Stones To Mars Meeting (Baltimore, Md.), Mar. 28-30, 1966, pp. 433-438.

7. Anon.: Feasibility of Using Undersea Facilities to Provide Psychological and Physiological Data Applicable to Lengthy Space Missions. NASA CR-94259, Mar. 11, 1968.

8. Duff, I. F.: Medical Study of the Experience of Submarines as Recorded in 1,471 Submarine Patrol Reports in World War II. USN Bulletin of Medicine, no. IX, 1947.

9. Dunlap, R. D.: Psychology and the Crew on Mars Missions. Paper presented at the AIAA/AAS Stepping Stones to Mars Meeting (Baltimore, Md.), Mar. 28-30, 1966, pp. 441-445.

10. Kolcum, E. H.: International Space Station Plan Pushed. Aviation Week and Space Technology, vol. 93, no. 15, Oct. 12, 1970, p. 12.

11. Yuganov, Ye. M.; Krylov, Yu. V.; and Kuznetzov, K. S., eds.: Standards for Noise Levels in Cabins of Spacecraft During Long-Duration Flights. (Transl.). Problems of Space Biology, vol. 7, NASA TT F-529, May 1969, pp. 296-303.

12. Gerathewohl, S. J.: Work Proficiency in the Space Cabin Simulator. Aerospace Medicine, vol. 30, no. 10, Oct. 1959, pp. 722-735.

13. Ebersole, J. H.: The New Dimensions of Submarine Medicine. New England Journal of Medicine, vol. 262, 1960, pp. 599-610.

14. Ruff, G. E.: Psychological and Psychophysiological Indices of Stress. Unusual Environments and Human Behavior. N. E. Burns et al., eds., Free Press of Glencoe (London), 1963.

15. Wang, G. H.: Brainstem Reticular System and Galvanic Skin Reflex. Federation Proceedings, vol. 14, 1955, p. 158.

16. Burch, N. R.: A Longitudinal Study of Behavior in the Small Human Group. Grant NGR-44-068-003 (private circulation) Nov. 26, 1969.

17. Lacey, J. L.; and Lacey, B. C.: Verification and Extension of the Principle of Autonomic Response-Stereotypy. American Journal of Psychology, vol. 71, 1958, pp. 50-73.

18. Flinn, D. E.; Monroe, J. T.; Cramer, E. H.; and Hagen, D. H.: Observations in the SAM Two-Man Space Cabin Simulator. Behavioral Factors in Selection and Performance. Aerospace Medicine, vol. 32, July 1961, pp. 610-615.

19. Hagen, D. H.: Crew Interaction During a 30-Day Simulated Space Flight, Preliminary Study. SAM report. 1961, pp. 61-66.

20. Henry, J. P.: Biomedical Aspects of Space Flight. Holt, Rinehart, and Winston Inc., 1966.

21. Berry, C. A.: Apollo 7 to 11: Medical Concerns and Results. NASA TM X-58034, Nov. 1969.

22. Berry, C. A.; and Catterson, A. D.: Pre-Gemini Medical Predictions Versus Gemini Flight Results. Paper presented at Gemini Conference, NASA SP-138, Feb. 1-2, 1967.

23. Berry, C. A.; Coons, D. O.; Catterson, A. D.; and Kelly, G. F.: Man's Response to Long-Duration Flight in the Gemini Spacecraft. Paper presented at the Gemini Midprogram Conference, NASA SP-121, Feb. 23-25, 1966.

24. Buyanov, P. B.; and Terent'yev, V. G.: Some Clinical Considerations in Selecting Astronauts for Long Flights. (Transl.). Selected Translations from Aerospace Medicine, JPRS 46751, Oct. 28, 1968, pp. 152-157.

25. Sisakyan, N. M.; and Yazdovskiy, V. I.: First Group Into Outer Space. (Transl.). JPRS manual, vol. 2, no. 25, June 1964.

26. Loftus, J. P., Jr.; and Hammer, L. R.: Weightlessness. Unusual Environments and Human Behavior. Neal M. Burns, Randall M. Chambers, and Edwin Hendler, eds., Free Press of Glencoe (London), 1963.

27. Adey, W. R.; Kado, R. T.; and Walter, D. O.: Computer Analysis of EEG Data From Gemini Flight GT-7. Aerospace Medicine, vol. 38, no. 4, Apr. 1967, pp. 345-359.

28. Adey, W. R.; Kado, R. T.; and Walter, D. O.: Analysis of Brain Wave Records from Gemini Flight GT-7 by Computations to be Used in a Thirty-Day Primate Flight. Life Sciences and Space Research, A. H. Brown and F. G. Favorite, eds., International Space Science Symposium (seventh), North-Holland Publishing Company (Amsterdam), 1967, pp. 67-93.

29. Simonov, P. V.: Studies of Emotional Behavior of Humans and Animals by Soviet Psychologists. Annals of the New York Academy of Sciences, vol. 159, art. 3, 1969, pp. 1113-1121.

30. Strickland, Z.: Soyuz 9 Medical Reports Puzzling. Aviation Week and Space Technology, vol. 93, no. 18, Nov. 2, 1970, pp. 51-53.

31. Anon.: Cosmonaut Biomedical Problems on Soyuz 9 Mission Detailed. Aviation Week and Space Technology, vol. 93, no. 15, Oct. 2, 1970, p. 19.

32. Bogachenko, V. P.: State of Psychic Activity in Subjects During Prolonged Confinement to Bed. (Transl.). Problems of Space Biology, vol. 13, NASA TT-639, Oct. 1970, pp. 170-174.

33. Marishchuk, V. L.; Dzamgarov, T. T.; Dem'yanenko, Yu. K.; Stupnitskiy, V. P.; and Khvoynov, B. S.: Stability of Psychic Functions During Prolonged Confinement to Bed. Problems of Space Biology, vol. 13, NASA TT-639, Oct. 1970, pp. 175-183.

34. Sorokin, P.A.; Simonenko, V. V.; and Korolev, B. A.: Clinical Observations in Prolonged Hypodynamia. Problems of Space Biology, vol. 13, NASA TT-639, Oct. 1970.

35. Purakhin, Yu. N.; and Petukhov, B.N.: Neurological Changes in Healthy Humans Subjected to Two Months of Hypokinesia. (Transl.). Space Biology and Medicine, JPRS 46456, vol. 2, no. 3 (Washington, D.C.), 1968, pp. 79-85.

36. Goshen, C. E.: Prospects For a Manned Space Laboratory. Industrial Medicine and Surgery, vol. 37, no. 5, May 1968, pp. 359-375.

37. Eberhard, J. W.: The Problem of Off-Duty Time in Long-Duration Space Missions. Vol. 2, NASA CR-96721, Oct. 1967.

38. Goldberger, L.; and Holt, R. R.: Experimental Interface With Reality Contact (Perceptual Isolation): Method and Group Results. Journal of Nervous and Mental Diseases, vol. 127, 1958, p. 99.

39. Flaherty, B. E.; Flinn, D. E.; Hauty, G. T.; and Steinkamp, G. R.: Psychiatry and Space Flight, USAF, ATC, School of Aviation Medicine, report 60-80, Sept. 1960.

40. Simmons, D. G.; Flinn, D. E.; and Hartman, B. C.: The Psychophysiology of High Altitude Experience. Unusual Environments and Human Behavior. N. E. Burns, ed., Free Press of Glencoe (London), 1963.

41. Mikushkin, G. K.: Circadian Rhythms and Their Importance in Space Biology and Medicine. (Transl.). Environmental Space Sciences, vol. 3, no. 1, Jan.-Feb. 1969, pp. 26-32.

42. Weybrew, B. B.: Impact of Isolation Upon Personnel. Journal of Occupational Medicine, vol. 3, 1961, pp. 290-294.

43. Kogan, A. B.: Effect of Prolonged Fixation on Some Functions of the Animal Organism. (Transl.). Environmental Space Sciences, vol. 3, no. 1, Jan.-Feb. 1969, pp. 43-45.

44. Davies, D. R.: Monotony and Work. Science Journal, vol. 6, no. 8, Aug. 1970, pp. 26-31.

45. Guedry, F. E.: Some Vesticular Problems Related to Orientation in Space, Acta Oto-Larynologica, vol. 65, 1968, pp. 174-185.

46. Graybiel, A.; Clark, B.; and Zarriello, J. J.: Observations On Human Subjects Living In A "Slow Rotation Room" For Periods Of Two Days. Archives of Neurology, vol. 3, July 1960, pp. 55-73.

47. Korobkov, A. V.: Problems of Scientific Development of Motor Activity as an Important Principle of the Psychological and Physiological Training of Cosmonauts. (Transl.). Environmental Space Sciences, vol. 3, no. 1, Jan.-Feb. 1969, pp. 1-5.

48. Morey, R. L.: Circadian Rhythms -- Interaction of Endogenous Cycles as Affected by Prolonged Existence in Interplanetary Spacecraft (private circulation).

49. Rummel, J. A.: Circadian Variation in Human Physiological Variables. Biomedical Research Office. Manned Spacecraft Center (Houston, Texas), Document DB 61-67, Dec. 6, 1967.

50. Folk, G. E.: Introduction to Environmental Physiology; Environmental Extremes and Mammalian Survival. Lea and Febiger (Philadelphia, Pa.), 1966, pp. 43-75.

51. Flinn, D. E.; Flyer, E. S.; and Holdrege, F. E., Jr.: Behavioral and Psychological Studies in Aerospace Medicine. Annals of the New York Academy of Sciences, vol. 107, May 22, 1963, pp. 613-634.

52. Frazier, T. W.; Rummel, J. A.; and Lipscomb, H. S.: Circadian Variability in Vigilance Performance. Aerospace Medicine, vol. 39, no. 4, Apr. 1968, pp. 383-395.

53. Adams, O. S.; and Chiles, W. D.: Prolonged Human Performance as a Function of the Work-Rest Cycle. Aerospace Medicine, vol. 34, no. 2, Feb. 1963, pp. 132-138.

54. Chiles, W. D.; Alluisi, E. A.; and Adams, O. S.: Work Schedules and Performance During Confinement. Human Factors, vol. 10, no. 2, Apr. 1968, pp. 143-196.

55. Rummel, J.; Sallin, E.; and Lipscomb, H. S.: Circadian Rhythms in Simulated and Manned Space Flight. Rassegna di Neurologia Vegetativa, vol. 21, 1967, pp. 41-56.

56. Adams, O. S.; and Chiles, W. D.: Human Performance as a Function of the Work-Rest Cycle. TR 60-248. Wright Air Development Division, Wright-Patterson AFB (Ohio), Mar. 1960.

57. Andrezheyuk, N. I.; Veselova, A. A.; Gurovskiy, N. N.; Dushkov, B. A.; Iseyev, L. R.; Kosmolinskiy, F. B.; Kozar', M. I.; Krutova, Ye. M.; and Manovtsev, G. A.: Effects of Different Work and Rest Routines on Subjects Kept in Relative Isolation. (Transl.). Selected Translations From Aerospace Medicine. JPRS 46751, Oct. 28, 1968, pp. 52-63.

58. Seminara, J. L.; and Shavelson, R. J.: Effectiveness of Space Crew Performance Subsequent to Sudden Sleep Arousal. Aerospace Medicine, vol. 40, July 1969, pp. 723-727.

59. Weybrew, B. B.: Psychological and Psychophysiological Effects of Long Periods of Submergence. Analysis of Data Collected During a 265-hour, Completely Submerged, Habitability Cruise Made by the U. S. S. Nautilus. Naval Medical Research Laboratory Report No. 281, Feb. 18, 1957.

60. Fraser, T. M.: Leisure and Recreation in Long-Duration Space Missions. Human Factors, vol. 10, no. 5, Oct. 1968, pp. 483-488.

61. Serxner, J. L.: An Experience in Submarine Psychiatry. American Journal of Psychiatry, vol. 1, July 1968, pp. 25-30.

62. Natani, K.; Shurley, J. T.; Pierce, C. M.; and Brooks, R. E.: Long-Term Changes in Sleep Patterns in Men on the South Polar Plateau. Archives of Internal Medicine, vol. 125, no. 4, Apr. 1970, pp. 655-659.

63. Shurley, J. T.; Pierce, C. M.; Natani, K; and Brooks, R. E.: Sleep and Activity Patterns at South Pole Station. Archives of General Psychiatry, vol. 22, May 1970, pp. 385-389.

64. Rasmussen, J. E.; and Haythorn, W. W.: Selection and Effectiveness Considerations Arising From Enforced Confinement of Small Groups. Paper presented at Second Manned Space Flight Meeting, AIAA (Dallas, Tex.), 1963.

65. Gunderson, E. K.: Mental Health Problems in Antarctica. Archives of Environmental Health, vol. 17, Oct. 1968, pp. 558-564.

66. Cramer, E. H.; and Flinn, D. E.: Psychiatric Aspects of the SAM Two-Man Space Cabin Simulator. SAM TDR 63-27, Sept. 1963.

67. Maulsby, R. L.: Electroencephalogram During Orbital Flight. Aerospace Medicine, vol. 37, no. 10, Oct. 1966, pp. 1022-1026.

68. Walter, D. O.; Kado, R. T.; Rhodes, J. M.; and Adey, W. R.: Electroencephalographic Baselines in Astronaut Candidates Estimated by Computation and Pattern Recognition Techniques. Aerospace Medicine, vol. 38, no. 4, April 1967, pp. 371-379.

69. Pope, F. E.; and Rogers, T. A.: Some Psychiatric Aspects of an Arctic Survival Experiment. Journal of Nervous and Mental Disease, vol. 146, no. 6, 1968, pp. 433-445.

70. Smith, W. M.: Observations Over the Lifetime of a Small Isolated Group. Psychological Reports, vol. 19, Oct. 1966, pp. 475-514.

71. Kinsey, J. L.: Psychological Aspects of the "Nautilus" Transpolar Cruise. U. S. Armed Forces Medical Journal, vol. X, 1959, pp. 451-462.

72. Weybrew, B. B.: Psychological Problems of Prolonged Marine Submergence. Unusual Environments and Human Behavior. N. E. Burns, ed. Free Press of Glencoe (London), 1963.

73. Ferguson, M. J.: Use of the Ben Franklin Submersible as a Space Station Analog, Vol. I. Summary Technical Report, OSR-70-4, NAS 8-30172, 1970.

74. Ruff, G. E.; Levy, E. Z.; and Thaler, V. H.: Studies of Isolation and Confinement. Aerospace Medicine, vol. 30, no. 10, Aug. 1959, pp. 599-604.

75. Dushkov, B. A.; Znachko, V. A.; Kozar', M. I.; Kosmolinskiy, F. P.; and Zolotukhin, A. N.: Functional Changes in Chamber Tests. (Transl.). Selected Translations From Aerospace Medicine. V. V. Parin and I. M. Khazen, eds. JPRS 46751, Oct. 28, 1968, pp. 64-72.

76. Burnazyan, A. I.; Parin, V. V.; Nefedov, Yu. G.; Adomovich, B. A.; Maksimov, S. B.; Gol'dshvend, B. L.; Samsonov, N. M.; and Kirikov, G. N.: Year-Long Bioengineering Experiment in a Ground Complex of Life-Support Systems. (Transl.). Environmental Space Sciences, vol. 3, no. 1, Jan.-Feb. 1969, pp. 6-14.

77. Wise, H. G., Jr.: Analysis of Anticipated Problems, Effects of Confinement of Long Duration Manned Space Flights. Paper presented at NASA Symposium, Part 2. Nov. 17, 1966.

78. Rohrer, J. H.: Interpersonal Relationships in Isolated Small Groups. Symposium on Psychophysiological Aspects of Space Flight. B. E. Flaherty, ed. Columbia Univ. Press, 1961, pp. 263-271.

79. Rohrer, J. H.: Some Impressions of Psychic Adjustment to Polar Isolation. Bureau of Medicine and Surgery, U.S. Navy (Washington, D.C.), 1958.

80. Gurovskiy, N. N.: Several Peculiarities in Work Activities of Astronauts on Prolonged Space Flight. (Transl.). Studies on the Psychophysiology of the Work of Astronauts. N. N. Gurovskiy, ed., NASA TT F-593, Mar. 1970.

81. Nowlis, D.: Preliminary Observations on Leisure Time, Tektite II Habitability Assessment Program. NAS 8-25100, 1970.

82. Eddowes, E. E.: Survey of Leisure Time Activity -- Implications For the Design of a Space Vehicle. Aerospace Medicine, vol. 32, June 1961, pp. 541-544.

83. Solomon, P.; and Patch, V. D.: Handbook of Psychiatry. Lange Medical Publications (San Francisco, Calif.), 1969.

84. Hartman, B. C.; and Flinn, D. E.: Crew Structure in Future Space Missions. Lectures in Aerospace Medicine, Brooks AFB, Feb. 3-7, 1964, pp. 50-72.

85. Pearlman, C. A., Jr.: Separation Reactions of Married Women. American Journal of Psychiatry, vol. 126, no. 7, Jan. 1970, pp. 946-950.

86. Isay, R. A.: The Submariners' Wives Syndrome. Psychiatric Quarterly 42, 1968, pp. 647-652.

87. Nowlis, D.: Preliminary Review of Correlations Between Measures, Tektite II Habitability Assessment Program. NAS 8-25100 (private collection), 1970.

88. Haythorn, W. W.; and Altman, I.: Alone Together. Research task MR 022 01 03-1002. Bureau of Medicine and Surgery, Navy Department, 1963.

89. Flinn, D. E.; Hartman, B. O.; Powell, D. H.; and McKenzie, R. E.: Psychiatric and Psychological Evaluation. Aerospace Evaluation for Space Pilots, L. E. Lamb, ed. USAF School of Aerospace Medicine, AFSC, Brooks AFB, July 1963.

90. Gagarin, Y.; and Lebedev, V.: Survival in Space. Bantam Books, Inc., 1969

91. Flinn, D. E.; Hartman, B. O.; and Flaherty, B. E.: Management of Psychiatric Patients During Air Evacuation: A Study of Three Commonly Used Drugs. Aerospace Medicine, vol. 35, no. 12, Dec. 1964, pp. 1133-1140.

92. Parin, V. V.; Vinogradov, V. M; and Razumeev, A. N., eds.: Problems in Space Pharmaecology. Environmental Space Sciences (Translation), vol. 3, no. 1, Jan.-Feb. 1969, pp. 15-25.

93. Flinn, D. E.: Functional States of Altered Awareness During Flight. Aerospace Medicine, vol. 36, no. 6, June 1965, pp. 537-544.

94. Bales, R. F.; and Borgotta, E. F.: Size of Group As a Factor in the Interaction Profile. Small Groups. A. P. Hare, Borgotta and Bales, eds., Knopf and Company, revised ed. (New York), 1966.

95. Mann, R. D.: A Review of the Relationship Between Personality and Performance in Small Groups. Psychological Review, vol. 56, 1959, pp. 241-270.

96. Anon.: One Woman in Space. Nature, vol. 226, Apr. 11, 1970, pp. 98-99.

97. Cameron, R. G.: Effect of Flying on the Menstrual Functions of Air Hostesses. Aerospace Medicine, vol. 40, no. 9, Sept. 1969, pp. 1020-1023.

98. Link, M. M.: Space Medicine in Project Mercury. NASA SP-4003, 1965.