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ABSTRACT

Basic knowledge about Skylab experiments is presented in this book for the purpose of informing high school teachers about scientific research performed in orbit and enabling the teachers to broaden their scope of material selection. The seventh volume deals with the ability of the Skylab crew to live and work effectively in space. The content is divided into three sections. The first section is concerned with the methods and techniques of human engineering used to design work spaces, requirements, and tools. The second section is related to performance in a weightless environment, and the third is related to living in space and inflight aerosol analysis. Experiment backgrounds, experimental procedures, scientific objectives, and types of data output are discussed in each section. Student experiments are suggested for their application to classroom activities. Included are a glossary and a selected bibliography. (CC)

Skylab Experiments

Volume 7
Living and Working in Space

Produced by the Skylab Program and NASA's Education Programs Division in Cooperation with the University of Colorado

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C. 20546, May 1973

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PREFACE

Characteristically, new scientific knowledge reaches general application in classrooms years after it has been obtained. This long delay stems, to a large extent, from a lack of awareness that information is available and that it has relevance to secondary school curricula. To accelerate this process, the National Aeronautics and Space Administration has prepared a series of documents concerning Skylab experiments to apprise the educational community in detail of the investigations being conducted in the Skylab Program, and the types of information being produced.

The objective is not to introduce the Skylab Program as a subject in the classroom, but rather to make certain that the educational community is aware of the information being generated and that it will be available for use. Readers are urged to use these books as an aid in planning development of future curriculum supplement material to make the most appropriate use of this source of scientific knowledge.

National Aeronautics and Space Administration
Washington, D. C. 20546
May 1973

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INTRODUCTION

The Skylab Education Program

This year the United States' first manned scientific space station, Skylab, was launched into orbit to be the facility in which successive crews of astronauts can perform more than 270 scientific investigations in a variety of fields of interest. These investigations can be divided into four categories: physical sciences, biomedical sciences, earth applications, and space applications.

The Skylab Program will produce information that will enhance present scientific knowledge and perhaps extend the frontiers of knowledge on subjects ranging from the nature of the universe to the structure of the single human cell. It is the objective of the National Aeronautics and Space Administration that the knowledge derived from the Skylab Program's investigations be made available to the educational community for applications to high school education at the earliest possible date.

For this reason, the Skylab Education Program was created to assure that maximum educational benefits are obtained from the Skylab effort, documentation of Skylab activities is adequately conducted, and understanding of scientific developments is enhanced.

This document, one of several volumes prepared as part of the Skylab Education Program, has the dual purpose of (1) informing high school teachers about the scientific investigations performed in Skylab; and (2) enabling teachers to evaluate the educational benefits the Skylab Program can provide.

These books will define the objectives of each experiment, describe the scientific background on which the experiment is based, outline the experimental procedures, and indicate the types of data anticipated.

In preparing these documents an attempt has been made to illustrate relationships between the planned Skylab investigations and high school science topics. (Refer to Table 1.) Concepts for classroom activities have been included that use specific elements of Skylab science as focal points for demonstrations of selected subjects. In some areas these address current curriculum topics by providing practical applications of relatively familiar, but sometimes abstract principles; in other areas the goal is to provide an introduction to phenomena rarely addressed in high school science curricula.

Table I Related Curriculum Topics

SUBJECT EXPERIMENTS	INDUSTRIAL ARTS—ARCHITECTURE	BIOLOGY	PSYCHOLOGY	PHYSICS
Time and motion study Motor sensory performance		Gravitational effects on coordinated muscle movement	Task time measurement techniques; weightlessness as a stressed condition	Masses in motion
Web formation		Web spinning mechanisms	Spider web patterns	
Habitability/crew quarters Inflight aerosol analysis	Analysis of habitational environments		Perception of comfort	

It is the hope of the National Aeronautics and Space Administration that these volumes will assist the high school teacher in recognizing the educational value of the information resulting from the Skylab Program which is available to all who desire to make use of it.

Application

Readers are asked to evaluate the investigations described herein in terms of the scientific subjects taught in secondary schools. The related curriculum topics identified should serve as suggestions for the application of Skylab Program-generated information to classroom activities. As information becomes available from the Skylab Program, announcements will be distributed to members of the educational community on the NASA Educational Programs Division mailing list. To obtain these announcements send name, title, and full school mailing list (including zip code) to:

National Aeronautics and Space Administration
Washington, D.C. 20546
Mail Code FE

This volume describes a series of experiments being conducted on Skylab that will measure and evaluate the ability of the crew to live and work effectively in space. The methods and techniques of Human Engineering as they relate to the design and evaluation of work spaces, requirements, and tools are described, and the application of these methods and the Skylab measurements to the design of future spacecraft is discussed.

Acknowledgments

Valuable guidance was provided in the area of relevance to high school curricula by Dr. James R. Wailes, Professor of Science Education, School of Education, University of Colorado; assisted by Mr. Kenneth G. Jacknicke, Research Associate on leave from the University of Alberta, Edmonton, Alberta, Canada; Mr Russel Yeany, Jr., Research Associate, on leave from the Armstrong School District, Pennsylvania, and Dr. Harry Herzer and Mr. Duane Houston, Education and Research Foundation, Oklahoma State University.

The Skylab Program

The Skylab orbiting space station will serve as a workshop and living quarters for astronauts as they perform investigations in the following broad categories: physical sciences, biomedical sciences, Earth applications, and space applications.

The spacecraft will remain operational for an eight-month period, manned on three occasions and unmanned during intervening periods of operation. Each manned flight will have a crew of three different astronauts. The three flights are planned for durations of one month, two months, and two months, respectively.

A summary of objectives of each of the categories of investigation follows.

Physical Science

Observations free of filtering and obscuring effects of the Earth's atmosphere will be performed to increase man's knowledge of (1) the sun and of its importance to Earth and mankind, and (2) the radiation and particulate environment in near-Earth space and the sources from which these phenomena emanate.

Biomedical Science

Observations under conditions different from those on Earth will be made to increase man's knowledge of the biological functions of living organisms, and of the capabilities of man to live and work for prolonged periods in the orbital environment.

Earth Applications

Techniques will be developed for observing from space and interpreting (1) Earth phenomena in the areas of agriculture, forestry, geology, geography, air and water pollution, land use and meteorology, and (2) the influence of man on these elements.

Space Applications

Techniques for adapting to and using the unique properties of space flight will be developed.

The Skylab Spacecraft

The Skylab cluster contains five modules (see illustration).

1) The *orbital workshop* is the prime living and working area for the Skylab crews. It contains living and sleeping quarters, food preparation and eating areas, and personal hygiene equipment. It also contains the equipment for the biomedical science experiments and for some of the physical science and space applications experiments. Solar arrays for generation of electrical power are mounted outside this module.

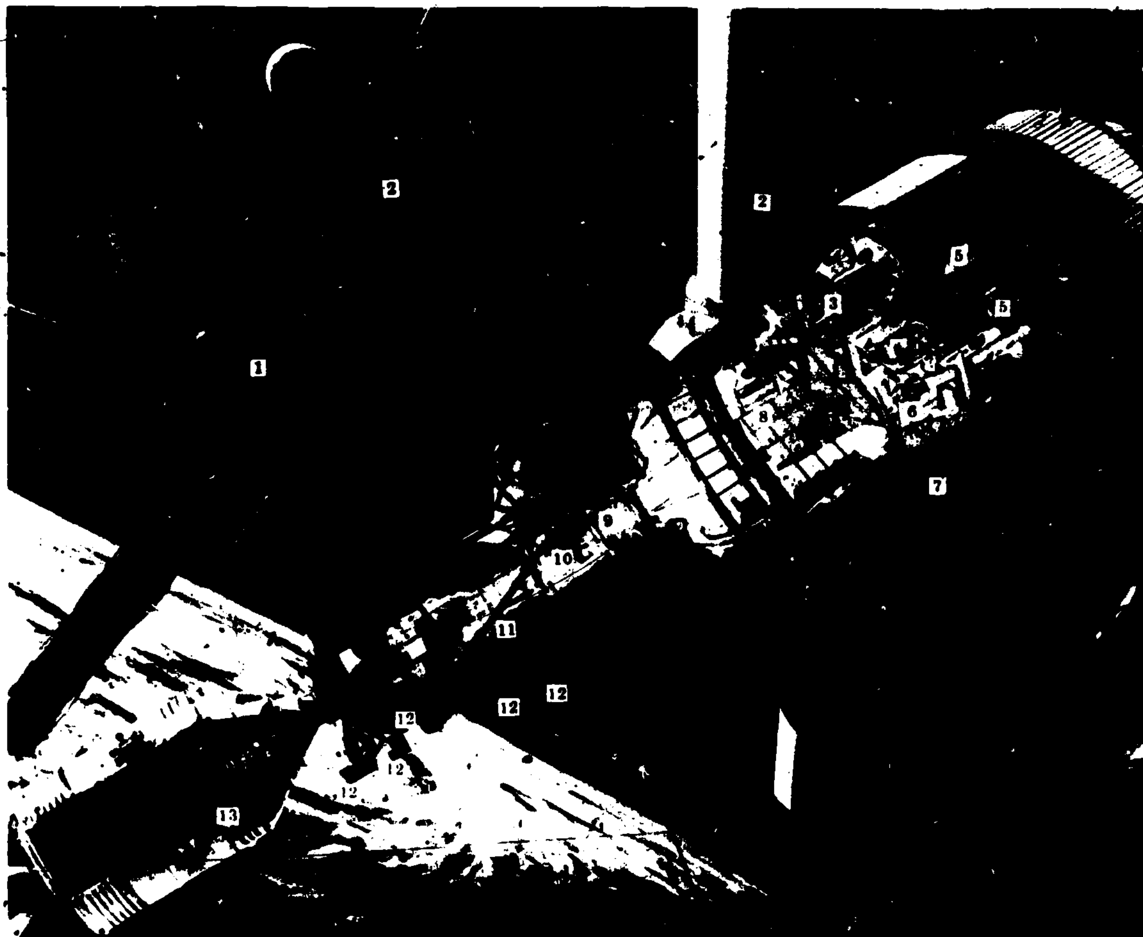
2) The *airlock module* contains the airlock through which suited astronauts emerge to perform activities outside the cluster. It also contains equipment used to control the cluster's internal environment and the workshop electrical power and communications systems.

3) The *multiple docking adapter* provides the docking port for the arriving and departing command and service modules, and contains the control center for the telescope mount experiments and systems. It also houses the Earth applications experiments and materials science and technology experiments.

4) The *Apollo telescope mount* houses a sophisticated solar observatory having eight telescopes observing varying wavelengths from visible, through near and far ultraviolet, to X-ray. It contains the gyroscopes and computers by which the flight attitude of Skylab is controlled. Solar arrays mounted on this module generate about half of the electrical power available to the cluster.

5) The *command and service module* is the vehicle in which the crew travels from Earth to Skylab and back to Earth, and in which supplies are conveyed to Skylab, and experiment specimens and film are returned to Earth.

Skylab will fly in a circular orbit about 436 kilometers (235 nautical miles) above the surface of the Earth, and is planned to pass over any given point within latitudes 50° north and 50° south of the equator every five days. In its orbital configuration, Skylab will weigh over 91,000 kilograms (200,000 pounds) and will contain nearly 370 cubic meters (13,000 cubic feet) for work and living space (about the size of a three bedroom house).



1 Apollo telescope mount
2 Solar arrays
3 Sleeping quarters
4 Personal hygiene
5 Biomedical science experiment
6 Ward room
7 Orbital workshop
8 Experiment compartments
9 Airlock module
10 Airlock external hatch
11 Multiple docking adapter
12 Earth resources experiments
13 Command and service module

Skylab Orbiting Station

Section 1

Human Engineering

BACKGROUND

Human engineering has been defined as that area of knowledge dealing with the capabilities and limitations of human performance as related to the design of machines, jobs, and other modifications of man's physical environment. Human engineering seeks to ensure that man's tools and environment are properly matched to his physical size, strength, and speed, and to the capabilities of his senses, memory, cognitive skill, and psychomotor functions. These objectives are in contrast to forcing man to conform or adapt to his physical environment. However, given the condition that man must adapt to a new environment (weightless spaceflight), human engineering techniques seek to measure his ability to conform to this new environment (Refer to Section 2.), and to ascertain the degree to which the planned design of the habitat facilitates efficient manned operations. (Refer to Section 3.)

Human engineering has also been termed human-factors engineering, engineering psychology, applied experimental psychology, ergonomics, and biotechnology.

Among the problems of human engineering are the design of (1) visual displays for ease, speed, and accuracy of interpretation of information; (2) audio signal systems and voice communications systems for accuracy of communications; (3) controls; and (4) seats, work stations, cockpits, and control consoles in terms of man's physical size, comfort, strength, and visibility. Human engineering addresses itself to problems of physiological stresses arising from such environmental factors as heat and cold, humidity, high and low atmospheric (or environmental) pressure, vibration and acceleration, radiation and toxicity, illumination (or lack of it), acoustic noise, and, in the case of spacecraft, weightlessness. Finally, the human engineer is concerned with man's psychological stresses arising from work speed and load, and problems of memory, perception, decision-making, and fatigue.

The foundation of human engineering was laid by Frederick W. Taylor, who demonstrated that proper design of work stations and procedures led to greatly increased productivity of workers. Early systematic studies were made by Frank B. and Lillian M. Gilbreth whose system of categorizing hand movements is still a standard time and motion study technique. The Gilbreths were uniquely qualified to undertake a task requiring understanding of the human factor as well as a knowledge of materials, tools, and equipment because of Mrs. Gilbreth's training as a psychologist and Mr. Gilbreth's engineering background.

World War II caused a great demand for psychologists and physiologists to assist engineers in designing aircraft, tanks, ships, submarines, and other weapons to ensure that these devices could be operated under stress by men with relatively little training. Often it was found that engineers had designed the equipment for themselves and, as a result, large servicemen could not fit in the allocated spaces, small pilots could not reach all the aircraft controls, or an appreciable percentage of the operators were lacking in sufficient strength or were confused by complex procedures for operating the war equipment. After World War II, formal courses in human engineering were introduced in psychology and engineering departments of colleges and by professional organizations in the United States and many European countries.

Early research efforts were directed at providing experimental data for some of the more obvious gaps in human engineering knowledge, such as the variations in the physical dimensions of men and women of different ages, the range of strength and speed capabilities of humans, and the physical conditions under which they could detect (or read) certain visual images and hear (or discriminate) certain sounds. As more sophisticated techniques were developed, other sensory capacities of touch, smell, and motion, as well as the more complex and subtle problems of training, stress, and fatigue, became amenable to laboratory experiments.

SCIENTIFIC CONSIDERATIONS

Anthropometry

The specialized field of human engineering dealing with the physical dimensions of the human body is called anthropometry. In designing a console, work station, aircraft seat, or a special piece of personal equipment, such as a spacesuit, it is important that the design dimensions used can accommodate as large a number of the intended users as possible. However, designing a console tailored to the largest person may mean that the smallest operator cannot reach all the controls unless various features of the equipment are adjustable. Moreover, people are not shaped in simple proportion, i.e., the person with the largest head does not necessarily have the longest legs, or the greatest waist measurement. There is no average man. The person who is average in one dimension is not usually average in another. To accommodate this discrepancy in the population of operators, certain features of a machine often need to be designed to be independently adjustable, as in the case of an automobile seat. While adjustment flexibility is not always possible, as in the design of a custom-made spacecraft couch for a particular astronaut, it is important in sizing most equipment to know what percentage of large people and what percentage of small people will not be accommodated, and to weigh the relative costs and advantages of adding adjustments or building the equipment in different sizes.

Anthropometry—literally, the measurement of the human body.

Displays and Controls

Problems associated with visual displays have been of considerable interest to designers of aircraft, ships, submarines, spacecraft, nuclear reactors, electronic equipment, and tools of all kinds. Human engineers have attempted to specify the light intensity required for accurately reading various dials and displays in relation to the illumination level of the background. Design recommendations have been established for specific tasks and environments, optimum shape and spacing of numerals and indicator marks on dials; colors that give the best contrast have been specified; and the distance from which markings of certain sizes can be read (resolution) has been determined.

Electronics has made possible a number of new visual display techniques: self-illuminating electroluminescent numerals and holographic photographs, which when illuminated by coherent light (Laser) beams, appear three-dimensional. Cathode ray tubes driven by computers can provide a tremendous variety of images, including letters and numbers (alphanumerics), graphs, and television-type displays. Consequently, in new aircraft, spacecraft, and other sophisticated applications, many of the single-purpose dials and indicators are being replaced by relatively few computer-driven displays, which are highly flexible and can display many different kinds of information. Sometimes these displays can be called up by the operator by feeding certain coded messages to the computer via a keyboard. Alternatively, a number of different indications, both qualitative and quantitative, can be integrated on a single display, such as the integrated aircraft landing displays now used on jet aircraft. The use of flexible, integrated displays to replace multiple single-purpose indicators and controls is rapidly developing throughout industry as a result of lower cost computers and electronic components.

Sound

With respect to auditory displays (sound signaling systems), human engineers can specify how loud various sounds must be to be heard against background noises of differing levels. Because consonants, which have relatively higher frequencies and lower loudness, are known to carry more information than vowels in the English language, the fidelity of voice communications systems at these higher frequencies (about 2000 to 4000 Hz) is recognized to be more important that the fidelity at lower frequencies. New electronic reading machines and mobility aids for the blind have made use of auditory signals to replace visual senses.

Control

An important human engineering problem is the coordination of displays with the controls by which responses to these displays are made. In practice there are many violations of even simple common sense design principles, such as locating controls adjacent to displays when they are used together, arranging for controls to move in the same direction as the associated display, or having all displays and controls move in the same direction to turn them off. Although the human operator can adapt to a reasonably broad range of forces and sizes of controls, some controls are still installed that require either more strength or sensitivity than many operators can exercise. Human engineering handbooks that summarize various experimental data and contain recommendations for proper display and control design and layout are now available.

Environmental Stress

Human engineers are concerned with the design of (1) man's environment to enhance his information processing ability and (2) to maintain his body functioning normally. These concerns require an understanding of man's tolerance ranges to heat and cold, to high and low pressures, to varying atmospheric concentrations, to acceleration and vibration, and now, in the age of manned space travel, man's ability to function properly in a weightless environment. Engineering solutions to these problems can take the form of spacesuits, diving suits, special clothing for extreme climates, and atmospheric control units for sealed cabins and tanks. Alternatively, working conditions can be arranged so as to limit exposure to hazard, for example, by determining the least fatiguing distance from an open door of a blast furnace, or by recommending the maximum time that can safely be spent at certain altitudes without supplemental pressure breathing apparatus.

Environmental Stress—extreme environmental conditions such as high or low temperature, high humidity or loud noise that causes discomfort to an individual, are examples of environmental stress.

Bodily comfort is dependent upon a combination of ambient temperature, pressure, humidity, air movement, and amount of clothing, all of which affect the body's internal mechanisms to keep the internal body temperature constant at 98.6° F. Proper respiration depends upon the combination of ambient pressure and oxygen concentration. Constant high accelerations, as experienced by astronauts during launch and reentry phases of spaceflights, can drain the blood from the eyes and brain and temporarily prevent man's proper functioning; such adverse effects can be prevented by orienting the body properly or by the use of partial pressure suits that keep the blood from pooling in the veins of the torso and legs. Vibration is known to cause motion sickness if it occurs at certain frequencies at which parts of the body resonate sympathetically (2 to 5 Hz peak). Levels of thermal, pressure, atmospheric, acceleration, and vibration stresses, which are individually mild, can have violent effects when they occur in some combinations.

Safety

Human factor considerations often determine whether a particular vehicle, tool, or environment is safe. The ability of the human body to withstand various sudden acceleratory forces is an important aspect of highway safety. Seat belt design for automobiles is based on rocket sled experiments originally conducted to design crash harnesses and parachute harnesses for aircraft pilots.

Rocket Sled—a device used to test body restraints at extreme accelerations and decelerations.

Reaction Time

Human reaction time is also a large factor in accidents of all types. It has been shown that human reactions under the best conditions, such as those that exist when an alert, expectant test subject is required to push a button in response to a light signal, is about ¼ second. As the number, N, of response choices from among which the subject must choose increases, the reaction time increases as the logarithm of N. Reaction times can also increase many times as a function of boredom and fatigue, but reliable quantitative predictors for these factors are not now available.

Recent research efforts have attempted to determine the optimum work load for a human operator. This research is motivated by the gradual disappearance of routine tasks which can be performed at an even pace and somewhat independently of the environment. Man is used increasingly as a monitor of complex semiautomatic systems where the detection of certain low probability contingencies, or failure of the system, requires a rapid and dependable corrective action on the part of the operator. Examples of this type of monitor function occur in industrial inspection processes, monitoring of nuclear reactors, and the piloting of spacecraft and aircraft.

Early studies of standing watch on ship and radar monitoring indicated that man could remain vigilant only about ½ hour for signals that occur rarely if ever (such as a ship on a collision course with another at night, or in fog; or the approach of enemy aircraft or missiles). One technique employed to keep men on watch and radar operators alert is to introduce artificial signals which the operator cannot initially discriminate from the real ones.

The NASA has conducted simulations of long space flights where not only was the workload negligible, but, in some cases, sound, light, temperature, and gravity sensations were reduced to a minimum. Under these conditions, man becomes decreasingly alert and may even hallucinate to substitute imagined sensations to compensate for the lack of real sensations (stimuli).

At the opposite end of the workload scale, human factors research has determined the upper limits on what man can do with his sensors and muscles, both in transmitting information and in performing mechanical work. Man can transmit about 35 bits per second during such activities as piano playing and speaking, but for more routine manipulation skills his rate is much lower. As an engine for performing mechanical work, man is rather inefficient; experiments have shown that the average man even while operating at peak efficiency can produce about ½ horsepower for only about one minute. In order to do so, his body produces several times that amount of energy in wasted heat. (Refer to Volume 4, Life Sciences, for a more detailed discussion of man's energy expenditure.)

Bit—the discrete selection of one out of two alternative choices.

Man Versus Machine

A fundamental problem of ever-increasing importance for human engineers, is determination of what tasks should be assigned to man and what tasks to machines. It is a fallacy to think that many given tasks can be best accomplished solely either by a man or a machine, without aid from the other, because often some elements of both provide a mixture superior to either man or machine alone. For example, machines are superior in speed and power, more reliable for routine tasks (being free from boredom and fatigue), can perform computations at higher rates, and can store and recall specific quantitative facts from memory faster and more dependably than man. Man, by contrast, has remarkable sensory capabilities, which are difficult (and expensive) to duplicate with instruments in range, size, and power. (The ratio of the greatest to the least energy which man can either see or hear is about $1:10^{13}$.) Man's ability to perceive patterns, make relevant associations in his memory, and induce new generalizations from empirical data remains far superior to that of any computer existing, or planned. Thus, while man's information processing rate in simple skills is low, his information processing rate for these pattern recognition and inductive reasoning capabilities (of which little is understood) appears far greater. The science of allocating tasks to man and machines, based upon what each can do best, is still in the early stages of development.

APPLICATION

The science of human engineering is applied to the design of most modern industrial facilities to effect a safer and more efficient performance from equipment and operators. This science can also be applied to the design of other facilities such as domestic appliances, houses, cars, schools, stores, etc. It is expected that in the future the scientific methods and principles of human engineering will assume an ever-increasing role in man's daily life. This role will be emphasized as the population density increases, as urban development becomes more complex, and as technological developments stress man's built-in limitations.

Weightlessness

On Earth, the gravitational field results in a continuous directional force "weight" that acts on all objects. We learn to perform each and every task in the presence of this force. As a result, any task that requires physical effort is performed with some of the body's muscles working against or with gravitational forces, in lifting the arms or legs, moving objects, and orienting the body to an upright position. These muscular movements are strong habits. In the event that this feeling of weight is removed, it is expected some confusion may result, some loss of muscular coordination may be apparent, or there may be problems associated with orientation.

The following experiments, discussed in Section 2, consider the effect of weightlessness on physical activity.

Time and Motion Study

- Effects of weightlessness on the time and manner of accomplishing particular tasks.

Motor Sensory Performance (Skylab Student Experiment)

- Effects of weightlessness on motor sensory performance.

Web Formation (Skylab Student Experiment)

- Determine if a spider can function normally in a weightless condition.

The weightless condition can also impose unique requirements on the provisions for day to day living activities. The role played by gravity in ensuring that (1) a flow of water is available at a faucet; (2) waste products flow through sewers; (3) objects and people remain in their places when required, must be deliberately designed into the spacecraft.

The Skylab is the first space mission where man will experience long periods of weightlessness. The living accommodations provided in Skylab are assumed to be adequate; however, only limited data is available concerning man's problems in living and working in weightlessness. Section 3 of this volume covers the astronauts' evaluation of the living accommodations. The data obtained in the evaluation will be used for the design of future manned spacecraft.

Section 2

Performance in a Weightless Environment

CREW ACTIVITIES/MAINTENANCE STUDY

BACKGROUND

Previous space missions have indicated that man in space is capable of conducting many of the activities that he accomplishes on Earth. However, very limited data have been obtained concerning man's capabilities to perform various kinds of physical work in weightless space. The work in Skylab consists of a number of physical tasks related to the performance of the experiments and the conduct of daily operations. In this investigation, data will be obtained with respect to the astronauts' ability to assemble or disassemble equipment (manual dexterity), maneuver inside the spacecraft (locomotion), and transfer and handle masses (mass handling and transfer). With these data, the designers of future spacecraft will be able to design tools and equipment that are more effective in a weightless environment.

On Earth, in the presence of gravitational forces, many people have learned to manipulate tools and accomplish tasks efficiently. They have learned certain tasks such as turning a screwdriver, working with a wrench, and lifting and moving objects of various sizes from one place to another. These tasks appear to be relatively simple with respect to how they are accomplished, but it is important to consider the part gravity plays in these tasks.

Consider the forces involved when an individual applies a downward force to turn a wrench or to close the hood of a car. There is an equal and opposite reactive force on his body and, depending on his position and restraints, he will tend to move in the direction of this force (in this case—upward). The gravitational force, however, provides his body with the restraint that he needs to overcome this tendency to move. Gravity also results in a force of friction which keeps his feet from sliding but, more important, it provides a large stable component of force vertically downward (his weight). As long as he is applying a force less than his weight, he can work effectively in a stable position. He learns to rely on the stability that gravity has provided.

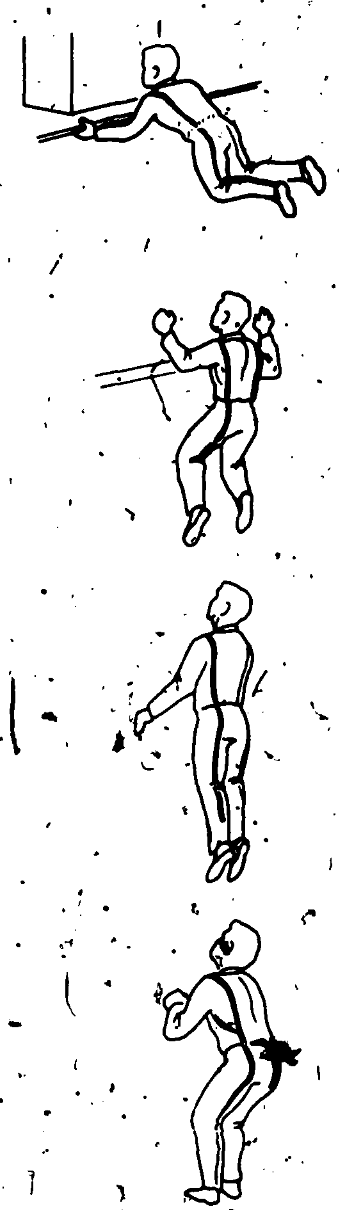
When an astronaut in the weightless environment of the Skylab applies a single directional force, his body, without the stable force component (his weight), will begin to move in the opposite direction. He must learn to "counter" his applied force by holding on to some stable fixture in the work area.

The same counter force is required when he attempts to transfer masses in space. Although a mass is weightless in orbit, it still requires some coordinated effort to put it in motion, or to change its direction, or to stop it after it gets moving. It may require some experience in order to learn to handle objects in space with the same dexterity as they are handled on Earth.

Of course, if the astronaut wants to move his own body from place to place within the Skylab he only needs to push himself from a wall or floor with a small force and he will move in a straight path until he is stopped by the opposite wall or ceiling, although, if the pushoff force is not transmitted through his body's center of gravity, he will have some component of attitude rotation in the resultant force that may cause him to arrive at his destination improperly oriented. Since an equal force will be required in deceleration, he must be prepared to absorb the impact safely. Therefore, some experience in locomotion is needed in order for the astronaut to learn to stop properly.

Another aspect of working in space is the dexterity needed to manipulate small tools and components. Being weightless, small components will not "rest" on a surface. They will be subject to small forces such as air currents or accidental bumps that could send them off and out of reach. The additional care that must be taken to handle small parts in space may require some learning time until adequate control techniques are learned.

Human engineers who must plan designs for future manned spacecraft equipment are interested in the performance capabilities of the astronauts in the weightless conditions. They need to know (1) the problems encountered in handling and moving masses from place to place, (2) if some tasks are easier, quicker, or slower than the same tasks performed on Earth, and (3) if there are any special techniques or coordinated maneuvers that must be used to move about the spacecraft. Knowledge of all of the particular performance factors that relate to activities in weightlessness is needed in a design analysis. In order to obtain this information, observations will be made of the various activities that are scheduled for performance in Skylab. The activities include operational tasks, maintenance tasks, the disassembly and reassembly of various items of equipment, housekeeping tasks and experiment tasks.



Locomotion

Onboard photographs and TV records will be made of the crewmen as they perform these various tasks. These photographs will be compared to data obtained in controlled observations of similar activities performed on Earth. This comparison will provide the outward observable differences.

Another source of data will be the subjective data obtained from the astronaut. The astronaut will be able to describe the problems encountered, the effectiveness or ineffectiveness of some work aids, or the need for additional handles or restraining devices, and the improvements in training techniques that could be incorporated.

All of the devices that are now incorporated in Skylab to assist in the performance of tasks in a weightless environment are based upon experience in previous missions and the designers' calculations and assumptions as to the physical capabilities and limitations of the astronauts. With additional data concerning the effectiveness of the man-machine relationship in weightlessness, a more effective design should result.

OBJECTIVES

In this experiment, the crew will evaluate Skylab man-machine relationships by gathering data concerning ability to perform work in the weightless environment on long-duration missions. Specific objectives are to—

1) document man's performance during prolonged weightless spaceflight;
2) evaluate the data obtained relative to the design criteria for Skylab;
3) report the evaluations and conclusions in terms useful to the designers of future manned spacecraft and the planners of future manned missions.

PERFORMANCE

Crew activity data acquired during preflight simulations and training sessions will be used to establish baseline data for comparisons with inflight data acquired for similar activities.

Evaluation data are required on each Skylab mission. For the nominal evaluations, the prime sources of data will be 16mm motion pictures, TV coverage, and voice-recorded or logbook-recorded comments concerning the adequacy of performance as a function of Skylab/crew work interfaces. Crew subjective and technical comment during postflight debriefings will provide a substantial portion of data inputs. Crew comments on selected portions of the inflight activity films will also assist in the evaluations.

Representative Inflight Activities

Representative inflight activities which are intended to be photographed include:

1) removal of film cassette from experiment magazine;
2) transfer of ambient food bale from food locker in forward compartment to pantry in wardroom;
3) setup and use demonstration of ATM "chair" restraint;
4) assembly of articulated mirror system and film carrousel on the spectrograph;
5) reloading teleprinter paper cartridge;
6) replacement of mol sieve charcoal canister;
7) performance of various maintenance tasks.

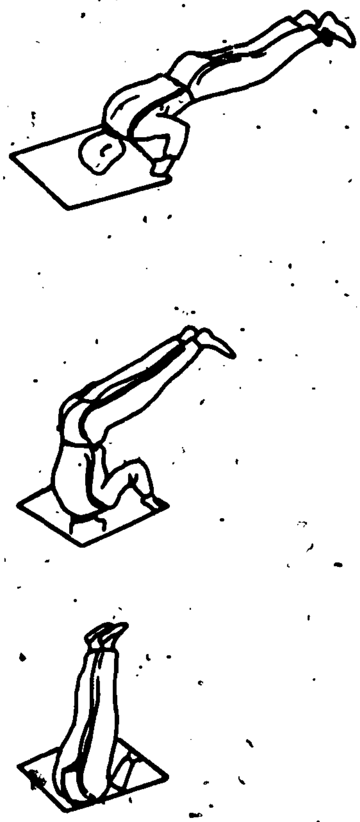
All physical activities, however, will be subject to evaluation by the astronauts at any time during the mission.

DATA

The motion picture film, voice recordings, and logbook will be returned after each mission, and a debriefing session is planned for the astronauts.

Debriefing—questions addressed to pilots or astronauts following a mission.

- What unanticipated problems occurred in performing various activation, housekeeping, or experiment activities to date? Can the problems be traced to the lack of or inadequate preflight simulations, training techniques, etc?
- How effective are the various tools used thus far; in particular, what tools are well-suited and what tools are poorly suited for use in weightlessness?
- What work activities planned for an individual astronaut have required assistance from another crewman? Are there any activities scheduled as two-man tasks that could be performed by one man?
- Evaluate both the beneficial and the detrimental effects of weightlessness on the following types of activities:
  1) individual work activities while restrained at a specific work location;
  2) handling and transferring various sized equipment items;
  3) work activities requiring assistance from another crewman;
  4) personal maintenance activities (personal hygiene, donning/doffing garments);
  5) waste management and cleanup chores;
  6) locomotion in and through the various Skylab compartments.
- What significant improvisations (procedural, equipment arrangements, or modifications, etc) have you accomplished as a result of adapting to living and working in weightlessness?



It has been observed that ability to maneuver in a weightless environment is better for some activities than the designer had anticipated.

BACKGROUND

Time and Motion Study

Time and motion study has been an accepted technique in industry for more than half a century, and has generally been used for the purpose of establishing standard times for industrial operations of all types, including repetitive as well as nonrepetitive operations. The technique has been used as a basis for improving the work conditions of a particular operation by making the work place more convenient and efficient for the operator.

One of the principal techniques for analysis, especially when very accurate results are desired, is the use of motion pictures. The motion picture film provides a permanent record of the operation, and many aspects that would ordinarily be missed in conventional stop watch time study can be analyzed. Motions and groups of motions can be studied extensively, and if additional data other than motion pictures is available, they can be correlated with the film analysis. Such films are frequently used for training of time study practitioners in various phases of the work.

Time and motion study has been strongly influenced by human factors and experimental psychologists, and has developed into what is now known as human engineering, with more emphasis on the physiological aspect of human work. This is especially true of research work in the field. The use of computers to analyze data, as well as to process the large amounts of data generated in experimental work, has advanced the field to a higher level of sophistication.

In addition to the specific objectives proposed, this experiment is an exploratory study to provide data for the analysis of any temporal changes in the pattern of inflight performance compared to the performance pattern developed in training on Earth. This experiment will also provide data to facilitate analysis of differences in specific motion patterns in preflight and inflight task performance.

Some information from previous spaceflight reports indicates that performance of specified tasks during spaceflight requires a greater amount of time than did the same task on Earth. For example, Gemini 7 astronauts reported it took "considerably" longer to remove space suits in space. No specific studies or quantitative evaluations have been reported regarding the increased time requirement. This experiment is designed to evaluate the effect of weightlessness on inflight time requirements by providing definitive measurements of astronaut performance.

A systematic study of the controllable conditions listed below will permit an evaluation of the effects of training, degree of movement, and extent of motor coordination on the efficiency with which learned tasks are performed during spaceflight. The experiment design will enable statistical analysts, by means of analysis of variance, tests of significance, etc, to determine if differences are chance or real. With adequate control, this study will determine the differential significance of weightless environment on the performance of such tasks as—

1) astronaut training:
   - familiar with tasks, but not highly trained,
   - highly trained on selected tasks;

2) movement:

- none required from location, but manipulation of equipment is required,
- movement required from point to point within the spacecraft (translation),
- fine motor coordination,
- gross motor coordination;

3) feedback:

- visual feedback,
- no visual feedback,
- tactile feedback,
- no tactile feedback,
- auditory feedback,
- no auditory feedback,
- combinations of two or more of the above feedbacks.

Tactile—perception by the sense of touch.

SCIENTIFIC OBJECTIVES

The Time and Motion Study experiment is unique in that it is totally dependent upon the films of flight crew activities (both experimental and operational) as the primary nonintrustive data source.

Nonintrusive—observation of a subject without disturbing his activity.

This experiment will determine through analysis of movie film the effectiveness with which crewmen perform inflight tasks compared with their performance of the same tasks during preflight training (zero-gravity aircraft flights and neutral buoyancy simulations).

Neutral Buoyancy—overall density of an object which is almost equal to that of water. A tendency to remain stationary when submerged at depths under the water.

Neutral Buoyancy Simulator—objects in space, being weightless, behave a little like neutral buoyancy objects in water. Astronauts train by handling equipment models of a neutral buoyancy under water.

It is believed that these inflight tasks will generally take more time in space than they did on Earth, although it is conceivable that some tasks may be simplified, but there will be a minimal loss of efficiency, depending upon the nature of the task. Weightlessness and other variables of spaceflight, such as a 5 psia atmospheric pressure, will affect not only the time required but the motion patterns required to perform the tasks. Analysis of data from this experiment will—

1) provide data on how man performs specific tasks in spaceflight and the variables affecting the time and motion patterns required to perform these specific tasks. These data will provide valuable information for the design of procedures, mission timelines, methods, tasks, and equipment for future missions.
2) provide data on the effectiveness of restraint systems used and the energy cost of astronaut movements.
3) provide clues to any possible degradation of skills or learning adaptations caused by extended space flight.

4) assist in defining the training time and level of training which a crewman requires to perform inflight tasks efficiently.

5) assist in defining the time and resource requirements that may be anticipated for ground based training, including neutral buoyancy and weightless training flights for specific astronaut activities.

6) assist in defining proper interface of man and equipment in weightless environments.

Motion picture film provides a permanent record and allows investigators to study time and motion patterns as coordinated activities, subordinate activities, and specific activity elements.

A coordinated activity is one that involves all the activities needed to complete a task (e.g., deployment and retrieval of large piece of hardware). Subordinate activity is a grouping of task activities that are related in function and time (e.g., obtain hardware from stowage locker). An activity element is a one-step activity within a subordinate activity (e.g., grasp hardware package).

The films from this experiment will be analyzed visually (frame by frame) and the results of this analysis will be further processed by computer analysis to allow plotting of learning and adaptability curves as well as the rate and change of the crewman's ability to perform tasks in a spaceflight environment.

The time it takes a crewman to perform a task (coordinated activity, subordinate activity, or activity element), as well as the order in which he performs that task will be analyzed.

This analysis will show any changes in the time required for these tasks and any alterations in the pattern by which he performs the task (i.e., procedural steps rearranged or steps eliminated). The analysis will show whether the alteration was necessary because of the crewman's adaptability or because of the equipment design. For example, an increased time in performing a task may mean that the crewman is losing efficiency because of the length of time in weightlessness and the spacecraft environment, or it may mean that the equipment he is using has not been designed properly.

Analysis of this filmed data is expected to help develop crewman working limits within which he may reasonably be expected to work in a weightless environment.

The experiment tasks to be filmed are—

1) attachment of biomedical sensors, translation to and from points within the spacecraft, ingress and egress of confined enclosures; mounting, applying restraints, and operating the bicycle ergometer.

Bicycle Ergometer—an exercising bicycle without wheels used by the astronauts.

2) deploying and retrieving a large piece of hardware from the scientific airlock.

3) deploying and retrieving a medium-sized piece of hardware from the scientific airlock.

4) donning and doffing the pressure g ent assembly (spacesuit).

5) periodic maintenance of hardware that requires removal and installation of assemblies, and donning of such hardware (such as the astronaut maneuvering unit).

6) food preparation and food residue mass measurement.[4]

Donning—the act of putting on wearing apparel.

Doffing—the act of removing wearing apparel.

These tasks were selected because they involve both gross movements and on-the-body manipulative tasks. Also, they can be broken down into coordinated activities, subordinate activities, and activity elements.

Table 2-1 lists the specific experiments and activities that are to be filmed during the time and motion study experiment for all three Skylab missions.

Table I. Typical Film Activities

Photographed Activity	Test Condition
Donning vectorcardiogram (VCG) sensor, harness and belt; transition, ingressing, and egressing confined enclosures; donning metabolic apparatus; mounting, applying restraints, and operating ergometer	Total of 8 performances by 2 crewmen 4 times each, including at least 4 performances of metabolic activity by one crewman.
Deployment and retrieval of large hardware	
Deployment and retrieval of medium-size hardware	
Donning and doffing of the pressure garment assembly (PGA)	At least 1 performance by 2 crewmen donning and doffing PGA
Periodic maintenance of hardware that requires removal and installation of assemblies and donning of such hardware where applicable	At least 3 performances by 1 crewman, one of which must be the suited run
Food preparation and food residue mass measurement	4 performances of at least 2 crewmen working simultaneously

EQUIPMENT

The experiment equipment consists primarily of a 16mm camera used to photograph the experiment activities, and such support equipment as various camera lenses, a high-intensity lamp, and various film and photographic accessories.

PERFORMANCE

The schedule for performance of this experiment is dependent upon the mission schedule of experiments performance.

Based on ground mission control updates of the flight plan, the cameras and support equipment are positioned in the designated location for the particular experiment to be photographed.

The film is annotated before each filming by holding a log sheet in front of the camera for a short time. At the end of the day, the astronaut will advise the Mission Control Center of the experiments filmed, the percentage of film, and the cassettes used.

DATA

A total of 38 film cassettes [4600 meters (15,200 feet)] of 16mm film will be returned after the performance of this experiment. In addition to photographic records, other data, such as crew voice recordings, crew logs, and telemetered data, will be returned to Earth and serve as a useful supplement to the film data.

SKYLAB STUDENT EXPERIMENTS

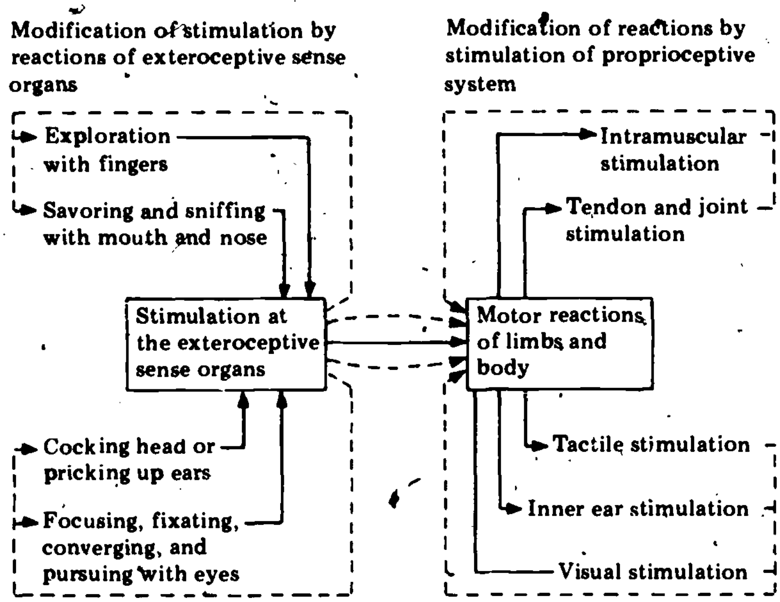
BACKGROUND

Motor Sensory Performance

Planning for future space missions anticipates the use of man to improve mission effectiveness. The necessity for human performance data is obvious, if useful work involving man and machines is to be performed in space. Erection, activation, inspection, repair, and a variety of maintenance operations may benefit from direct participation by an astronaut. Also, safety considerations impose the necessity of reliably determining astronaut performance capabilities.

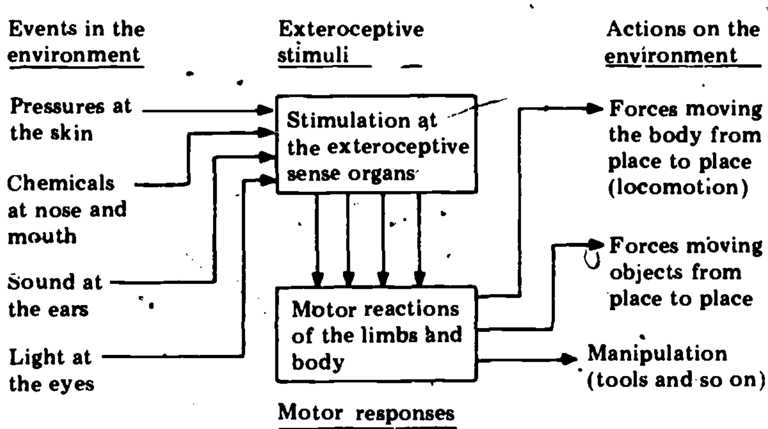
Presently, there is a lack of information in the United States space program on human motor sensory performance (Figures 2-1 and 2-2) as affected by long duration weightlessness conditions. However, some research on bed-rest studies has shown a significant deterioration in motor sensory performance as a function of time. Subjective comments and operational information from previous United States space flights have not indicated any problems related to motor sensory performance with exception of one Apollo flight. Subjective comments from this flight did indicate a deterioration in human strength capability. Russian literature on long-duration space flight has also mentioned some deterioration in motor sensory performance as a function of mission duration.

A quantitative experimental evaluation of human motor sensory performance degradation will be investigated on Skylab, so that the true boundaries of man's capabilities can be verified. Not only will this experiment furnish data required to accomplish the stated objectives, but data derived from this experiment can have value in helping to establish human engineering design guidelines for future space hardware and maintenance activities, and provide information on the influence of environment on human motor sensory performance.



Note: The feedback loops for exploring and enhancing external simulation and those for controlling motor responses are shown. The dashed lines represent neural actions and the solid lines represent physical actions.

Figure 2-1 Feedback Loops of Stimulus-Response Diagram



Note: It should be noted that stimuli produced by exploratory responses of the sense organs and gross motor responses of the musculature are not included. Therefore, Figure 2-1 should be superimposed on this diagram.

Figure 2-2 The Classical Stimulus-Response Diagram, Illustrating the Human Motor ~~Sensory~~ Segments

SCIENTIFIC OBJECTIVES

A standard eye-hand coordination test apparatus, developed by the Human Performance Group of the Department of Industrial Engineering at the University of Michigan, has been modified for use on Skylab in an experiment proposed by a high school student in the Skylab Student Project. This experiment will attempt to determine the effect of weightlessness on motor sensory performance. The method of measuring motor sensory performance used requires the test subject to follow a standardized test maze with a 119-hole aiming pattern. In this test, the time required to complete the entire test and the elapsed time between individual hole contacts are measured.

Data from experiment orbital performances will be compared with data obtained from preflight and postflight tests performed by the same test subject using identical equipment in order to determine any changes in motor sensory performance. An additional factor, in comparison of the orbital data with preflight and postflight data, will be the correlation of these data with extensive data compiled from use of this standardized test apparatus on many subjects from varied disciplines.

The objective of this experiment is to obtain data on motor sensory performance involving fine, manipulative tasks that can be used in planning, training, and equipment development for future manned space missions. This data includes quantitative information on the difficulty encountered in the performance of such tasks under weightless conditions over an extended period of time.

EQUIPMENT

To measure motor sensory performance, a pencil type stylus is inserted into 119 holes of 3.175-mm (1/8-in.) diameter in the sequence indicated on the maze (Figure 2-3). The impact of the stylus on the isolated backplate will be picked up by an accelerometer mounted on the backplate and recorded on telemetry tape recorders. Total time to complete the maze (and hole-to-hole elapsed times), will be available following ground reduction of the telemetry data that will include standard timing signals.

CREW ACTIVITIES

This experiment requires manual operation by the same astronaut twice during the mission. The first performance should be early in the mission, and the second performance as late as possible in the mission; and both should be conducted at approximately the same time of day following similar activities by the astronaut. During each performance, the astronaut will run through the maze twice, with each test-run taking approximately two minutes.

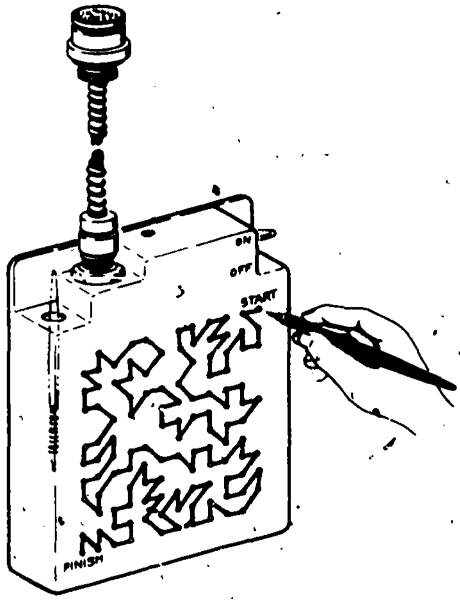


Figure 2-3 Standard Test Maze

It is desirable that the astronaut be trained in the use of the test apparatus to his own highest proficiency level before the mission. Progress in training will be determined by the decrease in variability of a set of runs. Training will terminate when the performance time is minimal, or constant. The final level of proficiency data in the skill maintenance training phase will be used as baseline data to evaluate inflight performance.

The impacts of the stylus, as sensed by an accelerometer, are converted by the experiment electronics into signals that are compatible with the Skylab telemetry system. The data are sampled at a rate of 320 samples per second. Astronaut voice comments and stylus clicks are recorded through the Skylab voice intercom channel.

BACKGROUND

Web Formation

This experiment, proposed by a high school student in the Skylab Student Project, will investigate the effect of a weightless environment upon the formation of spider webs.

Gravity is used on web construction because the spider, after attaching a web to one point, will fall to another point generating a segment of web along the length of the fall. The spider continues the web construction by interconnecting threads in an organized manner. To orient itself in space, a spider has organs in its joints which are sensitive to pressure. These organs report stresses due to gravity. It is not known how the spider will perform the essential orientation task when deprived of this sense of position. Perhaps a web cannot be formed.

Spider webs have previously been studied while the subject spider has been under the influence of drugs during the weaving operation. Scientists attempt to associate the system affected and the nature of the effect by studying these deformed structures. For example, spiders under the influence of caffein have been observed to construct erratic and haphazard webs, indicating perhaps a state of hyperactivity.

SCIENTIFIC OBJECTIVES

Web Formation

The objective of this experiment is to observe the web formation of the Common Cross spider (Araneus Diadematus) when constructed in a weightless Skylab environment. The resulting web, if any, will be compared to that formed by the same spider in the Earth's gravitational field to determine any variations in construction details. The purpose of the experiment is to determine whether the spider can function normally when deprived of its sense of gravity. Perhaps other senses (such as sight, touch, and taste) could compensate for this loss. Should the web show an eccentricity, it may be inferred that the spider was disoriented; and it may provide clues as to how other insect-like animals would react to a weightless environment. Experiments in later programs with more advanced animals in the same environment may contribute to scientists' understanding of how reason and abstract thought may offset disturbing external influences on behavior.

EQUIPMENT

The web building process will be observed and recorded using a 16mm motion picture camera. Motion pictures will exhibit actual construction methods and any difficulties encountered during the building of a web. The 16mm data acquisition camera, operating at 6 frames per second, will photograph the web formation process. The camera and camera lighting is triggered by an automatic camera actuator that detects the spider's motion. A timer then shuts off the camera and lights until the next motion is detected. The portable lights which are secured to the experiment enclosure provide lighting to facilitate photographing the web (Figure 2-4).

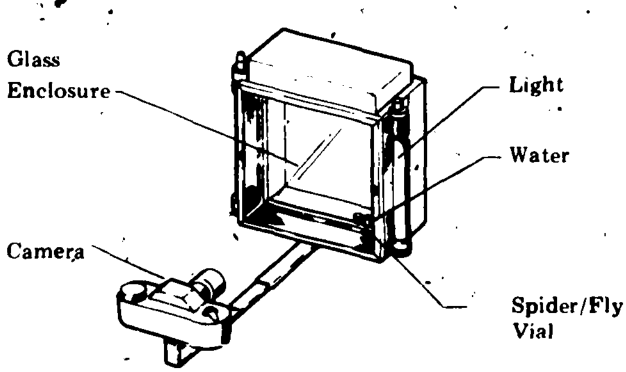


Figure 2-4 Spider Web Container

The experiment enclosure is launched in the orbital workshop (OWS) and is deployed by the astronauts to a suitable location in the OWS for operation. This location will be in an area of relatively high ambient light, but one where the lighting is reduced during crew sleep cycles so that the normal day-night environment is maintained. Temperature and pressure measurements of the OWS ambient environment in the vicinity of the experiment enclosure are required for postmission data analysis.

The spider and food supply (a common housefly) and a water supply vial are housed in a container and carrying case in the command module and launched with the crew. The astronaut will attach a spider/fly vial and a water vial to the deployed experiment enclosure in the OWS within seven days after the spider was inserted in the vial. A spare spider/fly vial is available as a backup test subject for contingency purposes.

To obtain high resolution photographs, the astronauts will photograph the web formations with a still camera. These still photographs will establish references and structural details of the webs when construction has been completed.

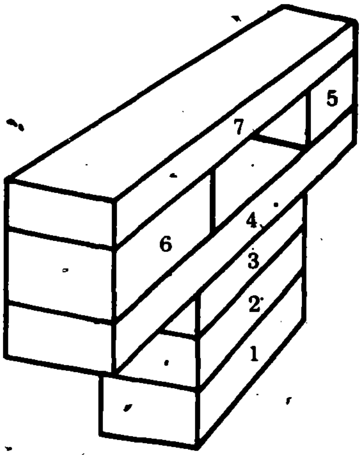
CREW ACTIVITIES

The crew will unstow and deploy the experiment equipment, attach and load the cameras, attach the portable lights and power and control cables as required by experiment preparation procedures. Crewmen will make casual observations of the experiment during the mission, to determine if a web has been completed, and will obtain 35mm photographs of any completed web formations present, as well as make voice records of any comments concerning the experiment.

CLASSROOM DEMONSTRATIONS

Influence of Body Orientation on Performance of Tasks

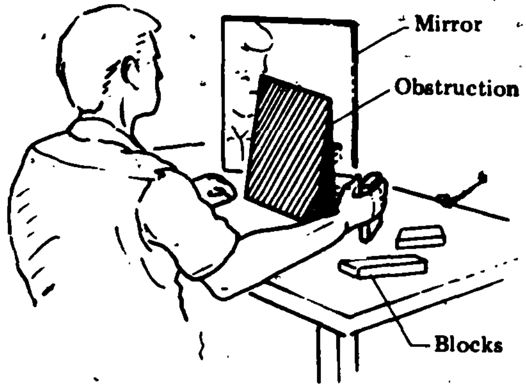
While sitting at a table, have subject construct a tower with some numbered building blocks like the one shown. With full use of his hands, he should build the structure while looking at its reflection in a mirror. He should proceed with this activity several times until he believes he is proficient in building the structure quickly and accurately. Each repeated activity should be timed.

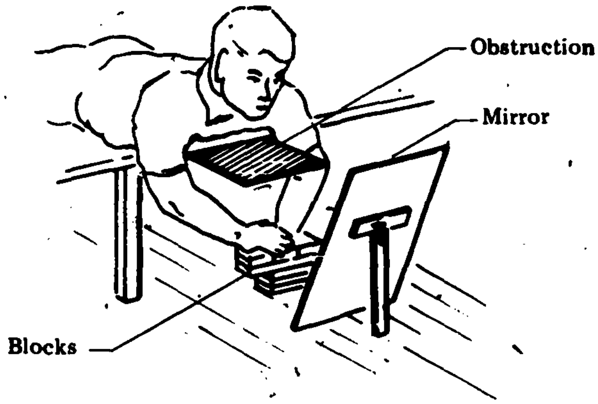


Blocks

Then have subject lie face down on a table with his arms and head hanging over one end. Have him duplicate the previous structure reflected in a mirror on the floor and record time until he can build it as fast as he did while sitting. The blocks should face the same direction in the assembled structure and should be scattered at random (but within reach) in disassembly.

The conclusion to be reached is that in learning a task, the orientation of the body with respect to the direction of gravitational forces is a factor in the time required to perform the task.





Body Orientation Effects on Performance

Analysis of Common Activities

Have the students analyze the performance of a number of common activities such as—

1) tightening and loosening a bolt;
2) opening and closing a door and trunk lid of a car;
3) playing a musical instrument (piano, guitar) and a game (tennis, pool).

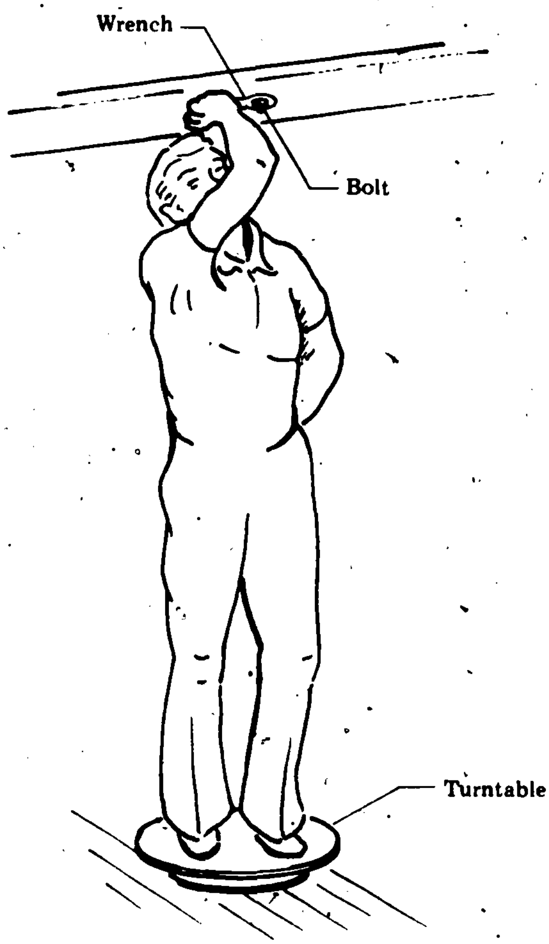
While performing and observing the selected tasks, the students should identify. The—

1) purpose;
2) mode of performance;
3) performance requirements;
4) magnitude and direction of forces involved;
5) reactions internal and external to the system;
6) what external environmental forces are necessary (such as gravity);
7) what compensations must be made for the absence of these forces.

Have the students conduct a practical demonstration using the following procedure.

Construct a structure similar to that shown in the sketch. Place a turntable on the floor directly beneath the structure. With no other means of support within reach, the student stands on the frictionless turntable and tightens or loosens the nut and bolt in the structure directly over his head.

Have the students analyze the activity and develop concepts to accomplish the task, except for elimination of the frictionless turntable.



Section 3

Living in Space

BACKGROUND

Habitability—the ability of a facility to accommodate the living requirements of personnel.

In any structure that must accommodate the living needs of people for long periods of time, the design objective is concerned with satisfying the human activities of eating, sleeping, working, relaxing, moving about, and maintaining personal hygiene. The hardware facilities provided for these activities include eating and food preparation spaces, passageways, bath and toilet facilities, sleep stations, work areas, recreational areas, air conditioning devices, communication systems, lighting equipment, and all of the detailed fixtures within these areas which in some manner interface with personnel using the structure.

In a ground-based structure such as a house, the design of living accommodations are relatively straightforward. The designs are based on years of experience and although there are some objections to the efficiency of some of these devices, they are fairly functional and relatively safe. In the Skylab there is a particularly different situation in that the habitational equipment must accommodate the astronauts for long periods of weightlessness, and there is limited past experience for habitational design.

In order to design facilities to accommodate the Skylab crew, the designer made calculations and assumptions on the capability and limitations of the astronaut performing tasks in a weightless environment. The designer knew that if an astronaut were to perform the simple task of eating, for example, it would be necessary to ensure that the crewman maintained a particular orientation with respect to the table and ~~his tray~~ of food. In a weightless environment, a simple chair would not work because, being weightless, the crewman's body would tend to float about, making the task of eating somewhat difficult. Because of this, designers considered provisions for restraining the astronaut's position without relying on weight, and restraining devices were provided at the tables for this purpose.

Eating

Drinking

On Earth, soup and other drinkable liquids are held in a convenient container by gravitational forces. In the weightless environment, liquids form into spheres and tend to wet all sides of an open container making it difficult to control. The designer, understanding the physical problems associated with liquids in space, has provided an enclosed flexible container for liquids. The astronaut, by placing his mouth over an orifice, or a nipple, in the container can drink by applying pressure on the container, forcing liquid out.

All of the various habitational facilities and devices will be evaluated with respect to all of the activities in which an astronaut can become involved. The following list is a summary of the elements of habitability features that will be evaluated:

environment,

architecture,

mobility and restraints,

houskeeping,

communications,

personal hygiene,

food and water,

garments and personal accouterments, and

off-duty activities.

The astronauts are expected to gather data on the habitational designs in a manner which can be most readily used by designers, i.e., a critical evaluation that is specific and in engineering terms. Enough objective background data should be assembled by the astronaut to provide a good basis for his evaluation. Photographs showing the activities of eating, sleeping, washing, and working will illustrate the weightless orientation of the astronaut with respect to the habitational hardware. Moving pictures will illustrate the maneuverability of the astronauts through the passageways and in and around equipment, and their capability to handle portable items. Measurements of habitational parameters such as temperature, humidity, distances, light levels, and noise levels will provide basic data for the analysis required in design.

Subjective Evaluation—an evaluation of a condition made by an individual based on his feelings.

Subjective evaluations are required also. A subjective evaluation will provide a description of a problem to which there may not be an immediate or apparent solution. Any kind of remarks reflecting the feelings of an astronaut concerning the function of a piece of equipment or an activity may be important information. A comment such as—"I keep bumping into the box behind me at this work station"—will prompt the designer to look at the arrangement and determine what is actually causing the problem. It may be that more room is required for that activitity or that the astronaut's restraints are too loose or it may be that additional restraints are required.

The evaluation data are to be obtained at early, mid, and late periods on each of the three Skylab missions to allow for identification of changes in preference and ways of performing activities as a function of time spent in a weightless environment.

SCIENTIFIC OBJECTIVE

The objective of the experiment is to measure, evaluate, and report habitability features of crew quarters and work areas of the Skylab orbital assembly in engineering terms useful to the design of future spacecraft.

The facilities that will be evaluated include all of the spaces and devices which the crew will use in day to day activities of eating, sleeping, working, relaxing, and maintaining personal hygiene.

Figures 3-1 through 3-6 identify the location and configuration of some of the habitational facilities used by the astronauts.

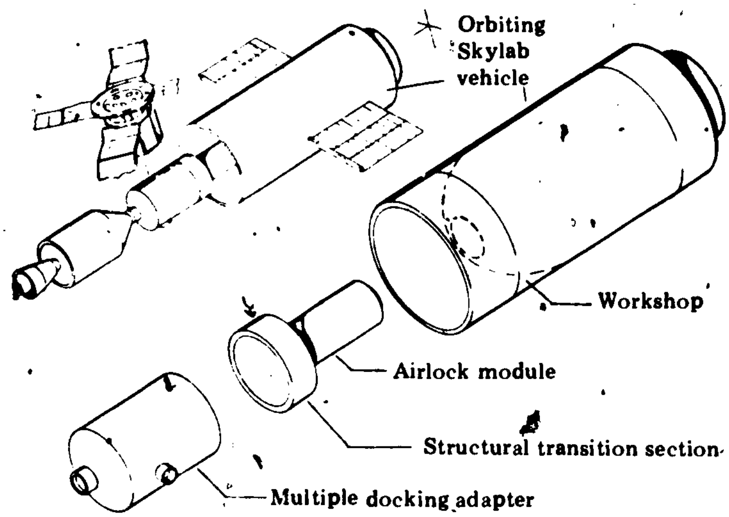


Figure 3-1 Breakout of Skylab Habitability Modules

PERFORMANCE

Individual Crewman Subjective Data

Subjective comments will be scheduled periodically through the mission but may also be voice-recorded during nonscheduled periods at the crewman's discretion. In the absence of other crewmen, he will record subjective data using evaluation forms as a guide for comments.

Film Records

Film records are required of selected crew activities to provide data relevant to the habitability elements of dining, sleeping, housekeeping, and moving about the vehicle. Representative examples of the activities to be filmed are—

1) consuming a meal;
2) ingressing and egressing the sleep restraint;
3) donning and doffing clothing;
4) performing personal hygiene tasks;
5) performing various houskeeping chores.

Environmental Measurements

Environmental measurements will be obtained at the crewmen's discretion to supplement their own subjective impressions of the adequacy of the onboard environmental parameters.

Environmental Parameters—
- air temperature
- humidity
- light levels
- noise levels
- smells

Debriefing Questionnaire

Periodically throughout each mission the astronauts will discuss habitability evaluations in a group session. Representative questions from a questionnaire form provided to prompt discussion are—

1) What particular aspects of Skylab seem well designed and arranged for living and working in a weightless environment? What aspects are deficient, and how?

2) Which is preferable, the floor ceiling orientation of the workshop, or the open cylindrical arrangement of the Multiple Docking Adapter? How do the tasks being performed influence your preference of orientation?

3) How adequate are the restraints and mobility aids throughout Skylab? Are more needed?

SUBJECTIVE EVALUATION GUIDE 1

INSTRUCTIONS

Evaluate and voice-record the overall adequacy of the equipment items. Descriptive comments are encouraged, especially concerning:

1) functional performance;
2) convenience of use location and orientation;
3) comfort and ease of use.

RATING DEFINITION

Excellent	Improvements are not needed and would only be a matter of personal preference
Very good	Minor improvements are possible but not really necessary
Adequate	Some shortcomings found and a few improvements are desirable
Poor	Numerous shortcomings found and improvements are necessary
Unacceptable	Gross shortcomings found and improvements are mandatory

DATA

Voice recordings of the astronauts' subjective comments as well as photographs, motion picture film, and measurement data will be returned after each flight mission. The data will be compiled in a report for use by designers of future manned spacecraft.

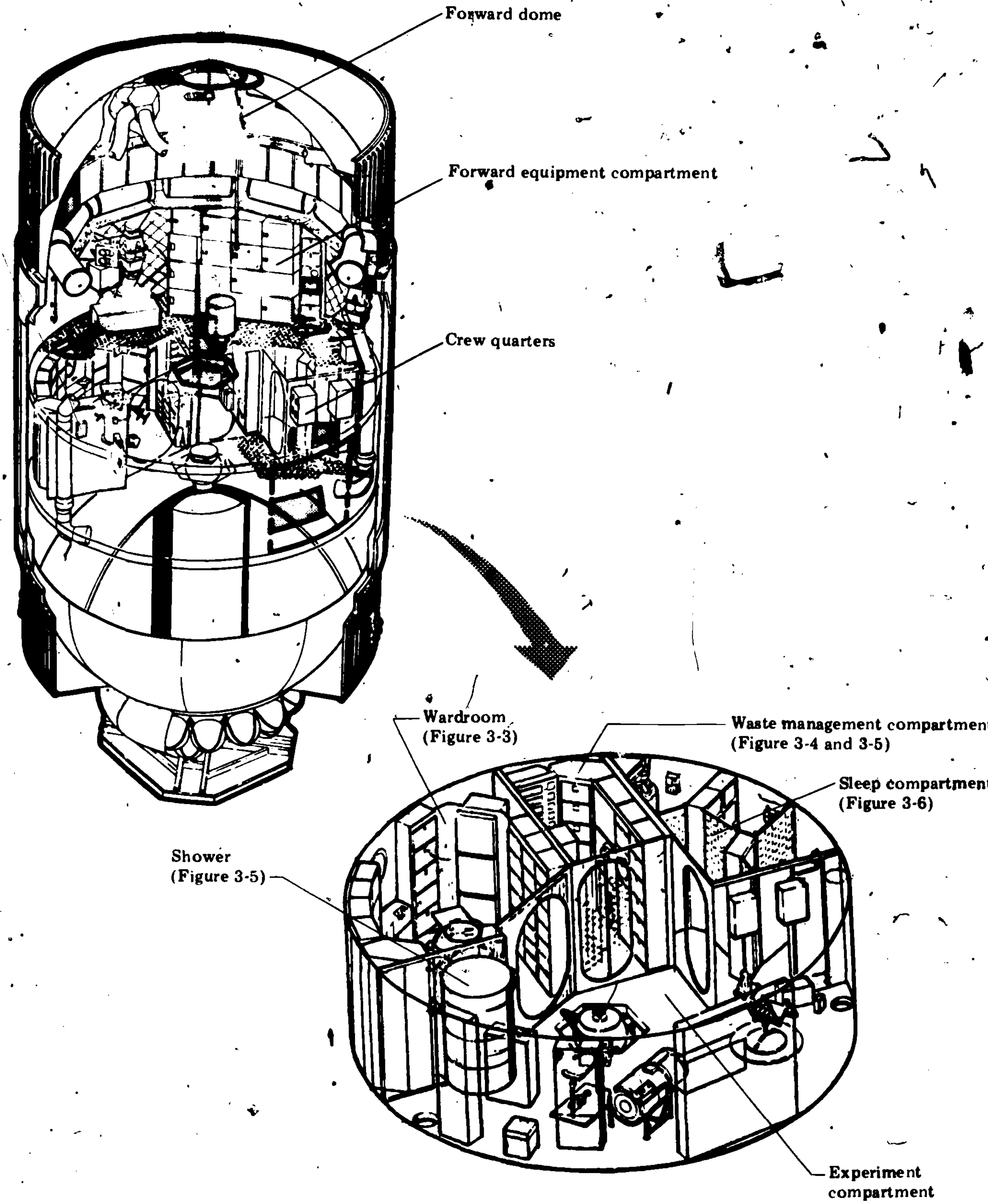


Figure 3-2 Crew Quarters in the Workshop

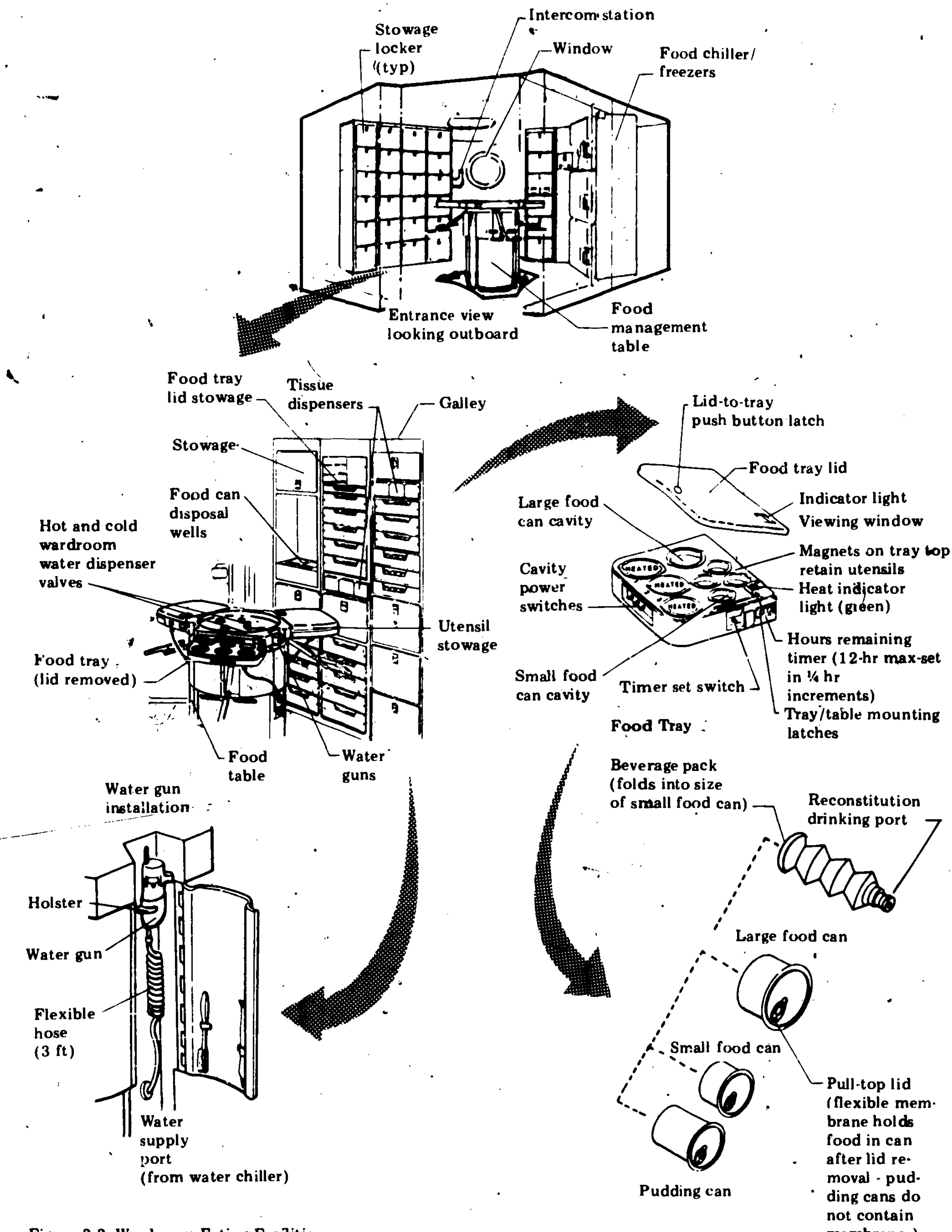


Figure 3-3 Wardroom Eating Facilities

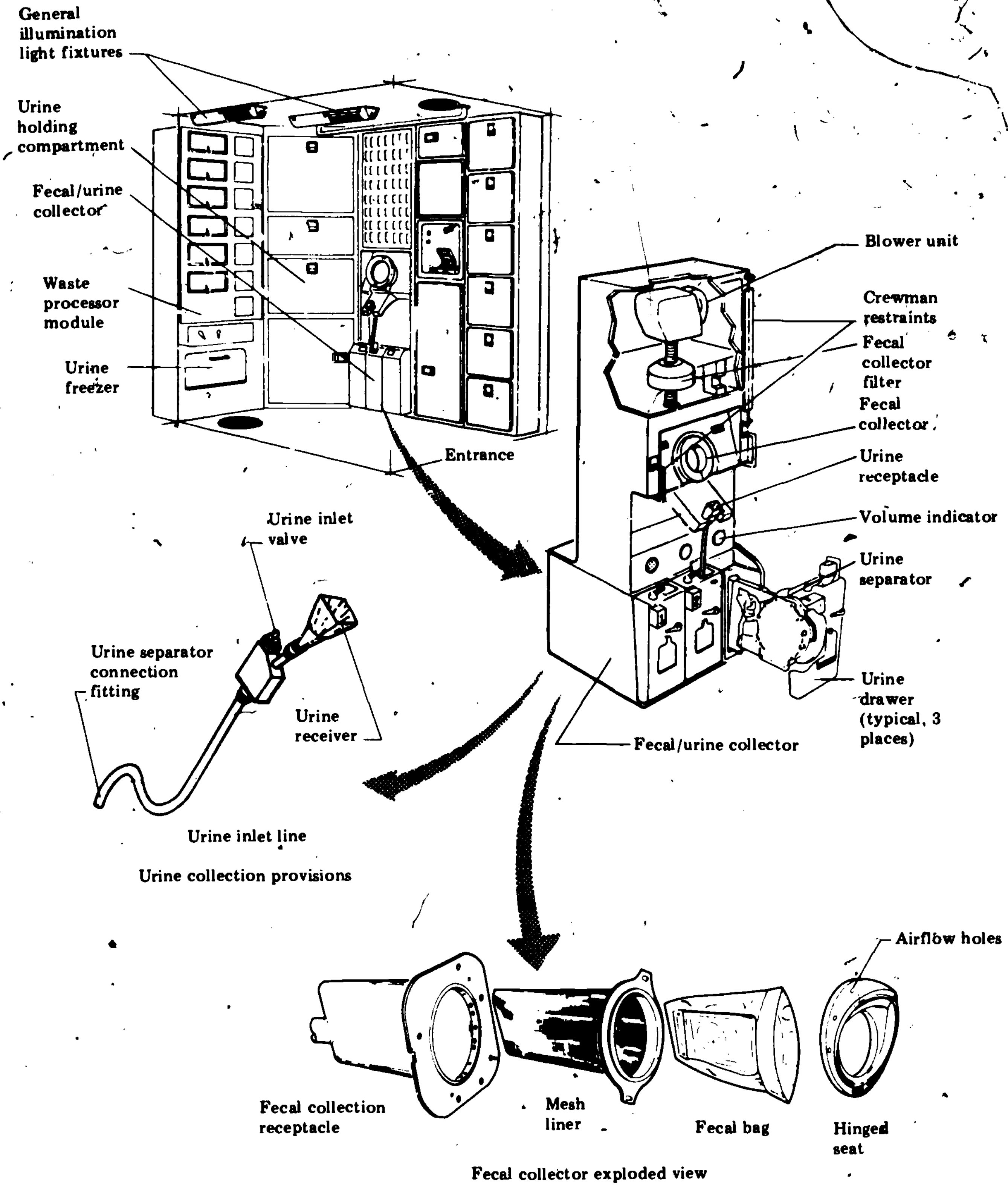
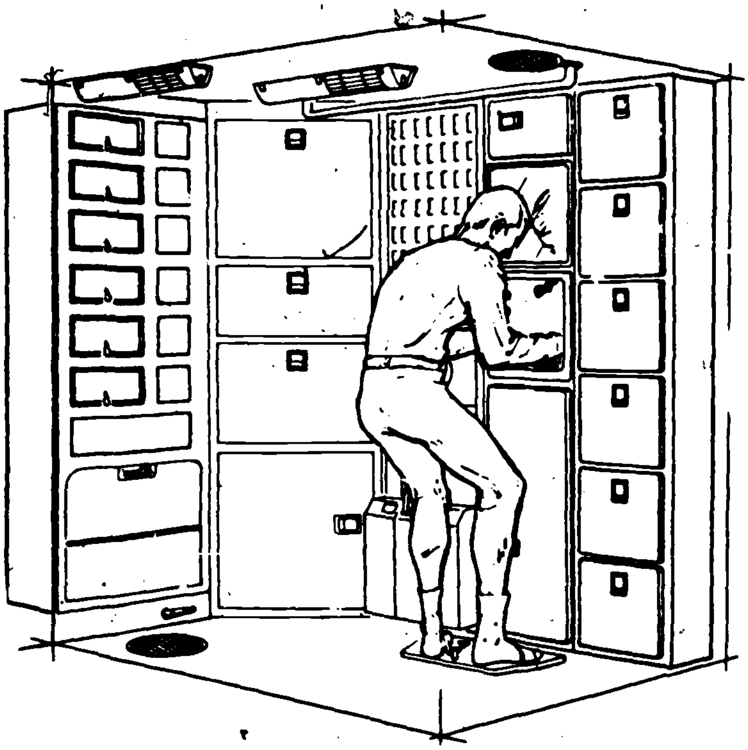
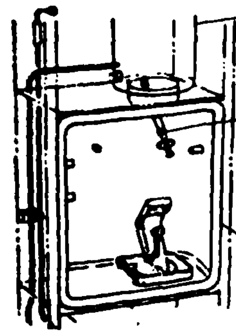
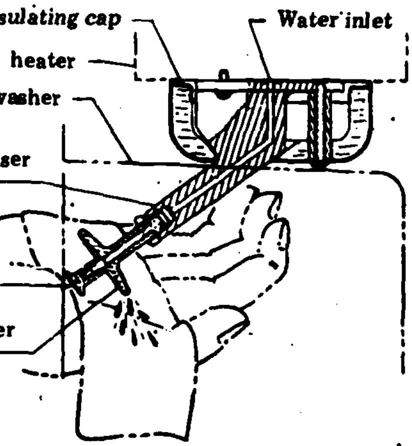


Figure 3-4 Waste Management Compartment

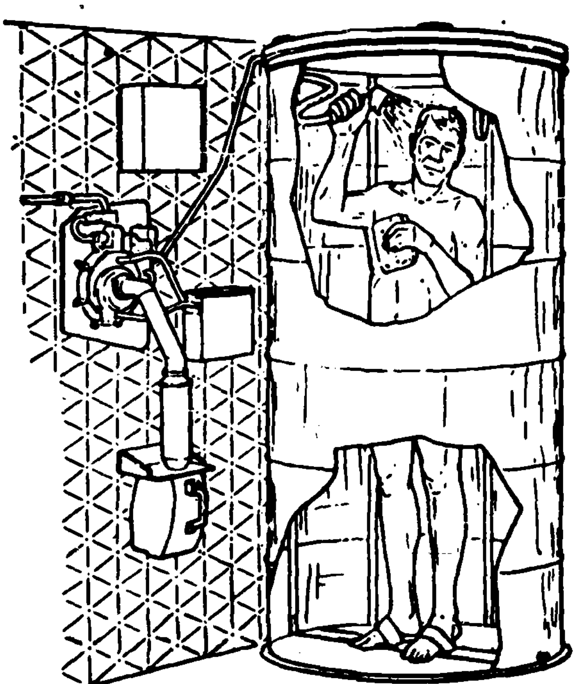


Washing hands





Water dispensing valve



Taking a shower (see Figure 3-2)

Figure 3-5 Personal Hygiene

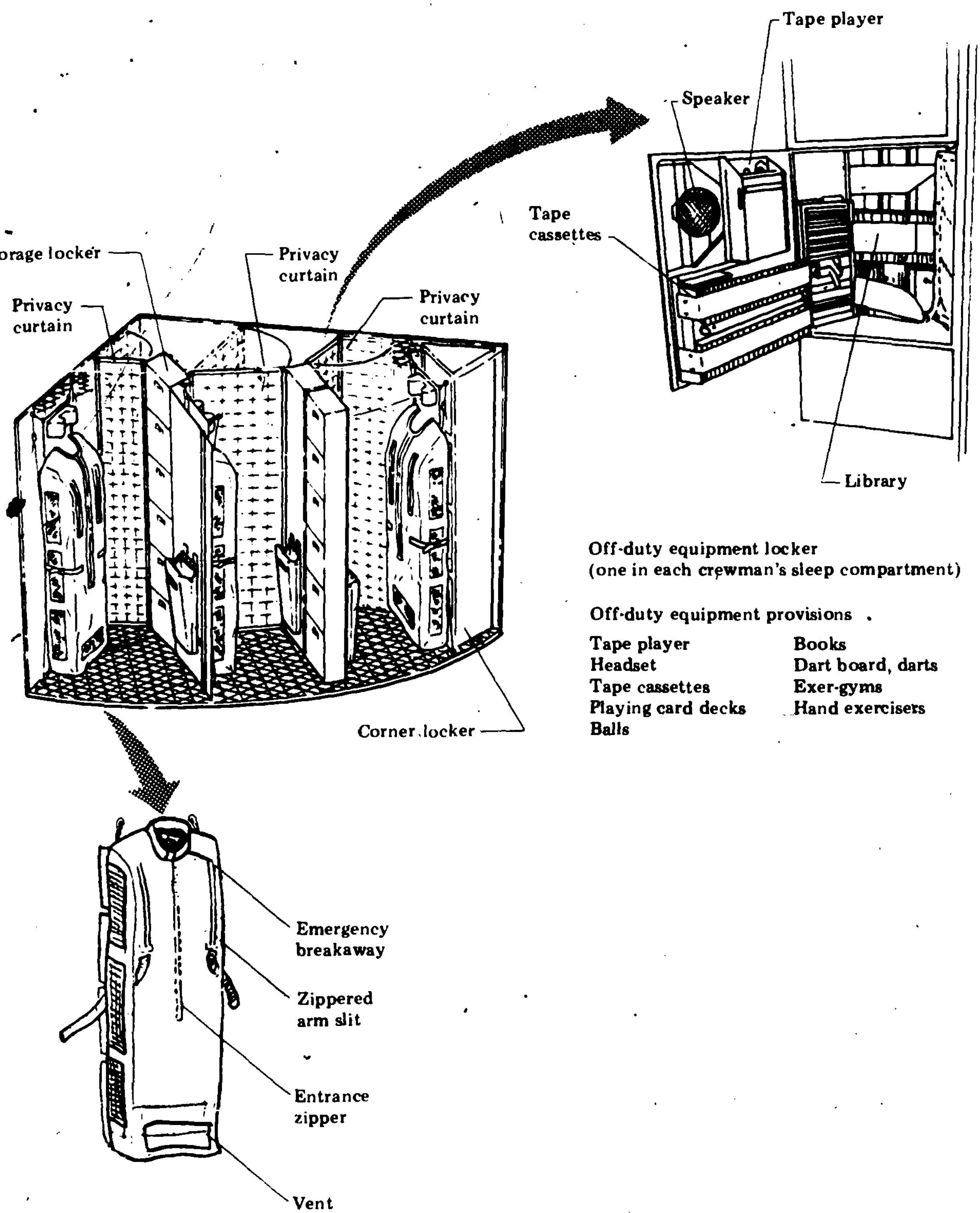


Figure 3-6 Sleep Compartment

CLASSROOM ACTIVITIES

Have the students conduct analyses of various architectural features of the school or home. Candidate features include classrooms, hallways, bathrooms, kitchens, arrangement of the total structure, etc.

The students should identify the fundamental purpose of the feature and the necessary requirements for achieving the purpose. Evaluation parameters would include (1) arrangement: Is the purpose adequately supported?; (2) lighting: Can the purpose be fulfilled safely?; (3) acoustics; (4) esthetics: To what extent do the esthetics enhance or impair achievement of purpose?; (5) hygiene: Does the design facilitate maintaining the appropriate level of cleanliness?; etc.

Then ask the students to redesign the particular feature they had analyzed. A redesign can consist of a simple sketch of the physical arrangement of the building, furniture or fixtures, or a sketch of redesigned furniture, bathroom fixture, or decor.

INFLIGHT AEROSOL ANALYSIS

BACKGROUND

The concentrations of dust-like particles in the air is one of the environmental considerations in Skylab. Before the Skylab was launched, measures were taken to ensure that the air and all equipment on board were free from dirt. However, as the crews live and work inside the Skylab, there is a possibility that small particles could be generated. Lint from clothes, particles from the crewman's body, and bits of material from the equipment used, are all sources of matter that could be generated and suspended in the Skylab's atmosphere. These particles, of course, will float freely in the weightless environment, being subject only to the circulating air currents within the vehicle.

Lint Generated in Skylab

Large sized particles and liquids will be trapped in the air filter system, but the fine particles (up to 100 microns in diameter) will continue to circulate throughout the living quarters.

The concern with the aerosols (fine suspended particles) is that if enough is generated, it will become objectionable or even injurious to the crewmembers.

This experiment will analyze the air to determine the amount of aerosols in the Skylab, the size of the particles, the buildup over a period of days, and the variations in concentration that may exist from one location to another.

Aerosol—a gaseous suspension of fine particles

Measurements will be made in several specific locations within Skylab and up to 20 measurements will be made at the crewmen's discretion. The data collected will help in assessing the generation, circulation, distribution, and filtering of particles in weightlessness and the closed environment of the spacecraft. The conclusions drawn from this data could lead to changes in spacecraft design and better spacecraft housekeeping procedures.

OBJECTIVES

The objectives of this experiment are to measure the concentration and size distribution of aerosol particles suspended in the air in the Skylab spacecraft. Specifically, the data from this experiment will be used to assess the:

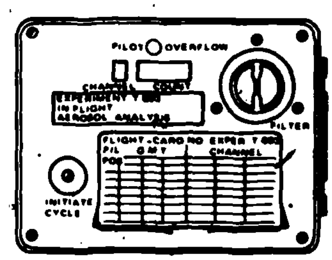
1) generation of particulate matter by crewmembers and spacecraft components.

2) effectiveness of air distribution, circulation, and filtering.

3) effect of weightlessness on the build-up and distribution of these particles.

4) tolerable levels of this aerosol matter inside a spacecraft.

EQUIPMENT



Aerosol Analyzer

Sampling the Aerosol

A portable, self-contained aerosol analyzer, will detect particle sizes from 1 to 100 microns and count particles of various sizes. The aerosol analyzer will collect and count particles in the Skylab atmosphere.

Air will be pumped into the analyzer and the particles in the air will be counted and classified as to size range. The inlet to the optical system is screened with a 100-micron screen to remove particles 100 microns or greater.

PROCEDURE

Samples will be taken every 10 days at the following locations:

command module,

forward dome,

experiment compartment,

forward compartment,

wardroom,

waste management compartment.

The astronaut will operate the analyzer at each location. After 70 seconds, a count will be displayed for channel 1 (1 to 3 microns particle size). The operator records this on the card on the front of the analyzer. Eight seconds later, the reading for channel 2 (3 to 9 microns particle size) will be displayed and the data are recorded. Finally, after another 8 seconds, the reading for channel 3 is displayed and the data recorded.

DATA

The cards on the face of the analyzer and the filter impact unit will be returned at the end of each mission. The particles retained on each section of the impact unit (one section per sample location) together with the recorded count will serve as the basic data used for the design of future manned spacecraft.

Section 4

Appendixes

APPENDIX A

GLOSSARY

GLOSSARY

Aerosol	Fine suspended particles
Anthropometry	Measurement of the human body
Biotechnology	Human engineering
Bit	Descrete selection of one out of two alternative choices
Dexterity	Skill in using the hands or body
Doffing	Act of removing wearing apparel or other apparatus
Donning	Act of putting on wearing apparel
Ergometer	A bicycle ergometer is used by the astronauts for exercise. It is operated like a bicycle without wheels; the load being supplied by a mechanical resistance. The energy required to operate the device is measured.
Exteroceptive	Sensitive to stimuli originating outside the body.
Food Bale	Term used to describe a container of several small food packages
Human Factors	Human engineering
Locomotion	Act of moving from place to place
Motor	Pertaining to muscle movement
Musculature	Muscular system of the body or its parts
Neural	Pertaining to the body's nerves
Neutral Bouyancy	Overall density of an object which is almost equal to that of water. A tendency to remain stationary when submerged at depths under the water.
Neutral Bouyancy Simulator	Objects in space, being weightless, behave a little like neutral buoyancy objects in water. Astronauts train by moving the objects simulating activities of weightlessness.
Nonintrusive	Manner of observing a subject without disturbing his activity
Proprioceptive	Sensitive to stimuli produced within the body
Tactile	Perceiving by the sense of touch
Translation	The act of moving from one point to another
VDC	An abbreviation for volts, direct current

APPENDIX B

SELECTED BIBLIOGRAPHY

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1. *Manned Spacecraft: Engineering Design & Operation.* Edited by Paul E. Purser, Maxime A. Faget, and Norman F. Smith, 1964, Fairchild Publications, New York, N.Y.

2. *Human Factors Engineering.* Ernest J. McCormick, 3rd Edition, 1970, McGraw-Hill, New York, N.Y.

3. *Motion and Time Study.* Ralph E. Barnes, 4th Edition, 1958, John Wiley & Sons, Inc., New York, N.Y.

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