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LECTURES IN AEROSPACE MEDICINE  
EXPERIMENTAL APPROACH TO THE PSYCHO-  
PHYSIOLOGICAL PROBLEM OF MANNED SPACE FLIGHT

Presented By

Bryce O. Hartman, Ph.D

Chief, Psychology Section

Neuropsychiatry Branch

School of Aviation Medicine

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PROBLEMS OF MANNED SPACE FLIGHT

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In less than a decade, manned space flight has become a significant problem area for aviation medicine. The magnitude and multiplicity of the obstacles to putting man into space have led to the establishment of major research programs in space medicine. Staffing at the School of Aviation Medicine is in accordance with the team concept, and centers around a core of specialists in Aviation Medicine and aviation physiology, supported by physical, biological and behavioral scientists. Each problem is approached from the multi-discipline point of view. The extent of the participation of the various elements of the team is dependent on the nature of the problem and the applicability of existing scientific knowledge. As a result, each discipline participates in several different programs in varying degree.

To the outside observer, the resulting interwoven activity might appear like a tangled hank of yarn. This is not the case. Unifying concepts have evolved which provide an operating philosophy and some guide lines for organizing elements into effective working groups. Figure 1 illustrates the approach. In figure 1, I have modified a composite graph which originally summarized the effects of relative humidity and temperature (wet and dry bulb) on human behavior. We shall not be concerned with the specifics of this problem. Rather we shall use the figure to demonstrate that various combinations of physical and environmental stressors yield an area within which man as a biological specimen survives and functions.

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I want to use figure 1 not only to illustrate the organizing concepts, but also to demonstrate the role of psychophysiology in the problems of space medicine. A definition of psychophysiology is in order at this point. Psychophysiology is, in a general sense, a wedding of the physiologist at one end and the experimental psychologist at the other. It focuses on molar behavior at all levels, with less attention on further breakdowns to specific systems or the analysis of specific mechanisms. It's areas range from studies of skill, proficiency, and reliability (or resistance to decrement in performance) at one end, to the analysis of gross aspects of sleep and gross arousal levels measured bioelectrically at the other. As the activities in our psychophysiological program are described, this definition will become more specific. Let us turn now to an analysis of the concept illustrated in the graph.

In this discussion, survival is the first key word. The limits--the boundaries of the area in figure 1--can be considered to be finite and unequivocal. The man survives, or he dies. The second key word is functions. This is neither finite nor unequivocal. The functions we are talking about range all the way from the man close to the survival limits in our graph who is still alive but is non-functional, to the man in the center who is not only alive, but is also comfortable, effective, and capable of performing the most complex kinds of tasks.

First, let us see where we stand now. In terms of the current state of the art, in space medicine as well as space technology, the problems of

putting man into space are primarily physiological. The major practical problem of space medicine today is to produce a habitable micro-environment, and to extend the habitability of this micro-environment for increasing periods of time. Until this habitable environment is achieved, the behavioral scientist must work on very general problems, and can contribute little to the solution of specific problems in any specific weapons system. For relatively short periods, we have already achieved a useable micro-environment. Longer periods involve extended on-board logistical support, more complex vehicle construction, and increasing significance of environmental and physical stressors previously of little importance, all interacting in a complex fashion.

Once survival is achieved, space medicine moves into a graded series of problem areas. These are shown in general form in figure 1. The outer boundaries constitute the survival envelope. Minimum survivability, the zone adjacent to the survival envelope, involves major physiological problems. These focus primarily upon survival without damage to the occupant. In fact, the problems here might be considered more biological than physiological.

A little farther in are problems concerned largely with survival without cost to the occupant, irreversible damage now having been eliminated from consideration. In this zone, we become concerned not only with cost, but also with the ability of the occupant to function in some gross sense. For the first time, psychophysiology has a specific contribution to make. In

this zone, the psychophysicologist can support the physiologist in his assessment of the effectiveness with which gross functions are carried out. The role of psychophysiology is, however, supporting and secondary.

As we move inward toward the core of the survival envelope, we enter the zone where psychophysiology plays a major role. Problems in this area require the participation of the physiologist and psychophysicologist in the true sense of joint participation, each contributing equally to the assessment of problems. In this zone, the man now begins to perform functions which make a measurable though low order contribution to overall system performance. Problems in this area still require the assessment of cost to the occupant, but now the cost arises from the functions assigned to the man rather than from the effort of combating the environmental and physical stressors.

Finally, we move into the core. Here, man makes significant contributions to system performance. Successful completion of the mission is not possible without effective performance on his part. His higher-order capabilities are exploited as fully as possible. Problems of his proficiency (skill) and reliability become paramount. Psychophysiology becomes primary and the other disciplines take a supporting role.

This schema for an integrated team approach is straight-forward for space medicine. It provides an orderly progression to the steps for solving problems of putting man into space. But when we turn our attention to specific manned space weapons systems, we run into a complication. The designers

14

and engineers for these weapons systems are concerned with very functional kinds of questions. They are not content with survival without damage, or without cost. They want answers couched in terms of proficiency and reliability. Their requirements force us to plunge directly toward the core of the survival envelope, despite lamentable gaps in the literature and a distressing paucity of information on what man is going to do in the significant systems role he is being given. Our problem is to make this plunge with as few errors as possible.

This, then, gives a general picture of the framework within which the psychophysiological problems of manned space flight are approached. In the remainder of this paper, I will describe the work which we have been doing. Three major areas will be discussed: Our participation in the weightlessness problem, in the Space Cabin Simulator program, and in the analysis of dynamic behavior in the space cabin environment. In limiting my presentation to the psychophysiological program being carried out at the School of Aviation Medicine, I do not mean to imply that there are not other programs of significance. Other agencies, such as WADD, the Naval School of Aviation Medicine, and the centrifuge facility at Johnsville, are making valuable contributions to the problems of putting man into space.

#### Psycho-biological Aspects of Weightlessness

Weightlessness is one of the major psycho-biological problems of manned space flight. Survival, as such, is probably not a significant aspect of

prolonged weightlessness. In terms of our conceptual schema, however, the ability of man to function, even in a crude way, is most certainly questionable. The effects of prolonged exposure to the zero-G environment have proved to be exceptionally difficult to study. No techniques for producing prolonged periods of true weightlessness have been developed. Centrifuges have been of very limited value. The use of elevators and parachute drops has also been suggested, but such technique produced the weightless state for only a few seconds at a time. Flying an aircraft through a Keplerian trajectory has become a standard technique for producing longer periods of weightlessness. Weightless states on the order of a minute can be obtained by this technique, but it is apparent that this is far short of an effective procedure for analyzing prolonged periods of weightlessness.

The School of Aviation Medicine has made many valuable contributions to the evaluation of the problems created by weightlessness. Theoretical analyses have been made by Strughold (17, 18), Ritter and Gerathewohl (16), Haber and Haber (9), Haber (10), Gerathewohl, Ritter and Stallings (2), Haber and Gerathewohl (11), and Lamb (14). Using the Keplerian trajectory, a variety of physiological, functional and psychological changes have been studied experimentally. Ward, Hawkins, Stallings have studied problems of micturation (19) and nourishment (20). Hawkins (13) has used the Keplerian trajectory as a means of familiarizing the Mercury Astronauts with the experience of weightlessness. Gerathewohl (3, 4, 5, 6, 7) has studied several psychological aspects. The studies involving short periods of weightlessness can be

summarized as follows: (a) Many biological functions, such as eating and micturation, present problems, but these problems can be solved; many psychological functions, such as visual perception and motor coordination, will suffer some minor impairment, but the decrement is far from significant and the astronaut can compensate for the losses. This optimistic point of view must be tempered by the potential effects of prolonged exposure, which the theoretical analyses cited earlier have isolated as major obstacles. For example, we might assume that weightlessness will pose no special performance problems for the astronauts. At the present time, this is only an assumption. But these earlier papers do provide us with a jumping off point for other studies.

We must continue to be concerned over the effects associated with long periods in the weightless state. Gerathewohl (8) in an excellent review of the physics of weightlessness and the history of research on the problem, emphasized that prolonged weightless will produce major changes in the astronaut. He suggested that man will be able to tolerate prolonged exposure, but that this is not the problem. The real difficulty will be his ability to readjust to the one-G state upon return. He felt that the physiological effects (as in circulation, digestion, and muscular function) of returning to the normal gravity environment will involve major disturbances. He pointed out that the astronaut's job will be largely an "automatic, push-button affair" and that only on re-entry will skill be required. It is precisely at this point, however, that major physiological disturbances (and

concomitant performance disruptions) will occur.

Getting at the problems of prolonged exposure is exceptionally difficult. Earth-bound researchers have been limited by their inability to produce prolonged periods of weightlessness. Brief periods of zero-gravity produced by aircraft flying a Keplerian trajectory give us only a peek at many of the problems. Water immersion is one technique for partially simulating prolonged weightlessness. It creates many of the effects of weightlessness, particularly with respect to the musculo-skeletal and cardiovascular systems. In particular, in the hypodynamic environment, as in the zero-G environment, considerably less work is performed in carrying out a variety of functions.

Early this year we carried out an exploratory study in collaboration with the Space Medicine Department on the effects of prolonged weightlessness using the water immersion or hypodynamic technique. Because the problem is basically biological, the primary experimental procedures were physiological and medical. Work capacity, for example, was measured by the treadmill test developed by Dr. Bruno Balke during the many years he was here at the School. But losses in work capacity cannot be directly translated into decrements in the ability of a man to perform assigned operations in a functional space vehicle. Therefore, psychological tasks requiring psychomotor performance like that which might be required of an astronaut were added to the behaviors being studied. In addition, since sleep requirements in prolonged weightlessness are of concern, sleep behavior as measured by

EEG was added to the study. We ended up, then, with a team from medicine, physiology, and psychophysiology, exactly as one would predict from the concept presented in my introduction.

The study required six weeks to complete. The schedule is shown in figure 2. The subject spent the first ten days adjusting to a special diet selected to minimize the disposal of feces and to provide a known nutritional intake. From day 11 through 27 a series of metabolic and functional tests were carried out to establish baselines. This period included a 50-hour trial run of immersion. After recovery from the trial immersion, a period of seven days was spent in the tank. Pre-immersion, post-immersion, and recovery measures were obtained for all procedures.

The device used to produce the hypodynamic environment was a water-filled tank, shown in figure 3. A stable platform for the subject was provided by a contoured couch. Water temperature was maintained at 33°C by a heater. Psychomotor tasks were placed in a console installed on top of the tank. A regular schedule of eating, sleeping, performing the psychomotor tasks, and taking physiological measurements was followed. Included in this schedule was one hour each day out of the tank for a clinical evaluation and skin hygiene.

The results have been reported in three SAM papers. Graveline and Balke (1) obtained pronounced functional deterioration. Cardiovascular reflexes were severely disturbed and muscle tone diminished. There were marked deviations in blood and urine biochemistry. In the psychomotor area,

we (12) obtained systematic though minor changes in performance during immersion and gross disruptions in psychomotor behavior upon return to the normal one-G environment. The results on sleep behavior (15) were extremely interesting. First, there was a marked reduction in the amount of sleep needed. The subject, who normally sleeps a full eight-hour night, required less than four hours. Second, there was a marked constriction in depth of sleep, the most characteristic state being approximately light sleep, from which he could be easily aroused. Despite these marked alterations in sleep behavior, the subject gave every indication of being relaxed and refreshed each morning.

In terms of the practical problems of manned space flight, the study provided several different kinds of information. First, both in terms of psychomotor proficiency and physiological functions, the subject tolerated this quasi-weightless state very well. This finding agrees with results obtained from brief periods of weightlessness. Second, gradual and progressive alterations in physiological functions occurred during prolonged exposure. These culminated in marked intolerance for the normal one-G environment, a condition best characterized as marked debilitation. As a result of this debilitation, there were marked losses in functional capabilities. There was, in other words, marked biological impairment. The gross disruption in psychomotor performance which was obtained after prolonged immersion suggests that the biological impairment may be sufficient to prevent the man from performing meaningful tasks in a space vehicle during re-entry. The

problems of re-entry just described was our third finding. The fourth result, on sleep behavior, strikes a more optimistic note. It appears that sleep will not be the problem which might be anticipated. There may even be some bonuses. Less sleep may be required, which would leave the astronaut free for a longer work day. Furthermore, if the sleep findings can be extended, astronauts may have a reduced susceptibility to fatigue.

These, then, were the findings in our exploratory study. We identified some significant elements of the weightlessness problem and reached some tentative conclusions. The conclusions are testable. They should be examined in a series of studies to follow up the leads in this first look at prolonged weightlessness.

#### Proficiency Aspects of the Space Cabin Simulator Program

The SAM Space Cabin Simulators are the focus of a broad program involving several different elements. Most of these are described by Dr. Billy E. Welch, who is in charge of the program and the simulators. I will not go into these elements, except to point out that one major problem area is that of closed ecological life-support systems and another is that of logistical support requirement for manned space vehicles. The importance of these efforts is obvious. A third element is that of the maintenance of psychomotor proficiency in this simulated space environment for prolonged periods of time. This problem has two aspects. First, factors influencing astronaut proficiency are of interest in and of themselves. Second, changes in proficiency can be valuable adjuncts to evaluating physiological and systems data

obtained directly from the subjects and the simulator. Our contribution to this broad program has been to provide the psychomotor elements.

My group has worked, to this point, only with the two-man simulator. The program with the two-man cabin is an extension of the earlier research with the one-man cabin. In that program, Hauty made explicit the concept of operator reliability, using it as a more operational statement of the problem of the maintenance of proficiency at a level acceptable for over-all systems function. It is obvious that operator reliability has special significance for space flight, because of the extended commitment of the astronaut to the task and that fact that support or relief is feasible only to a minimal degree. Hauty's three years of research focused primarily on fatigue and diurnal variation, backed up by his earlier work on fatigue problems in military aviation. Before describing our own work, let me summarize results from the earlier program.

### Fatigue Effects

Hauty (25) emphasized that the fatigue problem in space flight is complicated by the prolonged commitment of the astronaut to a set of complex functions and by the deleterious effects of loss of sleep. He pointed out that performance deteriorates rapidly in simple tasks requiring detection of single signals. Such simple tasks will obviously be a part of the astronaut's job. He also emphasized the importance of individual differences in susceptibility to fatigue. Additional problems are the cumulative effects,

deleterious subjective changes, and inadequate perception by the operator of the decrement in skills which have occurred.

In a subsequent paper, Hauty (27) further emphasized the differential fatigue effects in different classes of tasks. The operator system in the one-man Space Cabin Simulator, shown in figure 4, required several different kinds of performance. Hauty concluded from his results that tasks based on gross, discrete cues are more resistant to fatigue than tasks based on minute cues, in which vigilance and alertness are important. He stated that vigilance is the function most affected by fatigue, a finding well supported by other research.

In a report on seven-day flights in the SAM Space Cabin (29), Hauty presented data showing that four pilots maintained proficiency within days and across days when following a working schedule of four hours on and four off. In contrast, his data on a series of 30 hour runs requiring continuous work (26) on the same tasks showed progressive decrement. He concluded that human reliability cannot be extended much beyond 20 hours of continuous work and that space flights should be programmed to maintain the most effective phase relationships between man's physiological cycle, the period of operation, and local time. He again emphasized that operator reliability could be improved by reducing the vigilance load.

In another paper based on prolonged runs in the SAM Space Cabin programs, Gerathewohl (21) used Kraepelin's work performance test (addition of digits). Gerathewohl stated that this test is particularly sensitive to

changes in proficiency at a long monotonous task. In contrast to Hauty's results, Gerathewohl found that the volume of work done increased each day, and that errors and corrections also increased. It is apparent that, even in the systems environment, the kind of fatigue effect obtained is dependent on task characteristics.

### Diurnal Effects

Diurnal variation is the other main factor studied in the one-man cabin program. Shifts in proficiency as a function of this cycle are hardly acceptable for space flight. One way around the problem would be to develop techniques for adapting a man to a different cycle matched to the requirements of any specific space mission. But can man be adapted to other schedules? The seven-day runs in the SAM Space Cabin, previously described (29), examined this problem. Instead of the normal schedule of 16 hours of activity and eight hours for sleep, subjects worked on a four-on, four-off schedule. Subjects quickly adapted to this schedule, sleeping part of every rest period both day and night. One subject showed only partial adaptation, sleeping little during the middle rest period, but this subject also had less total sleep than the others. The stability of performance across the three work periods each day was further evidence of effective adaptation. It appeared at this point that the diurnal cycle is easily altered. However, two subsequent runs of 30 hours duration with the subject performing continuously threw a different light on the problem. One run started at 1400 hours. This

run showed an abrupt loss of proficiency during the period normally devoted to sleep. In the other run, started at 0600, no such abrupt loss appeared during the period normally devoted to sleep. Both subjects showed the decrement in performance after 20 hours which has been previously described. Hauty (26) concluded that careful attention must be given to diurnal variation. Specifically, it appears that short space flights involving continuous work by the astronaut should be initiated at a point in the day where diurnal effects will be minimized.

In the one-man cabin studies, then, both factors were shown to be significant variables under certain special circumstances. Fatigue appears to be the more important of the two. Continuous performance is the key condition under which fatigue is an important problem. The diurnal cycle seems to be less of a problem. Again, the short flights requiring continuous performance require special consideration. It appears that diurnal effects on operator reliability can be minimized with relatively simple procedures, at least in terms of proficiency effects, and sleep schedules. These conclusions are subject to modification. Prolonged weightlessness may alter the long-term effects considerably.

#### Two-Man Cabin Program

The two-man cabin involves more than just a continuation of the one-man cabin program. First, and most obvious, it provides for two subjects, or even three under certain conditions. Second, it involves major advances in the closed ecological life-support area, including waste disposal and water recycling. Furthermore, the ecological aspects are more nearly "on-board."

Third, there are major advances in the logistical area, again including more "on-board" support features. And fourth, there is significant improvement in the operator task, or psychomotor apparatus. The apparatus contains many more elements, each of which is more "operationalized" to improve subject acceptance and face validity. It also has the capability of imposing a greater work load on the operator, which improves its sensitivity to the many functions being studied. The apparatus was developed by Hauty, who utilized some of the tasks and concepts which we have developed in our research on man as a systems operator as well as his own analysis of the astronaut's job. This last point is important. The astronaut is not going to be a space vehicle "pilot." He is going to function as the operator of a complex, semi-automatic system in a manner much like operators of many other advanced weapons systems.

The simulator imposes three broad categories of requirements on the subjects--management of the logistical aspects of simulated space flight (disposal of wastes, recycling of fluids, preparation of foods, etc.) management of the internal environment (control of atmospheric contaminants, etc., achieved through an environmental control panel in parallel with a similar system external to the cabin), and management of the operator system. While both the logistical and environmental functions involve a broad kind of proficiency, no attempt has been made to this point to evaluate operator effectiveness in these areas. Rather, an over-all evaluation of the simulator and its various sub-systems will be obtained for these functions. In contrast,

the operator system has no direct effect upon over-all system efficiency. It is, in effect, a completely independent sub-system, and has as its sole purpose the evaluation of the functional effectiveness of the men in the system during the flight. The remainder of this section will be concerned exclusively with the operator system.

Description of the Operator System

The operator system consists of six units: the master programmer, which programs and selects signals in the several tasks which the operator must perform, an assembly of sub-programmers which operate these tasks, two parallel display units, one inside the cabin at the operator's station and one outside for monitoring the system, an assembly of controls inside the cabin for performing the tasks, and a recording unit which gives a time history of performance and a measurement of response time for each signal displayed to the operator.

So far as the subjects are concerned, only the displays and controls inside the cabin are relevant. These are mounted in panels (shown in figure 5) on the left half of the operator's station, the right half being occupied by meters and controls for the environmental control system. The displays are scattered across three panels and are predominantly visual, only one task using an auditory signal (Morse Code). There are a variety of visual displays, including different types of meters and lights, in addition to one task presenting pairs of block-design patterns by closed-circuit TV. The controls are located on the two sides of the lower panel, and are either

lever-type or push-button switches. Compatibility of each set of controls and displays is achieved by location on the panel, the physical management of homogenous groups of controls, color-coding, and variations in operation and appearance for each task. A total of 14 tasks are in the system. The net effect of assembling a variety of tasks in one unit for one operator to perform is to produce a simulated systems task which is, in our nomenclature, multivariate.

In operation, most signals appear at the operator's station at regular intervals (72 seconds) but in varying combinations. Two tasks follow a different schedule in that the auditory task presents a new signal every five minutes and the matching task presented on a TV screen is on continuously and requires constant monitoring. All but the matching task have but one mode of operation--the programmer turns the tasks "on," and they stay on till the operator turns them "off." Time "on" for each signal is the measure of proficiency.

Signal rate (number of signals per unit of time) is a basic variable in systems tasks such as these. The operator system has three basic speeds built into the programmer. Twelve of the 14 tasks can be set at any of the three speeds; each independently of the other. Because of this feature, signal rate can be varied from 175 events (signals) to 350 per hour. By turning some tasks off, even lower signal rates can be obtained. The addition of signal rate permitted us to study a new variable in the program--work load. Work load is a factor effecting operator reliability, but in an instantaneous way

rather than in terms of long-term, cumulative effects like those seen in fatigue. The significance of short-term factors in operator reliability was discussed in my paper at the recent symposium on "The Psychophysiological Aspects of Space Flight" (22).

In order to give the subjects motivation and a frame of reference for operating the system, the tasks were given descriptive names and functions simulating those which man in space might be expected to perform. The tasks were conceptually assembled into four functional areas. The first was the Navigation and Orbital Flight Computer system which simulated the tasks of feeding position information via a polar-equatorial grid system into an airborne computer and monitoring a flight control servo system for controlling vehicle orientation. This system consisted of the "Polar and Equatorial Matrices," the "Gyro-Servo Sensors" and corresponding controls. The second area was the Airborne Radar and Doppler Position System (ARAD) which simulated operator tasks involving the continuous monitoring of a radar-type scope and position identification via auditory signals. This display involved the "ARAD Scope" and controls and a "UHF Code Panel." The third area of function was that of problem solving and decision making. Here the operator monitored a simulated Nuclear Power Control System via a display called "Reactor Control Monitors." This required him to override a machine system by solving simple problems in Boolean algebra using the "Reactor Servo" controls. The fourth area was that of monitoring displays and manipulating controls simulating a Data Telemetry System for gathering, encoding

and transmitting scientific data to ground-based stations upon command. This required simple data processing and differential control functions on the part of the operator. These displays consisted of a "Solar Radiation Monitor" and corresponding "Telemetry Coding" panel and "Radar and Infra-Red Lock-On" with related controls. An operating manual which elaborated on these names and functions, and which instructed the subjects on how the tasks were to be performed, was written. It appeared to have high acceptability for the subjects, and contributed to their motivation.

### The Simulated Mission

Another technique to add realism to the flight and to contribute to the motivation of the subjects was the development of a mission. For the first 30-day flight completed this summer, the following mission was developed. Some constraints in the selection of a "plot" are imposed by certain tasks in the operator system and by other repetitive requirements placed on the subjects, such as reporting periodically to "ground-control." Because of these constraints, we selected an orbital mission, rather than a "lunar probe" for instance. Each orbit was completed in 90 minutes. The repetition of signals and the periodic reports made sense in this frame-work. There were 16 orbits each day, and a total of 475 orbits in 30 days. A schedule was provided for keeping track of their progress day by day in terms of orbits. We hoped that this sort of "progress" would also contribute to

motivation.

### The 30-Day Schedule

The crew structure for this first 30-day run was that of two crewmen serving alternately as the system controller. The schedule which was developed consisted of 15 consecutive two day "packages." This schedule is shown schematically in figure 6. In each two day unit, each operator manned the system ten hours on one day and 12 hours on the alternate day. Each day the system was manned a total of 22 hours, with two one-hour periods (0700-0800 and 2000-2100) of ground control to complete the 24 hour cycle. Each subject manned the operator system for a three-hour work period, (mornings) a two-hour work period, (afternoons) and a five-hour work period (nights) each day. In addition, each subject had another two-hour work period every other day to provide for the rotation of subjects each day. In a two-day unit, each subject was on duty during every one of the 22 hours the system was manned. The long work-periods at night permitted the subjects to sleep as much as six or seven hours at a single stretch each day.

The ground-control hours were not completely free. The auditory task (Telemetry Coding) and matching task (ARAD) remained on, with the correct responses being made by either of the subjects. These hours were considerably less structured in order to provide periods each day when interpersonal behavior could be evaluated in a relatively unstructured setting. Interpersonal behavior was studied as a separate element of the over-all program.

During each ground-control period, the operator system was set to a new speed. Two speeds a day were scheduled. With this schedule, each six days was a "package," and yielded two sets of data for each of three speeds on each operator at each duty period. In 30 days, there were five such "packages."

It might appear, since only one subject manned the operator system at a time, that there was a considerable amount of free time. This was not the case. In addition to the required sleep periods, there were a variety of other duties to be performed, including fixing meals, operating the waste disposal and water-recycling units, checking and calibrating the environmental controls, etc.

#### The Variables Under Study

The psychomotor aspects of this first 30-day flight were under the supervision of Dr. R. E. McKenzie. A variety of variables effecting proficiency at this simulated systems task were under study:

- (1) The effect of prolonged commitment (30 days) of a two-man crew to a systems task under some simulated space flight conditions.
- (2) Duration of the work period. There were two-hour, three-hour, and five-hour periods for this evaluation.
- (3) The effects of differing signal rates, with five six-day units for this.
- (4) Circadian variation. The first two hours of each work period were

used for this evaluation. There was some contamination of this variable by our fixed schedule (i.e., the five-hour work periods always occur at night). Nevertheless, it was possible to at least explore the effects, as a guide to future flights.

(5) The several interactions of these variables.

The performance data from the first 30-day flight are still being analyzed. It appears likely, however, that there are no major differences to any of the variables just listed for either subject, though this should be regarded as a tentative summary only. There are interesting differences in performance for night versus day in the case of both subjects. One was more effective during the afternoon and the other was more effective at night. Because of this difference in the two subjects, however, it is probably not correct to attribute the difference to diurnal variation. A report on this flight will be published this spring (28).

Our general results (no major differences) are like those obtained by Hauty in the seven-day, one-man cabin flights. There are at least two possibilities in these results. The results may be valid because the subjects did not perform continuously in either this run or the earlier seven-day runs. As an alternative, the results are not valid because the operator systems in both simulators were too "tolerant" of operator decrement, i.e., they were too insensitive to changes in proficiency. Furthermore, in our flight the psychomotor work schedule had to be adjusted for time lost in repairing cabin malfunctions, which kept one and sometimes both subjects otherwise

occupied. The two-man cabin operator system is being modified now to permit operator loads which our own systems research (23, 24) have demonstrated to be in excess of the operator's capabilities. This modification will permit us to evaluate the latter possibility. At the moment, however, we have a tentative confirmation of the results of the one-man cabin flights where the operator had a regular schedule of work and rest.

#### Aspects of Dynamic Behavior in the Space Cabin Program

There is another aspect of our participation in the space cabin program which requires separate consideration. This is the study of what might be described as a clinically oriented evaluation of dynamic behavior, as contrasted with the experimentally oriented analysis of operator proficiency discussed in the previous section. For this element of the program, a behavioral science team consisting of clinical psychiatrists and clinical psychologists was assembled. This team had two objectives during the one-man cabin flights: (1) to identify gross changes in dynamic behavior resulting from the flight, using pre- and post-flight psychiatric evaluations and psychological tests; and (b) to evaluate any aberrant behavior which might occur during the flight. The behaviors in this latter objective, which have received the most attention, were the kinds of effects obtained in isolation, confinement, and sensory deprivation studies.

The background for our work in this area is given in a review of sensory deprivation studies by Wheaton (34) in 1958. Wheaton's review ranges from

anecdotal material to laboratory studies, and provides a useful, concise summary of the problem. Let me briefly summarize my point of view on this problem, which I prefer to call "the emotional aspects of unusual environments."

Historically, the current interest in isolation and confinement problems arose during the Korean War. A national concern developed over the behavior of American prisoners-of-war, though much of the information being disseminated at that time has been since demonstrated to be faulty. Again on the basis of basically faulty information, we assumed that one of the techniques used by the captors was a combination of isolation, confinement, and sensory deprivation. A series of laboratory investigations of this unusual environment were initiated, and some most interesting results were obtained. Illusions of all kinds, and losses in a variety of intellectual functions and modes of behavior were reported. In time, it became apparent that the POW problem was not concerned with this unusual environment. However, a most stimulating area of basic research on behavior was under way. It has continued to be a fruitful area for the behavioral scientist.

When the results of these studies are combined with additional information gained from the effects of other unusual environments, such as those which produce the break-off phenomenon (Graybiel), the cataract psychosis (Greenwood), and the respirator psychosis (Mendelson and Foley), a clear picture emerges. This picture can be summarized in four steps. First, in unusual environments, there are emotional responses which occur in perfectly

normal people. Second, these emotional responses can range from minor perceptual aberrations and minor changes in over-all emotional states to extremely dramatic, almost hallucinatory kinds of reactions. Again, we are still talking about perfectly normal people. Third, there need not be any specific physical or environmental stresses involved in these situations. Under stressors, we need to include both external stresses such as alterations in the oxygen content of the air or high heat loads or G forces, and stresses within the organism such as fatigue or some disease process. When these are present, the effects are sometimes more dramatic or more acute, or may appear sooner. Nevertheless, they are not necessary for the occurrence of emotional responses. And fourth, these effects are usually transient, recovery is rapid, and the effects have little bearing on the psychiatric or mental health state of the individual.

What does all this have to do with space flight? It is apparent that, in a space vehicle, we have an environment similar in many ways to the isolation and sensory deprivation situation. Wheaton, in another paper (35), details these similarities, and goes on to emphasize the critical nature of a vehicle malfunction. In that paper, and the one cited earlier (34, 35), he also emphasizes the role of individual personality characteristics in susceptibility to these effects. He points out that the SAM cabin program is an ideal place in which to study these problems. It is these kinds of problems which are being evaluated. One of the problems in this research is that you have to wait for "something" to happen. Fortunately, a variety

of events have occurred.

First, I want to discuss the results of the one-man cabin flights. Only minimal emotional disturbances occurred in the seven-day flights, with one exception. With all subjects, but in varying degrees, there was a gradual build-up in hostility, directed toward the crews outside the cabin. With one subject, the hostility increased to a point where there was a possibility that the flight would have to be terminated. This hostility occurred despite the high motivation of the subjects.

In the 30-hour flights, the results are much more interesting. An intensive evaluation of four such flights have been conducted. Steinkamp and Hauty (33) report that all four subjects experienced aberrations of some kind and in varying degree. They point out that in each case, the experience reduced operator proficiency. This suggests that these events can be a factor in over-all systems reliability. Flaherty, et.al. (30) present a more detailed analysis of the experiences of these four subjects, adding background information and a summary of the pertinent elements of the psychiatric and psychologic evaluation. They point out that illusions which involve plausible elements are a special problem of operator reliability, because the astronaut may regard them as "real" and initiate a course of action disastrous to the vehicle. They emphasize the need for psychological nurturance in the space flight environment. This might be considered to be a requirement for supportive therapy as well as for an environment constructed to keep the astronaut dynamically intact. In effect, what these

runs demonstrate is that these events will occur, and that additional stress (fatigue, in these runs) contributes to the occurrence.

This effort has been continued in the two-man cabin program. In the recent 30-day flight only one illusion was reported by one subject--this illusion being auditory and at a very minor level. Interestingly enough, it occurred while the other subject was asleep, a situation with greater isolation and sensory deprivation than the remainder of the day. The paucity of illusory events might be attributed to the greater psychological reserve of men in the crew situation, (or better psychological nurturance) though such a conclusion is quite premature.

For the two-man cabin program, a new element in the analysis of dynamic behavior has been initiated. Members of a crew interact, and this interaction can effect both operator reliability and system reliability. One of the clinical psychologists in my group has adapted an objective observational technique for scoring interpersonal interaction in the cabin situation. A schedule for systematic observation and scoring was followed, using the Bales Interaction Process Analysis technique. In addition, a pre- and post-flight battery of psychological tests were administered. An unpublished, preliminary report (37) of the results from this first flight has been completed.

This study was directed towards two objectives: (a) the relationship between individual personality characteristics and crew interaction; and (b) personality changes occurring as a result of the stress of the flight. Dr. Hagen, who carried out this part of the program, reached several

conclusions. First, though there were many areas of similarity, the subjects had significant areas of difference in personality. Second, each of the two men contributed unique components to the maintenance of crew equilibrium, and these components were measurable. In particular, they developed adaptive techniques to compensate specifically for their personality differences. Third, the external elements of the situation, the simulator and its malfunctions, the psychomotor apparatus, the regular work schedule and other functional assignments all made major contributions to the maintenance of crew equilibrium. And fourth, both subjects show meaningful changes in personality as a result of the flight. For one subject the changes were small. For the other, the changes were quite large. Several hypotheses can be developed from this first flight. These hypotheses will undergo testing in future flights.

In any event, it is clear that the approach used in the first 30-day run makes a valuable contribution to the analysis of crew problems. It will not really be too long before space medicine will be asked questions about crew structure. Let us hope that, through these studies, it will be possible to give some of the answers.

There is also a bonus from this preliminary study. We had two psychologically different subjects. We got different degrees of change in personality characteristics as a result of the flight. We cannot, of course, label either of these "good" or "bad." But "different" is the first step to demonstrating that personality characteristics are a meaningful part of

selecting astronauts. I'm sure most of us feel this is an obvious truism, but there have been far too few empirical demonstrations of its contribution.

The study of dynamic aspects of behavior is being carried out in anticipation of the time when these problems will assume more immediate importance than they do now. At present, there are more difficult obstacles to manned space flight. It is possible that untoward incidents may occur. There are indications that these can be minimized or treated by rather simple, straightforward procedures. Selection for psychological adaptability for space flight, which has been considered in detail by Flinn (31), may be a greater problem in the future. At the present time, I do not regard it as one of the more significant selection variables. The orientation of this section of the paper reflects these points of view.

#### SUMMARY

In this paper, I have described three major elements in the research on the psychophysiological problems of manned space flight at the School of Aviation Medicine. The unifying concept presented in the introduction provides a structure within which multi-discipline programs can function. Because the concept provides guidelines, each of us knows what kinds of participation are required. More time has been devoted into this paper to how we are approaching the questions than to results. There are still more problems than answers. In the hypodynamic study, for instance, we identified

several significant elements which need to be studied. In the space cabin program, we are making some headway on proficiency problems and on at least two aspects of dynamic behavior.

There is a great deal more work to be done. There are gaps in the problems we have been studying which need to be filled. Exciting projects are on the horizon. In the coming year, we hope to do more on the hypodynamic problem. We are getting under way on a very operationally-oriented program in bioelectrical techniques for assessing the functional state of man in space. We will continue to support the space cabin program. This paper is essentially an optimistic progress report. Next year's progress report should contain more answers and equal optimism.

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#### Proficiency

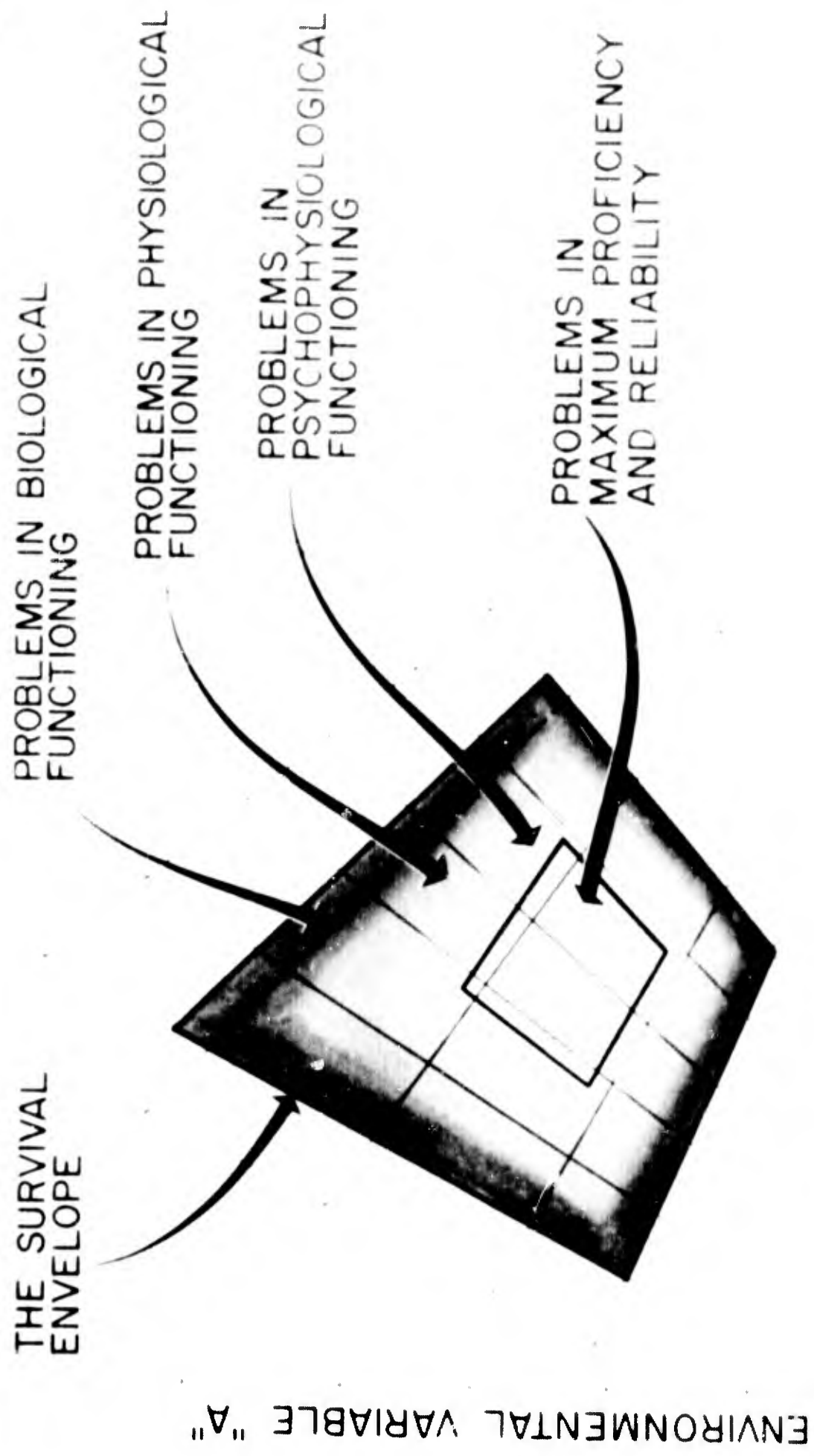
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ENVIRONMENTAL VARIABLE "B"

FIGURE 1

A schema for conceptualizing multi-disciplinary approaches to problems of manned space flight. The interaction of physiology and psychophysiology are illustrated in the concept.

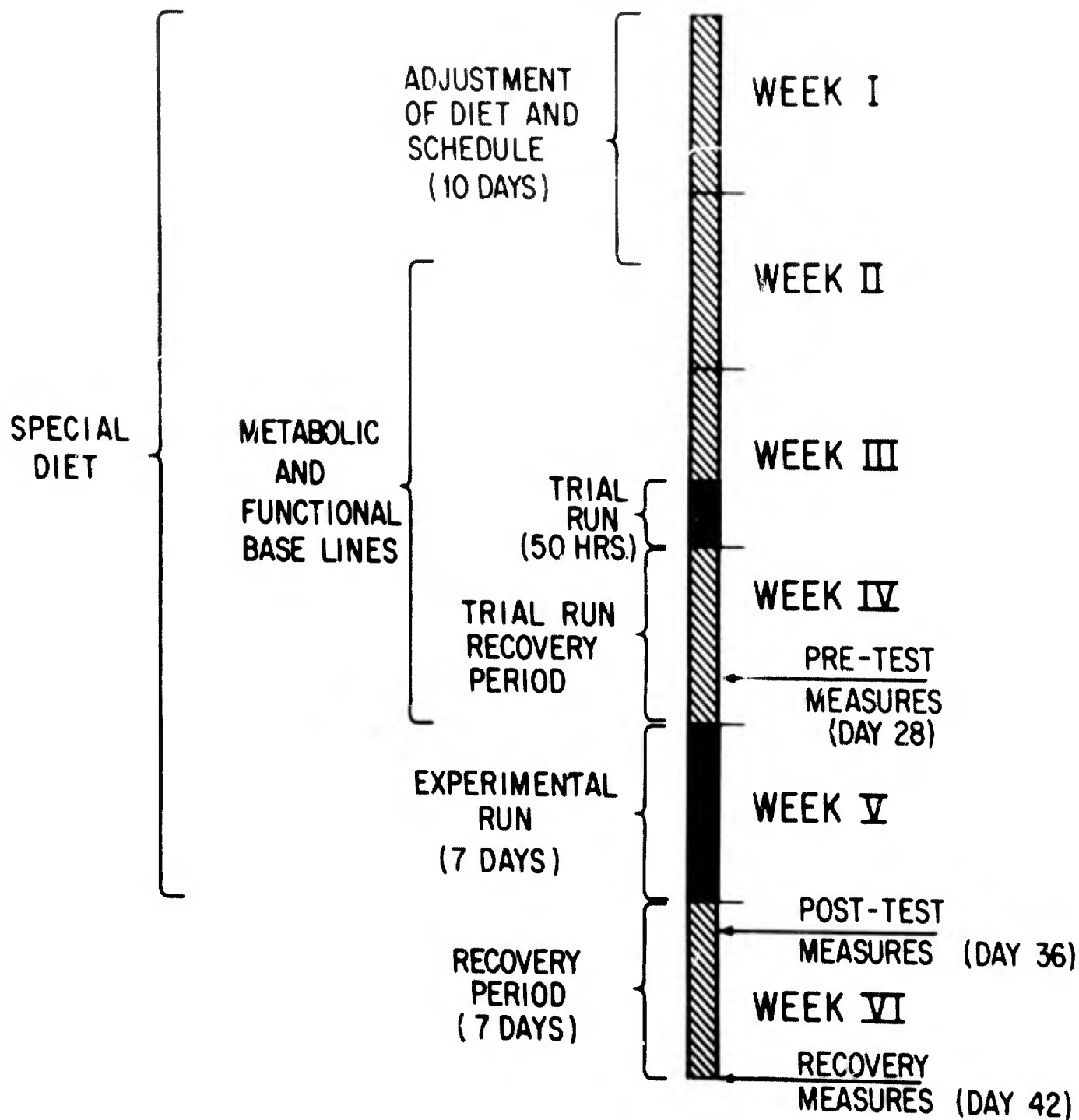


FIGURE 2

Schematic representation of the schedule for the hypodynamic experiment, by weeks. Black areas show periods of immersion.

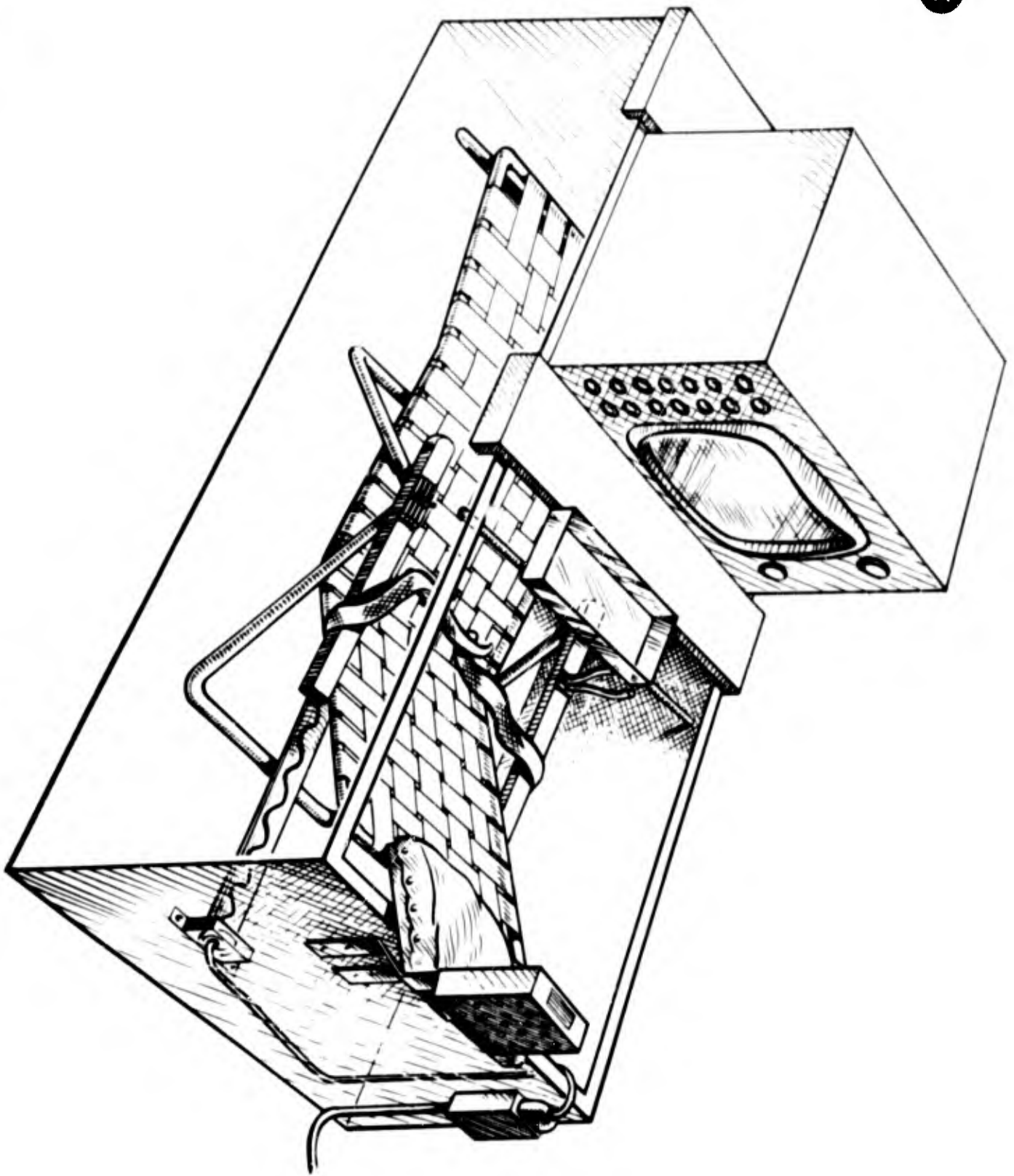


FIGURE 3

Photograph of the immersion tank showing the couch and heater inside, controls for the psychomotor tasks mounted on the couch armrests, and the task console and feeding trays above.

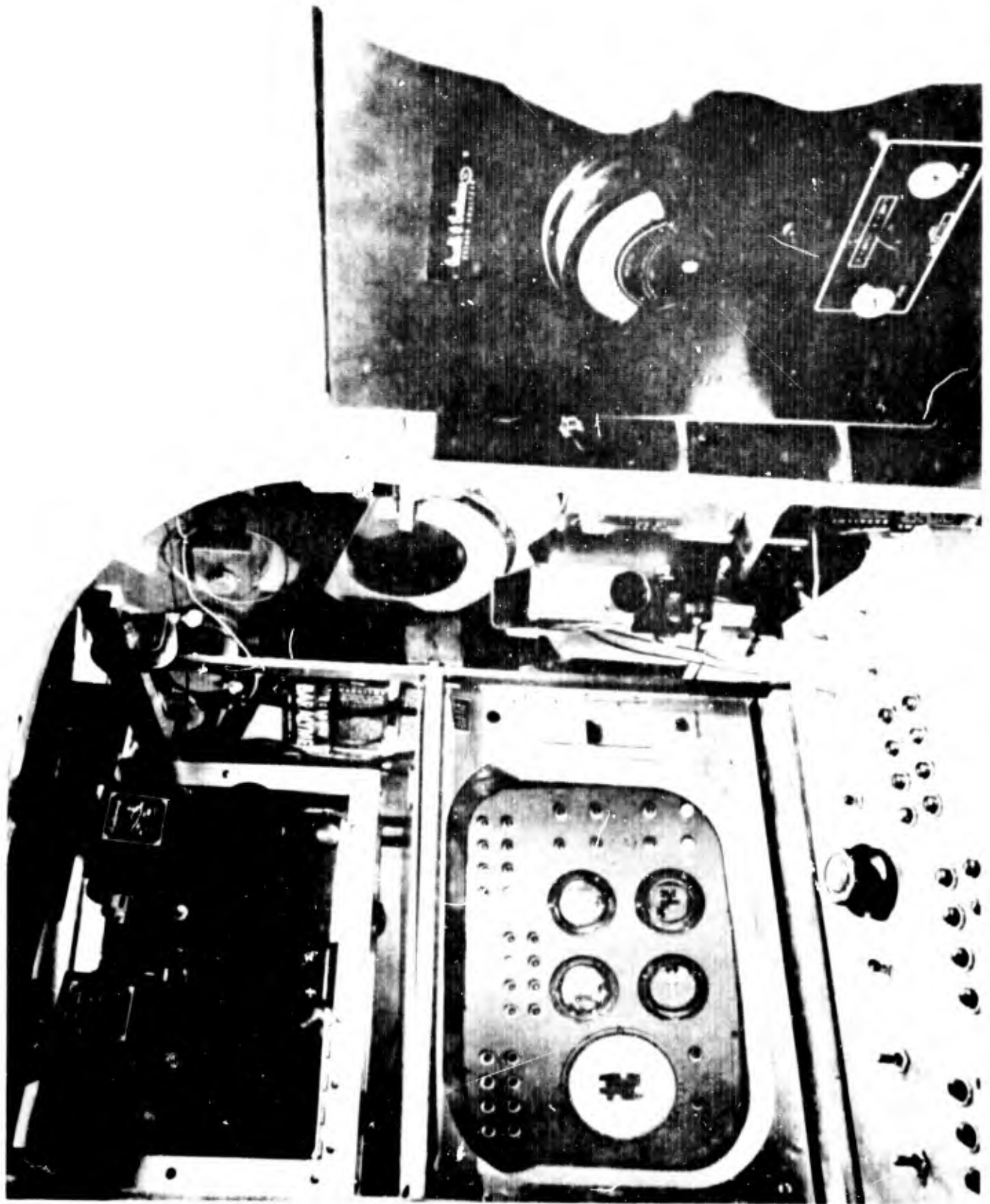


FIGURE 4

Photograph of the operator system in the SAM one-man Space Cabin Simulator. The display was presented by closed circuit TV and is shown above the controls, which were grouped on a sloping panel within arm's length of the subject.

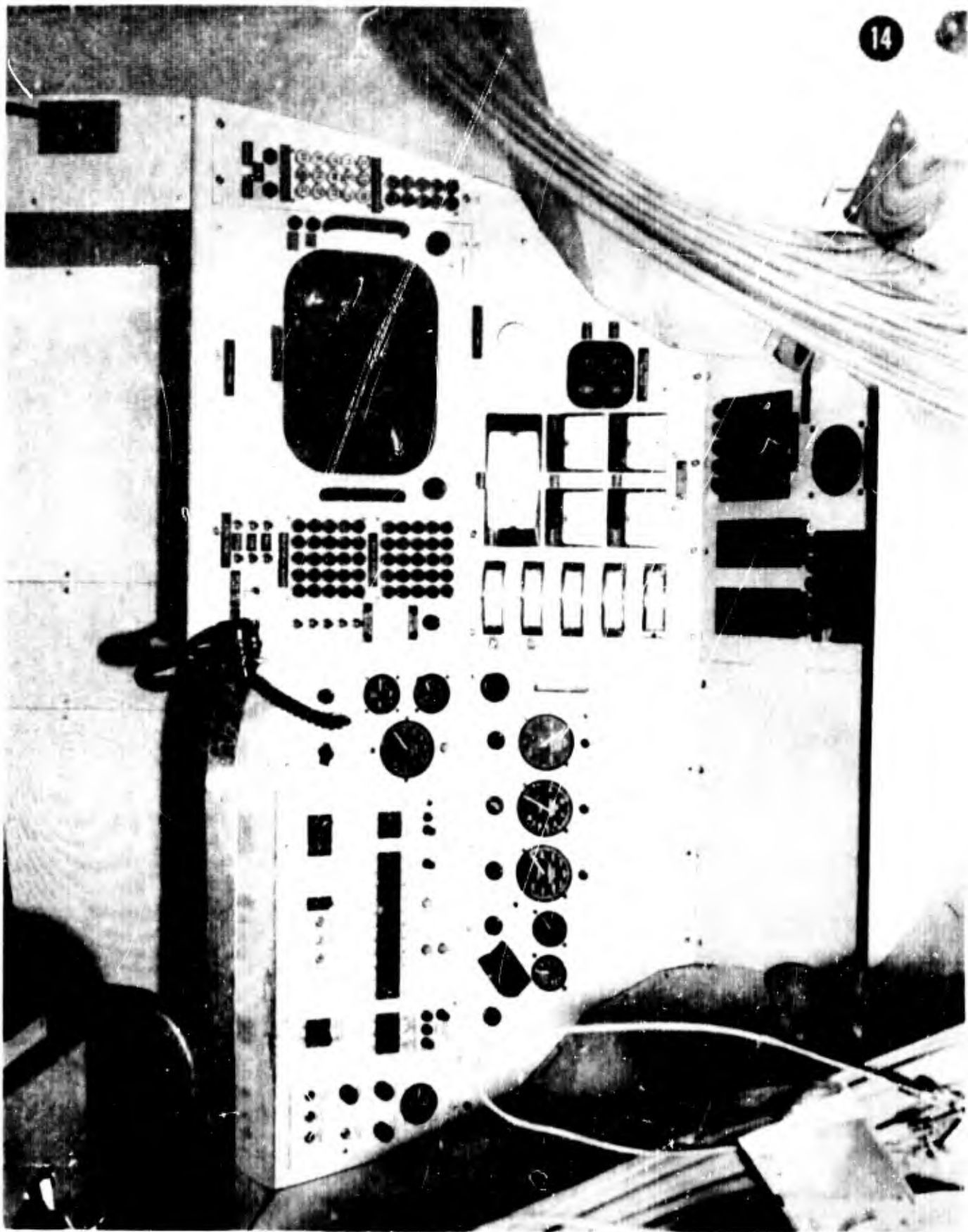


FIGURE 5

Photograph of the operator's station in the SAM two-man Space Cabin Simulator. Displays and controls for the psychomotor system are on the left. Displays and controls for the environmental monitoring and control system are on the right. Though there is space for two men at this station, each system is basically a one-man operation.

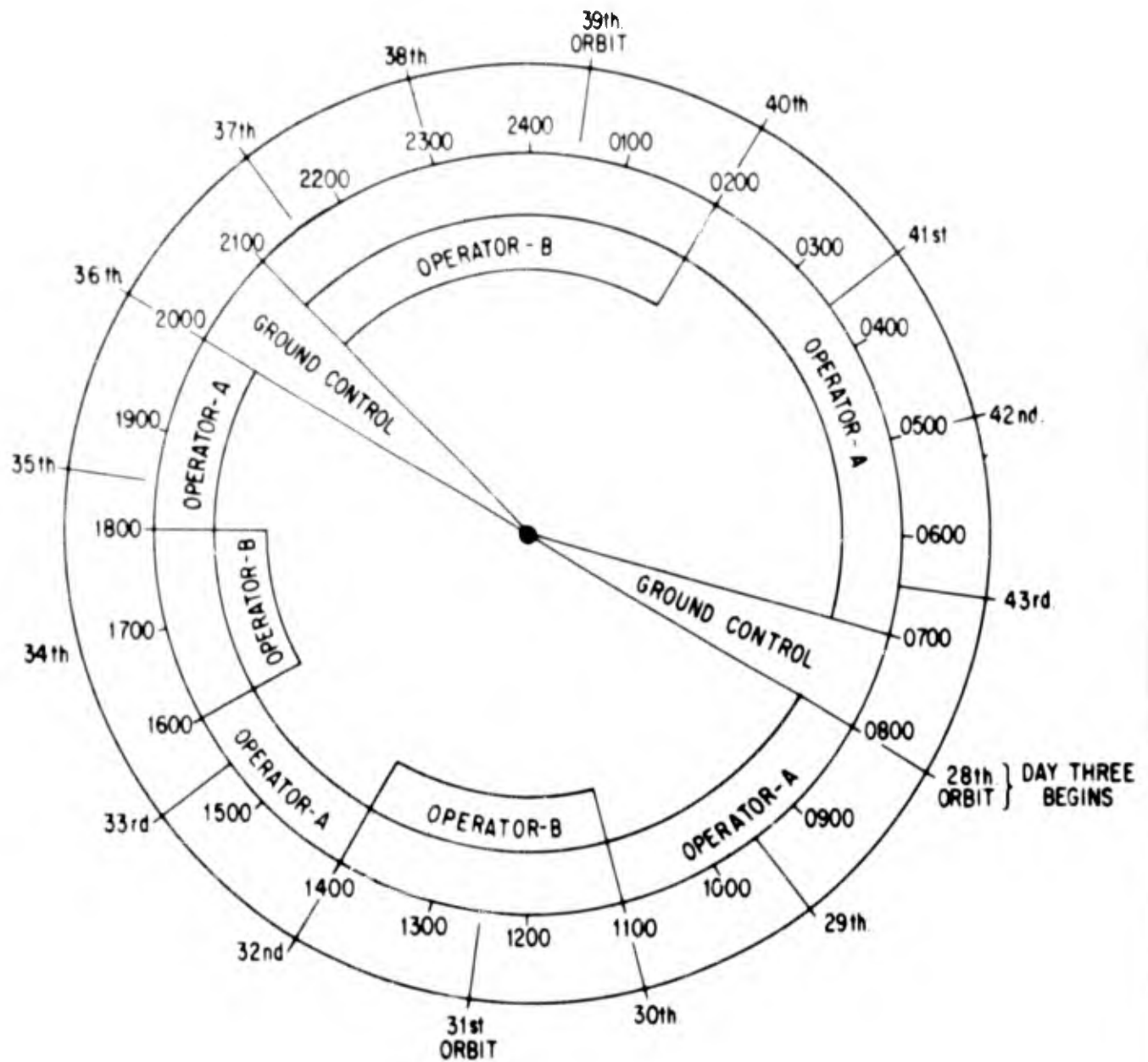


FIGURE 6

Schematic representation of a 24-hour period of the first 30-day flight in the SAM Two-Man Space Cabin Simulator. The work schedules for operator A and B, shown in the inner circles, were reversed on alternate days. Orbits for the simulated mission are also shown. The ground control periods were one-hour blocks when the psychomotor system was unmanned.