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Space Station Medical Sciences Concepts

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Space Station Medical Sciences Concepts

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This document should be useful to anyone interested in planning the life sciences aspects of the NASA Space Station. It supplements NASA Technical Memorandum 58248 "Medical Operations and Life Sciences Activities on Space Station" (October 1982). Some of the comments herein apply to a smaller Space Station, others apply to a more mature station.

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CONTENTS

ABSTRACT

This publication presents current life sciences concepts relating to Space Station including the following: research, extravehicular activity, biobehavioral considerations, medical care, maintenance of dental health, maintaining health through physical conditioning and countermeasures, protection from radiation, atmospheric contamination control, atmospheric composition, noise pollution, food supply and service, clothing and furnishings, and educational program possibilities. Information on the current status of Soviet Space Stations is contained in appendix B.

INTRODUCTION

Purpose and Background

This document will provide NASA planners and others with information concerning the life sciences aspects of the Space Station. It highlights the areas in which the Johnson Space Center (JSC) can contribute expertise in the development of the Space Station.

In October 1982, the Medical Sciences Space Station Working Group (MS^3WG) published NASA Technical Memorandum 58248, "Medical Operations and Life Sciences Activities on Space Station." Medical and life sciences requirements are presented as they were understood in the fall of 1982. Now, after the continued development of 13 focus areas, new and more specific medical and life sciences aspects of Space Station operations are addressed.

Approach

Members of the MS^3WG support life sciences for the Space Transportation System (STS) or have specialized knowledge of a certain area (see appendix A). These individuals have organized their focus areas in the following format:

- o One page for conceptual sketch
- o Two pages of narrative divided into the following sections:
  - Introduction/Background
  - Discussion
  - Recommendations
- o One page for table(s) and/or figure(s)
- o Appendix (optional)

For the most part, the focus areas represent the concensus of the MS^3WG. Divergent viewpoints are presented to stimulate discussion and facilitate decision making. The proposed Space Station atmospheric composition and pressure is emphasized.

The MS^3WG determined that the development of concept sketches with a description has helped force the crystalization of concepts faster than otherwise might occur. This helps prepare documentation development for Research and Technology Objectives and Plans (RTOP's).

This Technical Memorandum is divided into four general categories: Operations, Health Maintenance, Habitability, and Educational Implications. Under these categories, 13 concepts are discussed.

This document is written to supplement TM 58248. In addition, it should complement the recent NASA Headquarters Life Sciences Planning Document "Space Station Payload and System Definition." The MS^3WG anticipates a sequel to Technical Memorandum 58255 which will present other life sciences Space Station focus areas which are maturing at the present time. The Technical Memorandum is expected to be published in the fall of 1984.

EXECUTIVE SUMMARY

As NASA moves from two decades of exploration and flight test activities into the Space Station era of industrialization and construction, the character of the missions will change from short-occasional to long-frequent, and the character of the crews will change from the pilot-astronauts to scientist-technicians. With the changed emphasis, NASA can no longer rely upon a small population of physically fit astronauts to do its work. The crew physical condition will vary because an individual's vocational skills will dictate the choice rather than physical prowess. The change in mission objectives will solve some of the problems of today but create new problems tomorrow. This document, Space Station Medical Sciences Concepts, attempts to address some of the medically related factors which must be considered if NASA is to make this shift in mission emphasis. The problems suggested must be solved or at least addressed before planning for Space Station is complete.

Medical research activities must play an important role in early Space Station activities. Through research the industrialization of the later Space Station years will be made practical. Research will be needed to make the environment safe for this new work. Early medical research must address the "potentially serious" physiological problems of the crewmembers exposed repeatedly to microgravity for long durations. As the program evolves and preventatives and therapies are found, any person can safely participate in these missions. By that time, biological research will supercede medical research as biologists take advantage of microgravity to determine how gravity influenced the evolutionary development of plants and animals.

Gradually, biological research will use laboratory space previously needed in medical research. Preparing for biological research will require animal quarters and laboratories separated from the crew's living areas. This will require separate atmospheres and barriers not needed for medical research.

Extravehicular activities (EVA) are a major use for a Space Station. Only through these activities can repair and construction be performed. EVA requires spacesuits which must be repaired regularly and kept clean to prevent odors and disease. The high cost of spacesuits requires that the suit must fit several individuals and the durability must allow multiple trips. It must be easy to repair. The atmospheric pressure difference between the suit and the airlock must not be so great that a prolonged prebreathe is needed before a worker can leave for outside work. One solution would be to increase the suit pressure. This works well only if a glove can be developed which allows dexterous movements at the chosen suit pressure. Present glove designs do not work well if the pressure difference is greater than 5 pounds. If higher suit pressures are needed, it will be necessary to develop a mechanical hand to prevent the glove from being the limiting feature of the suit and of human EVA activities.

As the crew mix changes from the more straightforward military-like astronaut society of the present era, it will be necessary for biobehavioral scientists to help NASA develop a space station society with rules of conduct and a command structure to maximize crew productivity and minimize psychological problems inherent in living in remote, dangerous environments isolated from friends and family.

Inflight medical care is an absolute requirement of Space Station planning. In all probability, an illness requiring a rescue mission will result in death of the crewmember prior to the rescue. A rescue could take up to 21 days plus the time needed to return the individual to Earth. Health care will embody the triad of prevention, diagnosis, and treatment. Each will use biomedical equipment designed for the station, along with medical procedures proven in microgravity, and medical knowledge derived from terrestrial medicine. Any plan for a health maintenance facility must be flexible. The facility must be modular to allow quick change as mission emphasis changes and as new developments allow the use of more utilitarian equipment for diagnosis and treatment. The minimal requirements of the facility must include the following: routine laboratory capability; imaging capability; life support equipment; and a hyperbaric treatment facility capable of reaching pressures at least two times those in the Station.

Dental problems that cause disability or decreased work performance will occur at the rate of 1% for each 90-man days in orbit. Dental care in Space Station will build on the equipment and procedures used in Skylab. These included dental training for the crewmembers, preflight clinical experience, onboard equipment, and adequate supplies. For dental treatment in Space Station, a dedicated area will be needed with adequate restraint systems, lighting, and equipment for surgery, repair, and prophylaxis. Imaging capability will be needed. Techniques useful for wound closure as well as all other aspects of dental practice must be developed for disease prevention, treatment, and trauma repair.

Exposure to microgravity produces negative calcium and nitrogen balances from bone and muscle atrophy. This is accompanied by cardiovascular changes which temporarily cause the heart to be less efficient at the time the crewmember first returns to Earth. Exercise, whether voluntary or programmed by mission rules, has been the traditional method used to counteract these negative balances. With the long duration missions and repeated exposures of Space Station workers, new approaches will be necessary and will require early planning so that the physical conditioning will not be a burden to the individual. To the present, no ideal solution is available to accomplish this necessary task, and one could predict that intensive research will be necessary before NASA can learn how to protect Space Station workers from bone-muscle atrophy.

Crewmembers in the Station will be exposed to continuous high ambient radiation levels which could become lethal if a solar storm were to hit the station. It can be estimated that the exposure will approximate 15 rads/tour.

This exceeds current occupational limits for radiation workers in the United States. In theory, this could result in a higher incidence of neoplasms. Calculations suggest that this could shorten life by an average of 150 days. However, if the station is free of chemical contaminants and if the medical care is above that of the population in general, the actual level of increase and life shortening could be considerably below the predicted. This is somewhat similar to present-day NASA where the incidence of degenerative diseases in the astronaut corps is lower than in the population generally because only fit individuals are used and the medical care is near ideal. Plans should be made for increased shielding in the event of a solar storm. The presently planned rescue time would not give the crew the option of returning to a safe haven unless an Orbiter were continuously on Station. Radiation exposure considerations would relate to the orbital inclination and heighth. A flat orbit would sharply limit the Station's usefulness for Earth observations. A high orbital altitude while ideal for the Station mechanics would greatly increase the ambient radition exposure. A geosynchronoun's orbit is precluded if man is to be on board the Station because of the high radiation flux.

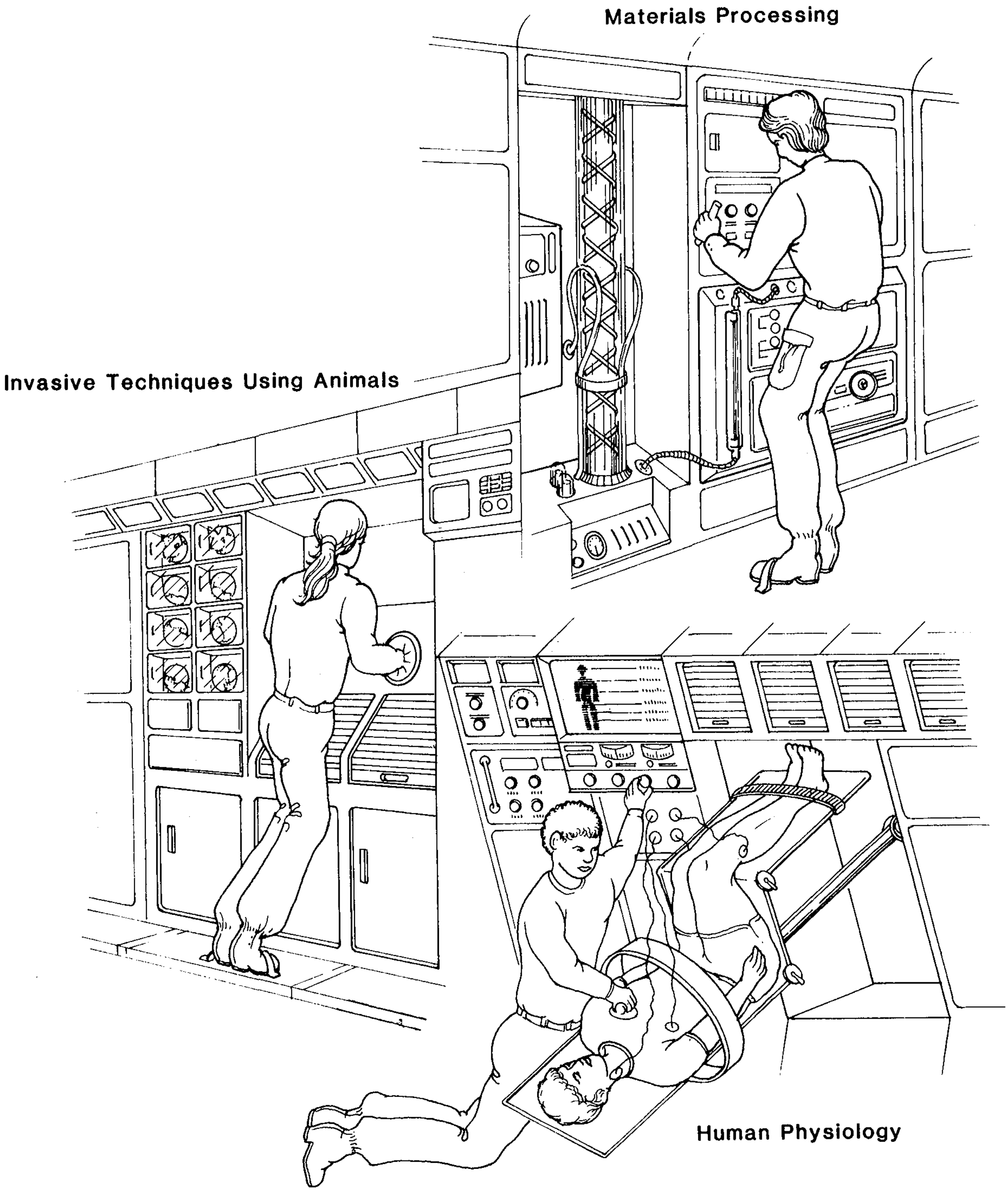
Atmospheric contamination control will be important since Space Station lacks the near infinite dilution of ambient air available without planning here on Earth. Methods to detect and remove contaminates must take high priority so that problems can be solved before launch. As the industrial activities increase, the number of toxic substances will increase. It will not be practical to perform human toxicity tests of every chemical used or potentially produced. At the present time, NASA controls this problem by rejecting anything which seems toxic. Commercial firms will not release all of their secret processes to the NASA management who must respect the public's right of disclosure. Therefore, ways must be developed to handle any toxic substance without prior knowledge of its concentration and even of its existence. Alarm systems will be needed since the crew is essentially sleeping in the contaminated factory. Similarly, fire control is an important aspect. Designing a fireproof habitat seems reasonable from a safety point of view but would be a near disaster from a human habitation view since it would preclude the use of personal garments and effects.

One of life's annoyances comes from noise pollution. Exposure to high intensity noise for long periods causes shifts in the auditory threshold and eventually deafness. The problem is intensified since the worker is unable to go home for 16 hours to get away from the noise of the workplace. This means no recovery each day so that the sound level must be safe for 24-hour living. On the other side, an environment that is too quiet can be a problem because attention is drawn to any sharp, random noise. The Space Station must be like a hotel with just enough white noise background to afford comfort, particularly at night during sleep. The ventilating fans, teletype machines, etc. all cause noises which can be unnoticed or disturbing depending upon other noise in the environment. When the noise is unpleasant or too loud, it will be necessary to use sound dampening blankets. Ideally, noisy equipment should not be used.

To maintain adequate motivation of the crew, it will be necessary to concentrate on the little things of life which make living in a remote, hostile environment bearable. Those who arrange living accommodations on remote drilling rigs and supertankers realize this and give the crews a living style that except for separation from family and friends is often better than at home. This includes food, clothing, and quarters. A bare-barracks type habitation module will not encourage the highly skilled personnel to return for multiple tours. It could encourage abherent behavior that will become a problem to the command structure. To the present, of necessity NASA has designed the crew food, furnishings, and clothing with operational considerations in mind rather than personal comfort and enjoyment. With Space Station, the long duration and repeated missions will require that NASA maximize the enjoyment from the surroundings. It may even need to allow personal clothing to be used during duty hours. Variety will be the watch word if boredom and dissatisfaction are to be prevented. An army travels on its stomach, the old adage goes. An absolute requirement will be tasty, noninstitutional food served in pleasant surroundings. The tastes of a variety of pallates must be respected.

Personal satisfaction is gained from being able to communicate with family and friends using a private system which is both accessible and reliable. This allows a crewmember to solve family problems and remove doubt and worry about family life.

Lastly, the Station personnel will have unobstructed views of Earth and the heavens. This will be an ideal place to hold classes and teach everything from astronomy to zoology. The scientists onboard offer the world a rich source of talent which can be used to teach. Plans should be made early to give the Station methods to transmit lectures to the ground and for the lecturer or teacher to receive feedback from the students. One can imagine an open university with highly talented scientists teaching courses in their field during their 90-day stay. Seminars designed to discuss the ongoing scientific program would both improve and hasten the scientific output. The stimulation of students vastly increases the scientist's knowledge and efficiency. Teaching courses will allow the professor to use free time in productive work rather than in leisure activities which could lead to boredom, depression, and feelings of loneliness.



MEDICAL AND BIOLOGICAL RESEARCH

Typical research activities to be performed on the Space Station will include physiological investigations of humans and animals, and materials processing.

MEDICAL AND BIOLOGICAL RESEARCH

Bernard J. Mieszkuc and John B. Charles

Introduction

Research activities aboard the Space Station will have several main areas of focus. Industrial and commercial activities are areas that will benefit from the microgravity, high vacuum and thermal extremes available in low Earth orbit, and will be accorded high priority in terms of resources. One of these resources will be the presence of human operators. Understanding human adaptation to the orbital environment and the implementation of an appropriate health maintenance program are high priorities. Basic biological research will contribute to the knowledge of physiological responses to spaceflight. Research will also be required for the development of a closed-environment life support system which should decrease the expense of Space Station operations. Some of this biological research will probably be deferred until dedicated facilities are provided. Basic scientific research in the physical sciences and astronomy will share personnel and equipment with the applied research activities in order to conserve resources.

The presence of humans in the space flight environment requires implementation of a medical program which will ensure their health. Previous spaceflight experience indicates that weightlessness can present serious physiological problems to crewmembers, including but not limited to those listed in the Table. Research in connection with current Space Shuttle flights will provide insight into some of these problems. However, Space Station activities will make possible a more thorough study of these and other space flight-related physiological problems.

Discussion

The proposed life sciences research program on the Space Station will be coordinated with the health maintenance program. The level of research activity will be determined by the Space Station configuration that is available, since a modular growth of the station is anticipated. Inside the initial configuration, a single module docked to an orbiter, research will consist of observing and monitoring the crewmembers, as well as collecting and storing physiological samples such as blood, urine, and feces for analysis after returning to Earth. An additional module will expand the research activities to include on-orbit processing of these samples. The availability of additional work and habitation areas will permit sophisticated medical facilities similar to those available in a one-physician clinic, with added capabilities. This area will be used for health maintenance and clinical research. Dedicated habitats and laboratories separate from the health maintenance facility will be required to conduct large-scale research with animals and plants. Of particular interest are the physiological effects of microgravity on organisms and the role gravity plays in the function of biological systems.

To implement this research, the Space Station must provide certain basic capabilities such as the resources to maintain the physical and psychological

SOME TOPICS FOR PHYSIOLOGICAL RESEARCH ON THE SPACE STATION

Redistribution of body fluids

Excessive excretion of electrolytes

Altered circulating levels of hormones

Cardiovascular deconditioning, cardiac muscle changes

Reduced red blood cell mass

Changes in red blood cell morphology

Loss of muscle tissue and negative nitrogen balance

Possible suppression of immunological systems

Bone demineralization and negative calcium balance

Vestibular function - otoliths and semicircular canals

Vestibular ocular and postural muscle reflexes

Gastrointestinal function, esophagus, stomach

Visual acuity

Pulmonary function and perfusion

Dysbarism in microgravity

Thermal regulation

Sweating

Pulmonary particle clearance

Psychological aspects of orbital living

well-being of crewmembers, some measurement of crew health and performance, onboard storage of experimental specimens, and two-way real-time transmission of video and other data between orbit and Earth. As the Space Station evolves, other capabilities should be added, such as limited onboard sample processing and analysis capability. Also needed is the ability to modify and upgrade equipment for medical and experimental procedures, and provisions for the maintenance of simple plants and small animals for periods of 30 days to a year. Finally, a larger biological research facility should permit automatic or semi-automatic operation of plant and animal habitats. Crew visits will probably be required. An onboard centrifuge would provide "pseudo-gravity" for experimental controls and low-gravity experiments. Ground-based facilities required to support the inflight studies include appropriate facilities for animal and plant-holding. Data analysis and laboratory facilities will also be needed.

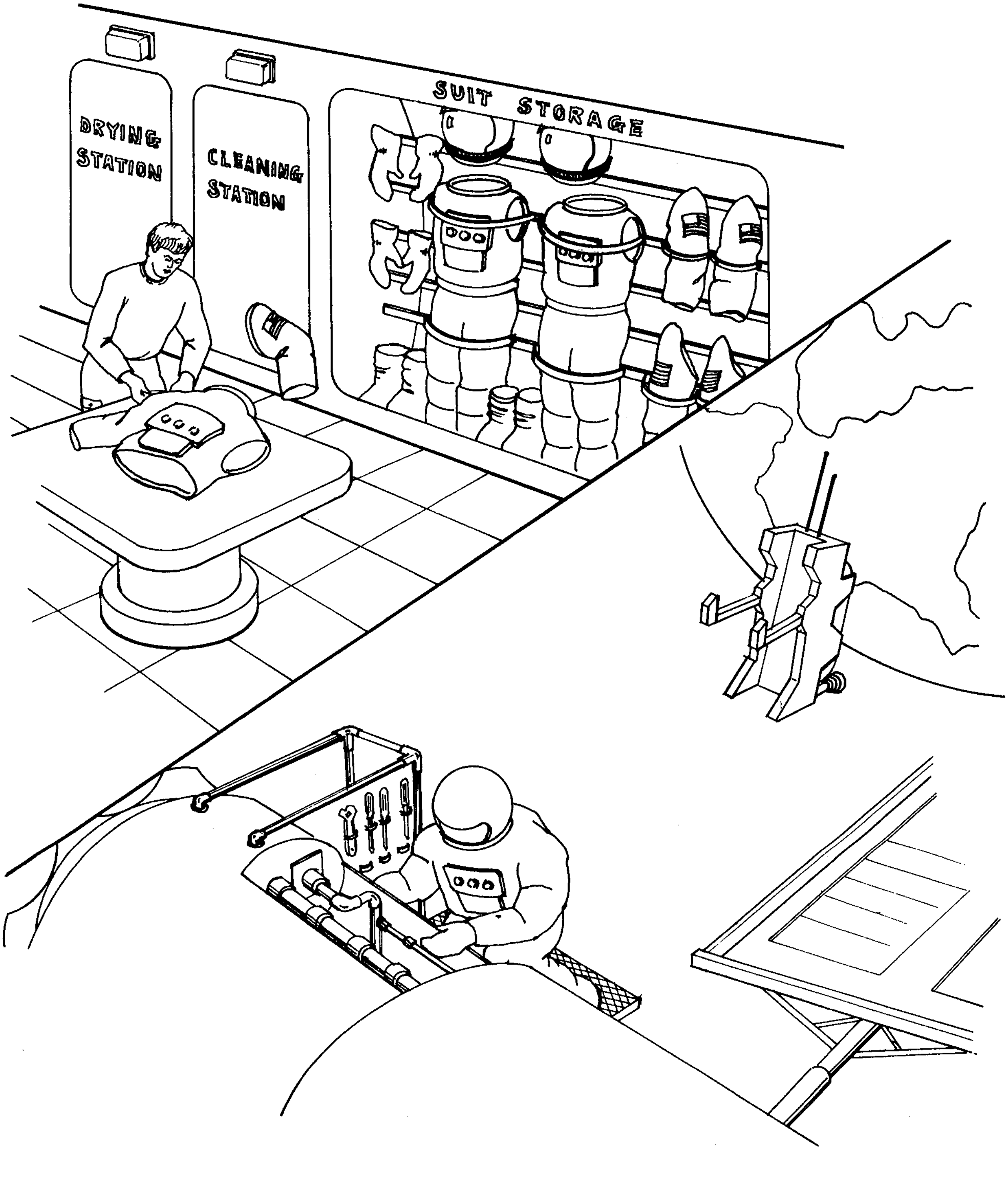
In addition to aiding the study of the physiological effects of weightlessness, laboratory facilities will permit the development of advanced life support systems and controlled ecology life support systems (CELSS). Although the Station will require periodic resupply, many consumables may be regenerated on the Station, thereby saving the cost of some Shuttle flights. The Space Station will have a continuing program of technology and subsystem development to improve life support systems. A major problem for a CELSS is the recycling of metabolic wastes to produce food and other consumables. Current efforts are related to the photosynthetic production of food and oxygen by higher plants and algae. Research will be directed towards understanding the fundamentals of these and other biological processes and their adaptation to weightlessness, as well as the interactions of biological systems with the spacecraft environment.

Research laboratories also will be available for industrial and commercial activities, like materials processing, with the potential for important scientific breakthroughs of high economic return. Such investigations will take advantage of the extended microgravity of orbital flight and the ultrahigh vacuum present in unlimited quantities. Specific areas include biological preparations; electronic materials; glass and ceramics; physical processes in fluids; and chemical, electrochemical, and metallurgical processes.

Recommendations

Since it will be the researchers themselves who determine the details of commercial and scientific research, they must be encouraged to generate recommendations early enough to take advantage of the flexibility of the initial stages of Station design. Similarly, the long lead-times inherent in equipment development necessitate the timely definition of hardware which cannot be met by off-the-shelf equipment.

During Space Station operations, provisions should be made for the routine and speedy incorporation of new knowledge into ongoing efforts. Special attention should be paid to the proper interrelationship of on-orbit activities. The very features of Earth orbit which make it attractive to industrial and scientific endeavors will influence the physiological capabilities of the human investigators. A continuing program of research into the biological effects of microgravity is absolutely necessary to maintain the productivity and morale of Space Station personnel.



EXTRAVEHICULAR ACTIVITIES

Pressure suits will be maintained, cleaned, repaired, and refurbished onboard the Space Station. Extravehicular tasks of resupply, inspection, and repair will be accomplished with the aid of portable work stations providing restraints, tools and information systems, and by remote controlled mobility units for transportation of the crewman and his equipment.

EXTRAVEHICULAR ACTIVITIES

James M. Waligora

Introduction

Extravehicular activities (EVA) refers to excursions by crewmembers outside the cabin environment in a pressure suit. The experience of Skylab has demonstrated the value and versatility of EVA in terms of planned resupply and maintenance of spacecraft as well as in repair of disabled spacecraft systems. It is anticipated that there will be extensive EVA activity originating from Space Station, possibly on a daily basis. Types of EVA activity will include refueling and refurbishment of satellite and Shuttle, repair and refurbishment of Space Station components, and fabrication of structures outside the Space Station. It is likely that structure fabrication will be automated, but EVA will be required for inspection of work and repair of robotic fabricators.

Discussion

As depicted in the figure on the facing page, the components of an EVA system will include a pressure suit; a life support system, either in backpack form or, more likely, integral to the suit; a work station to provide crewmember restraint, tool storage, two-way communication with an information retrieval system; and a remote controlled, summonable maneuvering system that will allow free movement of the EVA crewmember in the vicinity of the Space Station.

The crewmember must be able to move freely from the spacecraft environment to the pressure suit environment without prebreathing to prevent decompression sickness. The Table presents several combinations of cabin and suit pressures that could be used and still allow free movement of the crewmember from one environment to the other (in some cases, after preconditioning to the Space Station pressure).

Appendix C presents the rationale for analytically arriving at these combinations. These combinations are all equally acceptable in terms of the physiology and medical well-being of the crewmembers. The primary trade-off would appear to be between the increased flammability of materials with increased O_2 concentration at low cabin pressures and the reduction of arm and leg mobility at increased suit pressures. The pressure suit must also protect the crewmember from ionizing radiation both in low Earth orbit and in higher orbits out to and including geosynchronous. The use of hard rather than soft suit components may provide the needed reduction protection. The face plate of the suit must also protect against UV radiation.

Recommendations

In view of the extensive participation in EVA by a few of the Space Station crew it will be essential that the suit incorporate features to minimize crew fatigue. These features should include maximization of mobility and ease of work in the suit, as well as a quick donning and doffing capabiity to minimize "overhead" time at the beginning and end of EVA. Quick doffing and donning

PRESSURES AND PREBREATHE USED TO PREVENT ALTITUDE DECOMPRESSION SICKNESS IN SPACE FLIGHT

		Pressure psi	Oxygen %	Prebreathe
Gemini	Launch	14.7	100%	3 hr @ 14.7 on O_2
	Orbit	5.0	100%	None
	EVA	3.7	100%	
Apollo	Launch	14.7	100%	3 hrs @ 14.7 on O_2
	Orbit	5.0	100%	None
	EVA	3.9	100%	
Skylab	Launch	14.7	100%	3 hrs @ 14.7 on O_2
	Orbit	5.0	100%	None
	EVA	3.9	100%	
Shuttle STS	Launch	14.7	20%	None
	Orbit	14.7 - 10.2	20 - 26%	1 hr @ 14.7 on O_2 \ 12 hrs @ 10.2 on 27% O_2 + 40 min on 100% O_2
	EVA	4.3	100%	
Russian Spacecraft	Launch	14.7	20%	None
	Orbit	14.7	20%	40-60 min @ 14.7 on O_2
	EVA	5.8	100%	

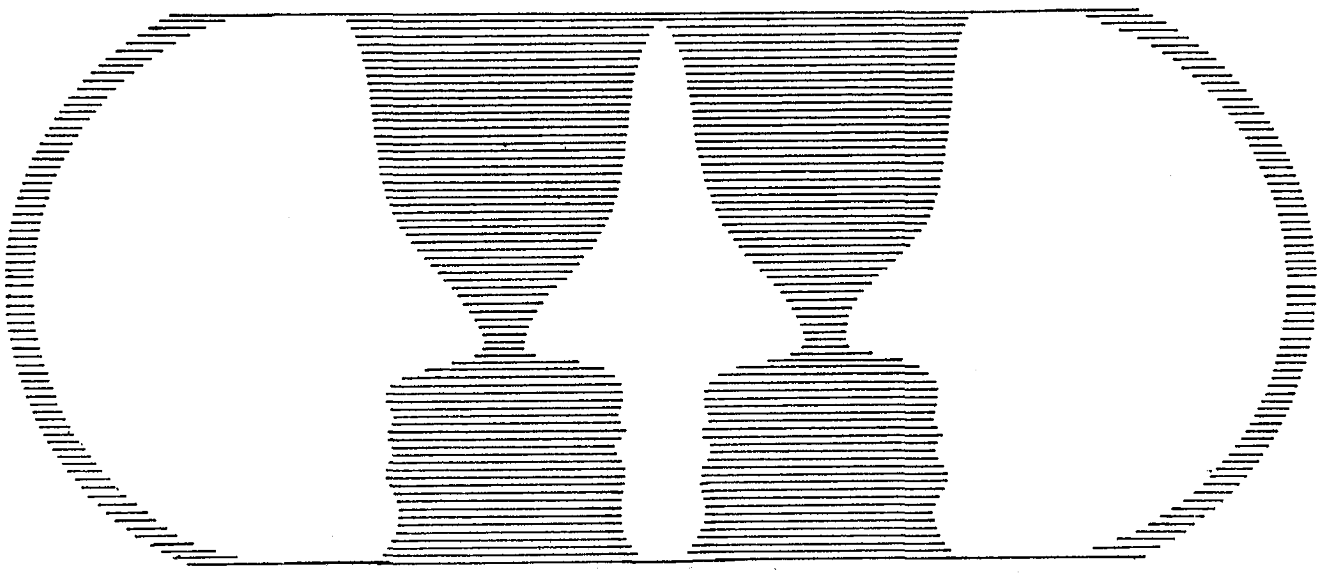
would allow a "lunch break" approach to long EVA's; however, improved insuit food and waste management systems should be an option for those situations where a long, unbroken EVA is required.

The pressure suit will be required to have a long service life. In addition it must be constructed in a manner that will allow it to be resupplied, maintained, repaired, cleaned, and refurbished on-station, as illustrated in the figure. These requirements will favor the use of hard components, modular design, simplified maintenance, and the development of sizing systems to maximize interchange of suit parts. The suit must be designed for easy cleaning to reduce buildup of microbiological flora. The development of washing and drying facilities, the use of bacteriostatic materials, and provision for a sterilization or partial sterilization capability will be required.

The Space Station EVA airlock should be designed in consideration of the fact that, despite precautions to prevent altitude decompression sickness, some probability of its occurrence will remain, particularly after use of contingency pressures of either the cabin or pressure suit. The treatment of choice for altitude decompression sickness is the application of hyperbaric pressure. To provide this treatment capability, the airlock should accommodate two occupants, and allow its pressurization to 2.8 atmospheres with 100% oxygen, the standard treatment pressure for altitude decompression sickness.

COMPATIBLE CABIN & SUIT PRESSURES TO ALLOW FREE MOVEMENT FROM ONE ENVIRONMENT TO THE OTHER

Cabin Pressure psi	Suit Pressure psi	Max O_2%	Constraints
14.7	8.0	26	None.
11.6	5.75	34	Stay at 11.6 psi 72 hrs prior to EVA.
10.2	4.8	38	Prebreathe 130 min prior to going to 10.2. Stay at 10.2 psi 72 hrs prior to EVA.
9.4	4.3	40	Prebreathe 220 min prior to going to 9.4. Stay at 9.4 psi 72 hrs prior to EVA.
7.5	4.3	48	Prebreathe 460 min prior to going to 7.5. Stay at 7.5 psi 8 hrs prior to EVA.



NEED FOR BIOBEHAVIORAL SERVICES

Leonard Gardner and Gary R. Coulter

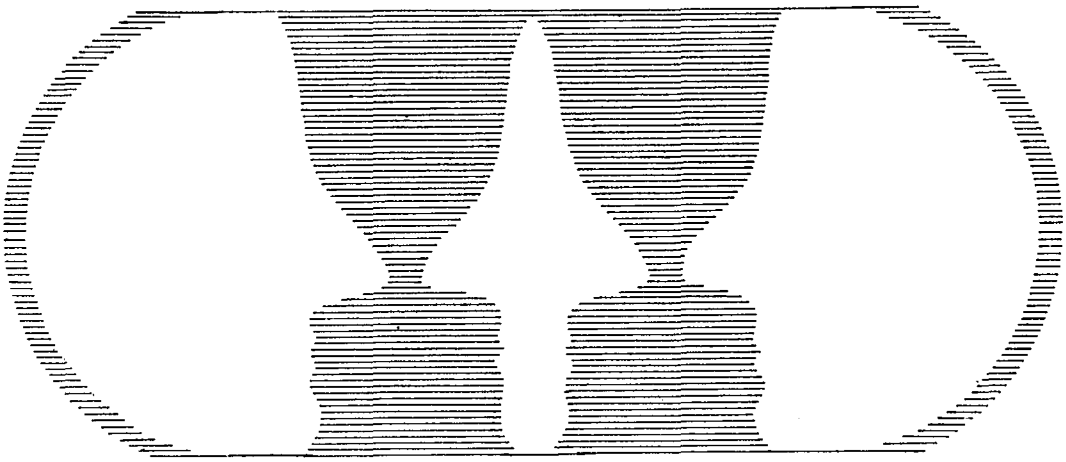
Introduction

NASA's biomedical operations and research programs continue to evolve to meet the novel challenges and needs required to support new space systems and missions. The purpose here is to acknowledge and call attention to the importance of an aggressive operationally-oriented program to deal with biobehavioral and psychosocial aspects of a space station. New and more complex space station systems and unique mission requirements dictate the need for evaluation, research, planning and implementation of such a program to be incorporated early in overall system development. Factors underlying the exigency for a prominent role for biobehavioral and psychosocial planning are longer missions, heterogeneous crews, role diversification, changes in command and social structures, and the importance of habitability considerations.

Discussion

In addition to career astronauts, Space Station personnel might be expected to include persons selected from outside the astronaut corps such as academic research scientists, construction engineers and workers, private sector commercial research and development scientists and technicians, and Department of Defense personnel. Such a mix will likely be necessitated by budgetary and user requirements. Thus, NASA's previous independence in personnel selection and mission assignment may necessarily evolve into collaborative decision making with outside agencies or companies. To derive maximum value from NASA's operational experience, it seems that establishment of specific biobehavioral standards and guidelines would be an approach worthy of serious consideration. It is inevitable that, heterogenous crews and mission roles, a less hierarchical, more egalitarian organizational structure will evolve having an impact upon both flight and ground command structures. Long missions and specific psychosocial patterns (between crewmembers and between the crew and ground control) also will greatly influence traditional authority structures.

NASA programs have relied successfully upon operational experience and common sense without detailed biobehavioral and psychosocial planning. The need was obviated largely by establishing a prestigious career professional astronaut corps selected principally from exceptionally qualified military flight crewmen, adhering to a vertical command structure, small crew size and/or short-duration missions. With the Space Station, these factors will change. The spirit of adventure will be modulated by mundane routine; the need for personal privacy will increase; separation from family and emotional support resources will intensify isolation and intra- and interpersonal tension; options for physical, leisure, and social activities will be restricted and a likely source of irritation and complaint. These and others will be influenced by crew interactions compatibility and cultural, sexual, and social makeups which can be catalogued under "habitability." Thus, the novel conditions on the Space Station strongly suggest that operational decision making will greatly benefit from, and indeed require, more specific psychosocial and behavioral information and planning in order to minimize potential problems as well as to maximize the achievement of mission objectives.



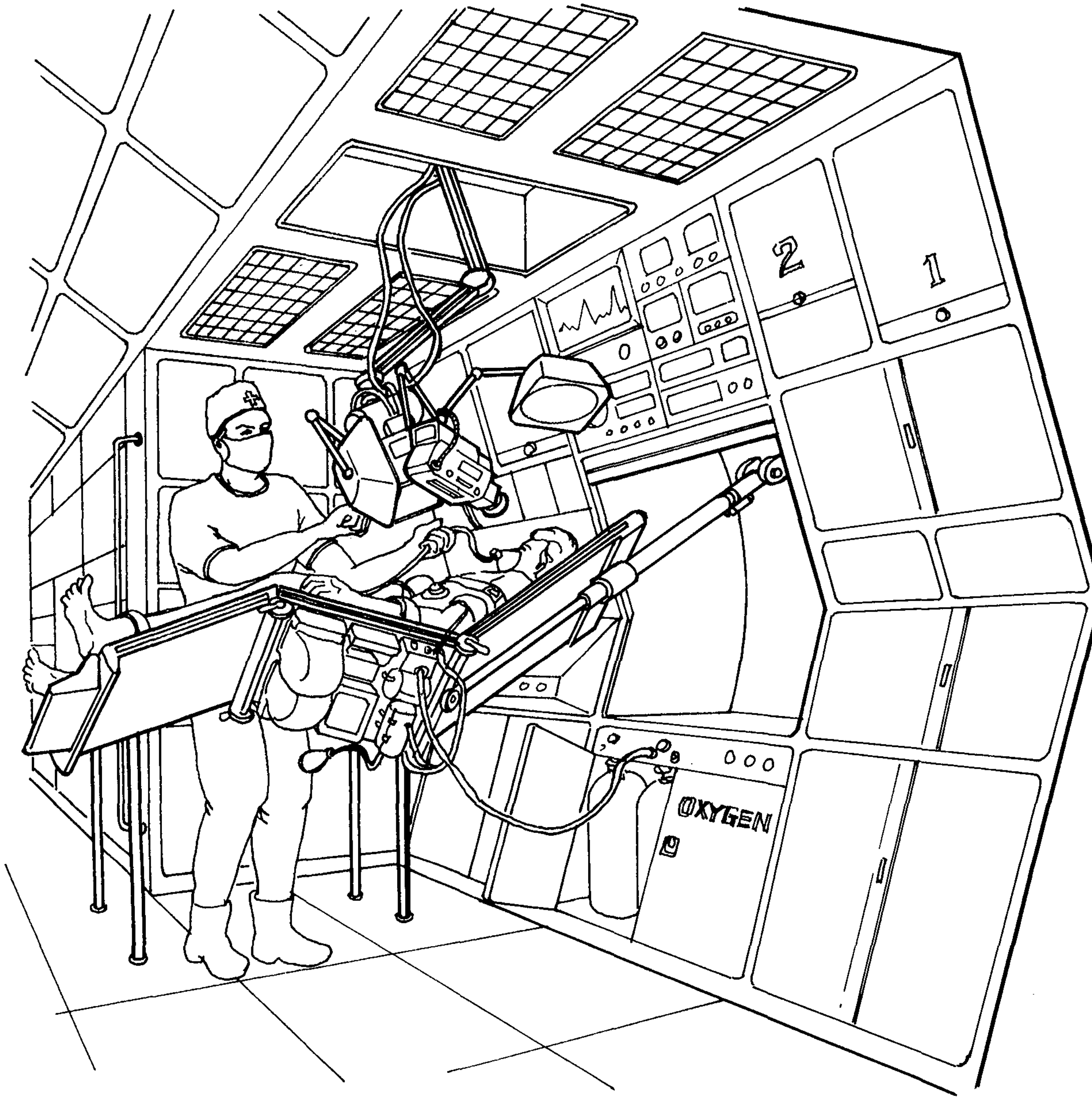
SPACE SYSTEMS AND MAN, THE OPTION: INTERFACING OR INTEGRATION

The complex systems, mission requirements, and crew productivity will be much more highly interdependent onboard the Space Station and can be optimized with greater reliability if biobehavioral factors are evaluated and incorporated early in program development. Human factors and man-machine interfacing are necessary but not sufficient. Biobehavioral input can positively augment these areas and contribute information essential to personnel selection, assignment and training decisions. Individual ability to complete tasks and crew productivity will depend in large measure upon such factors as stress and isolation tolerance, psychophysiologic adaptability, emotional self-control, family situation and stability, personality style, small group interactive skills, adaptive competence and others. Psychological and biobehavioral data which characterize these elements can be obtained and integrated to maximize crew compatibility, adaptability, productivity, and mission accomplishment.

Recommendations

The advantage of having behavioral information available has been stressed. However, the operational relevance of such information must be underscored. An operationally focused role for biobehavioral medicine is recommended. A biobehavioral operations group service would include the following: assessment of system mission requirements from a comprehensive behavioral perspective; profiling crew characteristics to optimize selection, assignment, and training decisions; providing biobehavioral training in physiologic self-regulation as a space adaptation countermeasure; training in stress management; providing psychoeducation in small group dynamics, conflict resolution, diffusion of emotional intensity and frustration, facilitating intra- and interpersonal harmony; providing ground-based support and behavioral ombudsmen for crews as they interact with mission control; and providing general and specific recommendations regarding psychosocial aspects to habitability design groups.

The inclusion of relevant, operationally focused biobehavioral input in the program development and operation of a Space Station would be a further example of NASA's biomedical operations and research meeting the needs of a new space endeavor.



MEDICAL CARE

A physician monitors an ill crewmember in the Space Station Health Maintenance Facility (HMF). The HMF is equipped with state-of-the-art clinical bioinstrumentation, diagnostic imaging, clinical laboratory, life support hardware, minor surgical capability, and general pharmacy.

MEDICAL CARE

Joseph C. Degioanni, James S. Logan, and Michael A. Reynolds

Introduction

Inflight health care is an absolute requirement for mission success. On-orbit medical care will promote crew safety and maximize performance. An inflight Health Maintenance Facility (HMF) could also prevent the unfortunate scenario of an unscheduled rescue mission for medical reasons. The estimated minimum time necessary to effect a rescue of an ill or injured crewmember from the Space Station may be 15 to 21 days. The impact of such an unscheduled emergency flight would be significant in terms of timelines, manpower, and costs. In all probability, an illness of sufficient severity to warrant a rescue attempt would result in patient demise prior to a "successful" rescue. Therefore, inflight medical care capabilities are essential to crew health, safety, and overall mission objectives.

Discussion

As mission complexity, duration, and crew size increases, the probability of significant inflight medical events increase. Therefore, flexibility must be inherent in the design of the HMF. It should be a dynamic facility on system, able to constantly change, so continuing improvements in medical science can be incorporated. In addition, a dynamic system can easily be adapted to provide medical support for unforeseen problems which may arise secondary to spacecraft and environmental or operational hazards (see table 1, Summary of Hazard Assessment). Of special interest are improved methods to predict, prevent, and control infectious disease inflight and evaluate the impact of low-level chronic exposure to toxic substances. In addition, the role of occupationally induced disease must be investigated and ameliorated.

In considering the appropriate diagnostic and therapeutic capabilities to be available on-orbit, the concept of the "acceptable medical risk" must be defined. For example, the treatment for appendicitis is an appendectomy. However, the capability for major abdominal surgery in early space stations will not exist. With proper diagnostic and therapeutic tools, a crewmember might be maintained until a rescue mission returns him/her to Earth for definitive therapy. Without inflight medical support capabilities, a rescue mission for appendicitis would probably be made in vain. On the other hand, uncomplicated cases of diverticulitis (inflammation of the colon) or cholecystitis (inflammation/infection of the gallbladder), once diagnosed, could be successfully treated inflight. The inflight medical capability will be equivalent to a level IV emergency medical facility unless a physician is present aboard the Space Station in which case the facility is upgraded to level III (see appendix--Classification of Emergency Services according to the Joint Commission on Accreditation of Hospitals, 1984).

Low weight, low volume, fully automated diagnostic laboratory equipment must be included in the HMF. Routine clinical chemistry, hematology, microbiology, urine analysis, and toxicologic monitoring are essential. In addition,

TABLE 1 - SUMMARY OF HAZARD ASSESSMENT (REF. NASA TM 58248)

- SPACE SICKNESS, EARLY MISSION AND INTERMITTENTLY DURING LATE MISSION
- DYSBARISM, JOINT BENDS, CEREBRAL BENDS
- OXYGEN DEFICITS AND EXCESS (OXYGEN TOXICTY)
- EXPOSURE TO TOXIC SUBSTANCES
  - Acute - hypoxia (e.g., CO, CN, etc.), chemical burn, cryogenic burn, allergy, pneumonitis/pulmonary edema, neurological symptoms
  - Chronic - pneumonitis, neurological deficits, gastrointestinal pathology; miscellaneous
- INFECTION: DERMAL, UPPER RESPIRATORY TRACT, PULMONARY, URINARY TRACT, FOOD-BORNE
- ELECTRIC SHOCK
  - Burns
  - Cardiac Dysrhythmias
- RADIATION (Polar Orbits Primarily)

Acute Sublethal Dose	nausea, vomiting, hematological depression
Acute Midlethal Dose	above + death in approximately 30 days
Acute High Dose	above + gastrointestinal denudation + death in approximately 1 week
Chronic Dose (Multiple Missions)	increased risk of leukemia, cancer, cataracts, and other late effects

- EMBOLISM, THROMBOPHLEBITIS
- TRAUMA
  - Minor - small lacerations, contusions, abrasions
  - Moderate - foreign body in the eye, deep lacerations, concussions, fractures of small bones of hand and foot
  - Major - fractures of long bones, ribs; skull fractures (includes subdural/epidural hematoma); penetrating injuries of visceral cavities; blunt thoracic, abdominal, musculoskeletal injury; joint instability; spinal problems
- BURNS - MAJOR AND MINOR
- THERMAL HEAT EXHAUSTION, FROSTBITE
- OCULAR UV BURNS
- BLOOD VOLUME - EXCESS EARLY, DEFICIT LATE

physical exam equipment (stethoscope, etc.), EKG, EEG, and some form of diagnostic imaging are required.

Besides treating the routine medical conditions expected to occur during space flight (see appendix D), the capability must exist to deal with acute critical care and trauma situations. Serious injuries and illnesses requiring surgery will be less probable but potentially more dangerous. To a first approximation, the probability of such events can be estimated from experience on nuclear submarines. During 7,650,000 man-days of Polaris submarine missions in 1963-1973 (see appendix E), there were 269 general surgery cases, of which 6 required transfer at sea and 70 were appendectomies. By comparison, eight-man Space Station crews would accumulate 2,920 man-days in a year's operation. On the basis of crude proportionality, one could anticipate a need for surgery once every 9 or 10 years and an appendectomy about every 35 years in space. A total of 44 patients were transferred from Polaris submarines at sea for all reasons during 1963-1973; this could correspond to one case requiring evacuation in about 60 years for the Space Station provided that crew physical health, age, occupational tasks, and living conditions are similar.

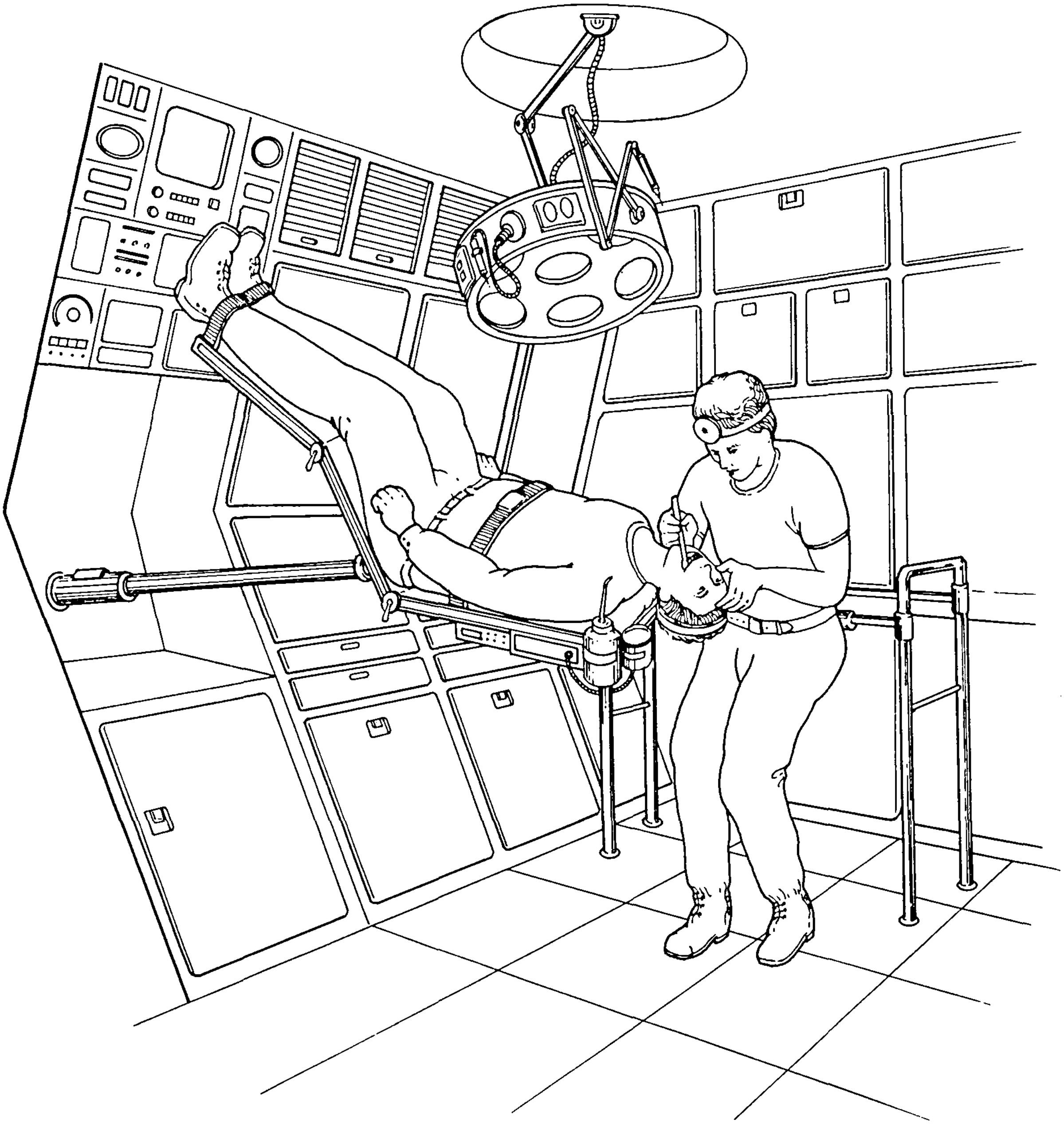
The capability to deal with acute critical care and trauma situations presupposes intravenous access, basic and advanced cardiac and pulmonary life support capability, and minor surgery/anesthesia equipment. A two-person hyperbaric treatment chamber to treat decompression sickness should be an early requirement. The need for physiological measurements to study human adaptive changes to microgravity such as SAS must be taken into account when specifications are made up for the diagnostic tools to be provided in the Space Station's medical equipment. Since these studies will also need a trained observer, it is likely that a physician, preferably a trained surgeon, will be needed in every crew to perform the dual function of caring for the crewmembers' health and observing them as subjects for research.

Recommendations

It is recommended that an area dedicated to the HMF be included in the initial Space Station module. In addition, it would be desirable to design the galley and dining room so that either might be made to serve as an emergency surgical area with adequate lighting, suction, oxygen, etc. The area should be made to allow it to be isolated from other crew activities and sterilizable.

Realistic requirements will be developed for a level III Emergency department capability similar to the Skylab facility for early missions, and particular emphasis will be given to identifying state-of-the-art diagnostic and therapeutic devices. High priority medical procedures/techniques such as minor surgery, tissue and sample handling, and drug therapy in the Space Station environment need to be identified and developed.

It is desirable that the HMF of the early Space Station contain provisions for the storage and retrieval of medical data from its scientific crews. The full extent of physiological changes resulting from long-term space flight can only be detemined through measurements made on a large population of Space Station inhabitants by surveying literally every crew until the data was obtained.



MAINTENANCE OF DENTAL HEALTH

The risk of a dental problem in flight can be met utilizing the medical facilities. The position of the patient can accommodate the convenience of the operator in a microgravity environment.

MAINTENANCE OF DENTAL HEALTH

William J. Frome

Introduction

In NASA's Manned Space Flight Program, provisions have always been made for treatment of unanticipated dental problems inflight. The earliest flights--Mercury, Gemini, and Apollo--were all of short duration and the provisions were minimal. Skylab, however, presented missions ranging from 28 to 84 days in length. For the Skylab series of flights, a more complete dental treatment capability was developed. Considerations of dental health will continue in a more sophisticated manner as NASA considers the Space Station Program.

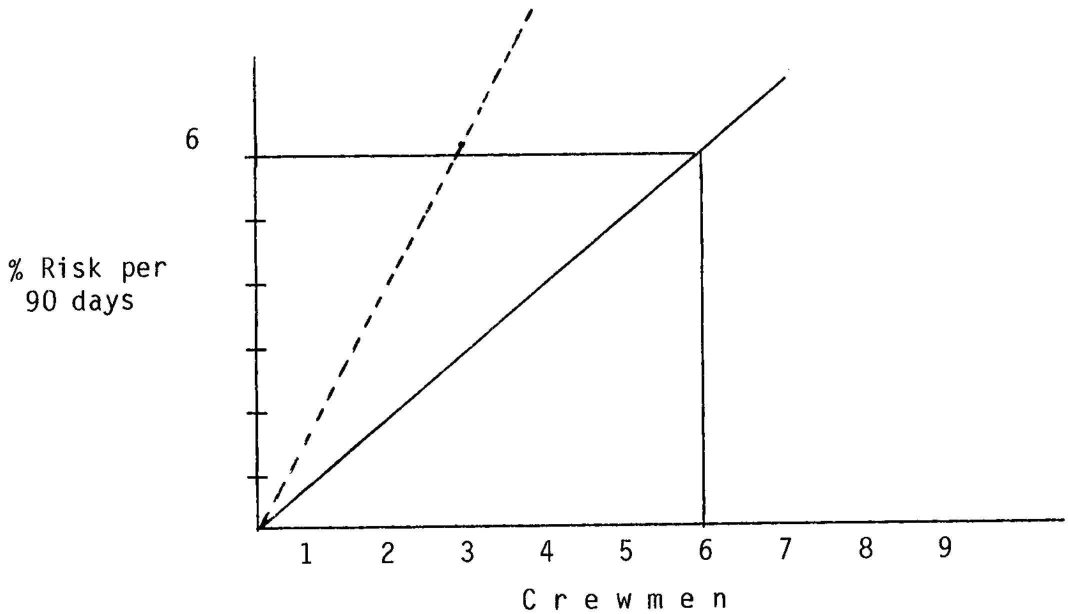
Discussion

The risks of a crewman developing an inflight dental problem severe enough to compromise his ability to function effectively have been calculated. Based on studies of the astronaut population, it is estimated that the risk is approximately 1 percent for each 90 man-days. That is equivalent to a problem of that severity occurring once every 24 years for an adult apparently in excellent dental health.

Dental problems most likely to appear are toothache (with or without swelling due to pulpitis or periapical abscess), peridontal abscess, or fracture of a tooth during normal function. Trauma in the space environment must be considered also. Dental decay would not be expected to be a consideration provided there continues to be the intense dental supervision of crewmembers during the preflight periods. Lesser problems, such as chipped teeth, fracture restorations, or benign oral soft tissue lesions would be expected to occur at somewhat more than twice that frequency. These lesser problems would not affect a crewman's ability to perform and would not be expected to increase in severity with time. However, it is expected that crewmembers will include nonastronauts whose dental history is less well-known. It is probable that risk estimates for those persons will be higher than for astronauts.

The dental treatment capability for Skylab consisted of developing a training program and the equipment to treat problems of a complexity up to and including tooth removal. To accomplish this, training sessions included lectures and actual clinical experiences in the appropriate procedures. Manuals were written to aid the astronauts inflight and arrangements were made for diagnosis and direction as needed from the mission control .

A general impression is that while the philosophy and treatment capabilities of Skylab should be retained, significant improvements should be made in the inflight facilities, equipment, and training. Preliminary suggestions include a designated treatment area with proper lighting and restraints for both the patient and the clinician or the dental aide. In considering restraints to movement, it should be pointed out that considerable force is required in some dental procedures: tooth removal, for instance. Suction also should be available as well as a more extensive collection of equipment and supplies than was present in Skylab. A more complete treatment capability would be useful only



The risk of a dental problem which might compromise a crewman's ability to function is 1% for each 90 days under ideal conditions which include continuous preflight dental prophylaxis and care.

The solid line is predicted from past experience with the astronaut corps and their use of Flight Operations Dental Clinic.

The hypothetical line is predicted if nonastronauts would become crewmembers and who have not had available adequate dental care prior to the mission.

Figure 1

if at least one crewmember with a background in biomedical sciences were to receive intensive training and extensive preflight clinical experience rather than minimal training for all crewmen as in Skylab.

Questions remain about treatment of dental problems in the microgravity environment and attempts to answer them should be made before a Space Station is inhabited on a permanent basis. These include operative problems that might occur in the oral area where saliva and blood might float freely rather than settle to the floor of the mouth. A separation of the debris could be serious. The difficulties in applying forces necessary for tooth removal in a microgravity environment should be explored, especially regarding restraints. Oral wound healing in the space environment should be confirmed. Information on factors such as bleeding and blood clotting involving both bone and soft tissue would be pertinent. Invaluable clinical experience and knowledge could be gained by experimentally removing teeth, probably in animal subjects. The use of local anesthesia in the microgravity environment should be evaluated. It could be hypothesized that in a microgravity environment the patients would be less prone to syncope--they would always effectively be in a prone position. Without the effect of gravity, anesthesia solutions would diffuse more uniformly in the tissues but might be more difficult to deliver without including bubbles.

Living in a microgravity environment could be stressful to unexperienced crewmembers. The probability exists that these individuals could develop or experience clinically significant exacerbation of their peredontal disease.

The drawing accompanying this article suggests a potential concept. In treating patients, it may be possible to liberate ourselves from some of our earthbound traditions. Since up and down are no longer meaningful with microgravity, we can position the patient for the maximum convenience of the operator. As can be seen in the drawing, the upper jaw in relation to the clinician has now become the lower jaw and viewing ability as well as operator access is remarkably improved. Other opportunities to capitalize upon the uniqueness of the space environment undoubtedly will be discovered.

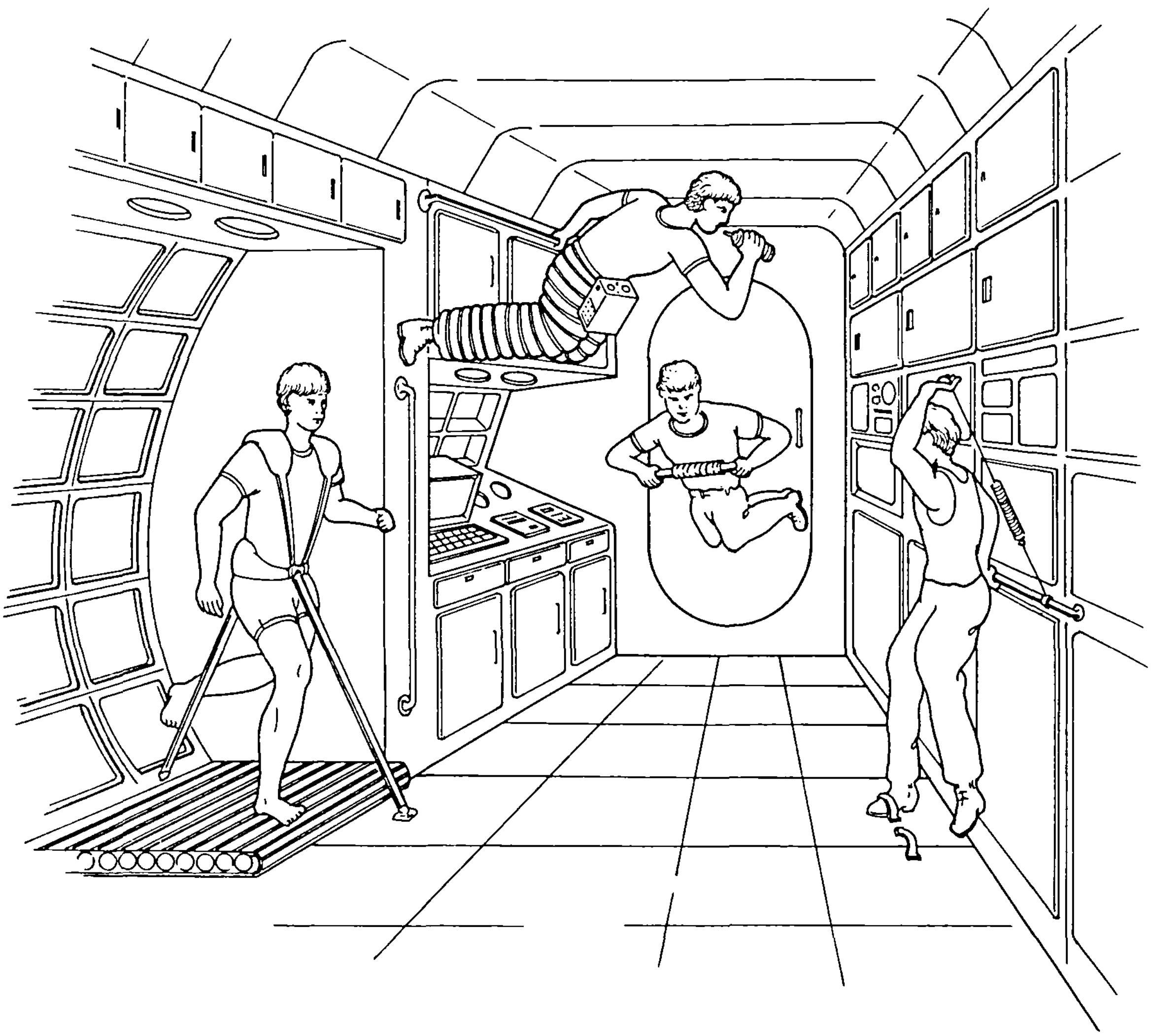
Recommendations

The following recommendations are made concerning dentistry in the Space Station:

a. In planning for a medical treatment facility, consideration should be given to the unique needs of providing adequate dental treatment. The facilities used for medical treatment could be adapted to dental treatment.

b. At least one individual crewperson should receive intensive preflight training in providing crew dental treatment in the space environment.

c. Wound healing must be investigated in the space environment. It would seem that tooth removal might be a promising method for this study as it is a relatively benign procedure and involves manipulation and healing of both bone and soft tissue.



MAINTAINING HEALTH THROUGH PHYSICAL CONDITIONING AND COUNTERMEASURES

Exercise will be utilized for recreation, physiologic testing, and maintenance of cardiovascular function and peripheral muscle tone. It will be supplemented by other techniques, such as lower body negative pressure and pharmacological techniques.

MAINTAINING HEALTH THROUGH CONDITIONING AND COUNTERMEASURES

Michael W. Bungo and John B. Charles

Introduction

The well-being of Space Station personnel requires attention to their physiological and psychological adjustments to the conditions aboard the Space Station, and to their readjustments to life on Earth after their return. One of the primary concerns is the physiological adaptation to weightlessness, in terms of its effects both inflight and afterwards. This adaptation includes the loss of skeletal calcium, of muscle mass and nitrogen stores, and of red cell mass and blood volume. Also, decrements in exercise capacity and orthostatic tolerance are seen after extended periods of weightlessness. Each of these changes is a predictable physiologic response to the reduced physical stress of life without gravity and is also a serious impediment to the resumption of regular activities on Earth.

Discussion

Previous efforts to counter the adaptive changes in space flight have centered primarily on exercise as a means of providing the musculoskeletal stress that is otherwise absent in weightlessness (see table). This work had made use of traditional exercise modalities, each having strengths and weaknesses in this application. For example, the bicycle ergometer used on Skylab provided for the maintenance of cardiorespiratory exercise capability, and also temporarily relieved the uncomfortable effects of the headward fluid shift. However, it was inadequate for the maintenance of skeletal muscle exercise capacity and mass. A weakness common to all of the methods has been the time required for any beneficial effects to be obtained. A single exercise may require several hours or more of daily use to be effective. The time problem is compounded by the number of different exercises required to maintain the desired degree of physical fitness, and the additional time spent on assembling and disassembling the necessary equipment and on personal hygiene afterwards. The total time commitment will be a significant fraction of the workday, which might otherwise be devoted to the activities initially necessitating the individual's presence aboard the Space Station.

Methods other than exercise have been investigated to counter the orthostatic hypotension commonly observed in astronauts immediately after flight (see table 1). The use of an antigravity garment to provide lower body positive pressure protected the Skylab astronauts from the consequences of blood pooling for several hours after their return. It was, however, a simple mechanical construct which did nothing to restore normal physiological function. Such restoration has been attempted through various other means. Intermittent thigh cuff inflation inflight, to promote blood pooling in the legs and thus preserve both circulating volume and vascular smooth muscle tone, proved to be ineffective during space flight. Experiments on returning Shuttle astronauts indicate that simple oral rehydration with an isotonic saline solution, to replace some of the lost plasma volume before atmosphere entry, provides a significant degree of protection from orthostatic hypotension following weightlessness. Ground-based studies combining rehydration with lower body

TABLE 1 - MICROGRAVITY COUNTERMEASURES INVESTIGATED IN SPACE FLIGHT

METHOD	GEMINI	APOLLO	SKYLAB	SALYUT	SHUTTLE
Exercise					
Isotonic Exercise	X	X	X	X	
Bicycle Ergometer			X	X	
Running Board, Treadmill			X	X	X
Non-exercise					
Thigh cuffs	X				
Anti-gravity garment			X	X	
Saline loading					X
Saline loading plus LBNP				X	

negative pressure suggest that a more prolonged rehydration and a larger sequestered volume can be obtained. This process has apparently been used with some success by Soviet cosmonauts at the termination of their extended stays aboard the Salyut space stations.

It should be noted that the exercise and non-exercise methods tested have not eliminated the wasting of the musculoskeletal system, nor have they counteracted the development of post-weightlessness orthostatic intolerance. Whether these results could be improved by more intense application of the methods described, or will require countermeasures yet undeveloped, must be determined by future research.

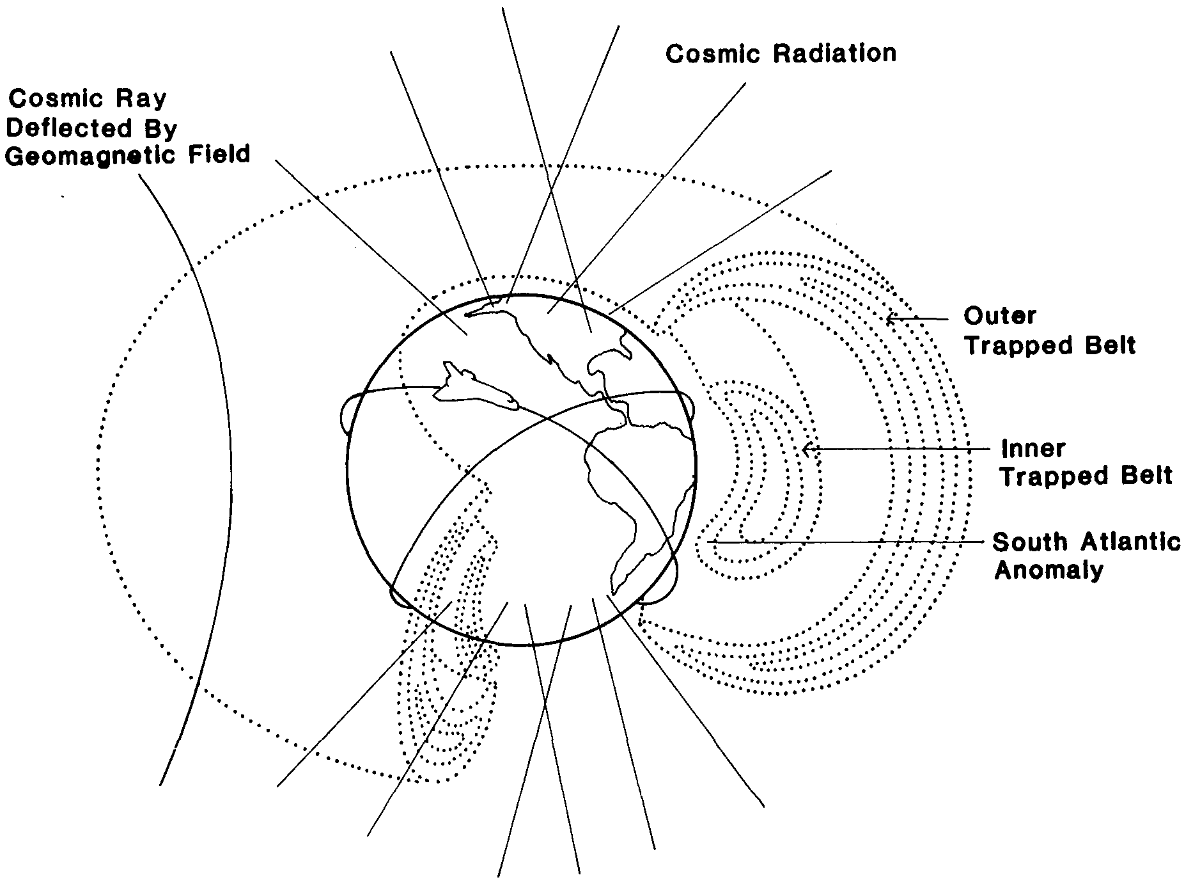
Recommendations

It must be recognized from the outset that, for the physiological well-being of the Space Station personnel, allowance must be made for an on-going program of physical exercise. The substantial daily time commitment must be weighed against an enhanced productivity when the individual continues his preflight regimen of physical exercise. Exercise will provide an outlet for the emotional upsets and frustrations to be expected during an extended stay in an unusual environment, under strong pressure to achieve results, and away from the support of family and friends. The crewmember's motivation also will be enhanced by the realization that, through physical conditioning, a speedy return to normal life on Earth will be possible.

From the foregoing considerations, a hypothetical physical conditioning and countermeasures prescription can be outlined. The planned exercise program will include loaded treadmill running for the maintenance of cardiorespiratory exercise capacity. Elastic bungee cords attached to a harness system will load the individual sufficiently to permit running on the treadmill. Additionally, the continuous impacting of the feet on the treadmill surface may sufficiently stimulate the load-bearing bones to slow, or even reverse, the skeletal wasting seen during long space flights. Skeletal muscle conditioning, especially of the arms and trunk, will be accomplished using isotonic and isokinetic exercise devices. Additional protection of the skeleton and the musculature may be provided by drug therapy.

An "end-of-tour" regimen will ease the transition back into Earth's gravity. As currently envisioned, this regimen will commence a week or so before the return to Earth. Daily exposure to about four hours of 30 mm. Hg lower body negative pressure combined with oral rehydration therapy, using a saline and glucose solution, will augment the body's decreased plasma volume and begin the readaptation of vascular smooth muscle in the legs to the hydrostatic gradients which are absent in weightlessness. The movement of fluid into the interstitial spaces will also be facilitated, preventing the loss of filtrate from the circulating blood volume after returning to Earth.

These recommendations are the products of work to date; the details will surely change in the light of research over the next several years. However, the general considerations discussed here can serve as a foundation for other aspects of Space Station design and operations planning.



PROTECTION FROM RADIATION

Schematic representation of the sources of ionizing radiation in space.

PROTECTION FROM RADIATION

D. Stuart Nachtwey

Introduction

The Space Station is expected to operate in a 28-1/2° orbit and at an altitude of 500 km. In this orbit, the major source of radiation will be the inner, geomagnetically trapped protons (Inner Van Allen Belt) (see fig.). Most of the radiation dose from the belt will be received during traversal of the South Atlantic Anomaly, a region where, because of an anomaly in the Earth's magnetic field, the inner belt dips down to lower altitudes. The other sources of orbital radiation--the outer belt, which consists primarily of energetic electrons, the galactic cosmic radiation, and the radiation from solar flares--will contribute only a little to the dose because of deflection by the geomagnetic field.

Discussion

The Space Station will likely have a minimum structural thickness of about 2 g/cm^2 of aluminum-equivalent material. Behind a shield of this thickness, at 500 km and 28-1/2°, the dose to the skin is about 240 millirad (mrad) per day and the dose to the bone marrow (5 cm dose) is about 150 mrad/day. Thus for a 90-day tour of duty, a crewperson could receive up to about 22 rad to the skin and 13.5 rad to the bone marrow and other organs from the trapped proton belt. Additional radiation to the skin might be received during EVA. A worst case situation (EVA during the four or so successive passes through the South Atlantic Anomaly) could add 3 rad to the skin for one 6-hour EVA.

At 28-1/2° and 500 km, the geomagnetic field protects against most of the radiation from solar particle events; only about 1% of the free space dose penetrates to that orbit. Nonetheless, some very rare but very intense solar flares have been recorded in free space at about 1000 rad. Therefore, the potential contribution to the total dose from anomalously large solar particle events must be considered in budgeting crew exposures.

The immediate impact of a nominal mission with about 15 rad/tour is negligible. The potential effect from this dose will be realized later in the crewperson's life mainly as an increased risk of contracting cancer. Although the risk estimates for radiation carcinogenesis have large uncertainties (about an order of magnitude) and are dependent upon a number of variables (age, sex, type of cancer, dose-response model, etc.), a rough estimate of increased lifetime risk from 15 rad would be 1.5×10^{-3}. One would expect 15 deaths from radiation-induced cancer in 10,000 crewpersons exposed to 15 rad. This increase represents about 1% of the expected 1640 out of 10,000 (1.6×10^{-1}) who would normally die of cancer sometime in their lifespan. Multiple tours would increase the inidividual's risk proportionately. For example, 150 rad accumulated during 10 tours would increase the risk to 1.5×10^{-2} which is about 10% of the natural lifetime risk.

The aforesaid value should be viewed in some perspective: 150 rad is calculated to yield, on average, 150 days of life expectancy loss. The average

TABLE 1 - SUGGESTED EXPOSURE LIMITS AND EXPOSURE ACCUMULATION RATE CONSTRAINTS FOR UNIT REFERENCE RISK CONDITIONS

Constraint	Primary Reference Risk (rem at 5 cm)	Ancillary Reference Risks			
		Bone Marrow (rem at 5 cm)	Skin (rem at 0.1 mm)	Ocular Lens (rem at 3 mm)	Testes (rem at 3 cm)
1-year average daily rate		0.2	0.6	0.3	0.1
30-day maximum		25	75	37	13
Quarterly maximum[a]		35	105	52	18
Yearly maximum		75	225	112	38
Career limit	400	400	1200	600	200

[a] May be allowed for two consecutive quarters followed by 6 months of restriction from further exposure to maintain yearly limit.

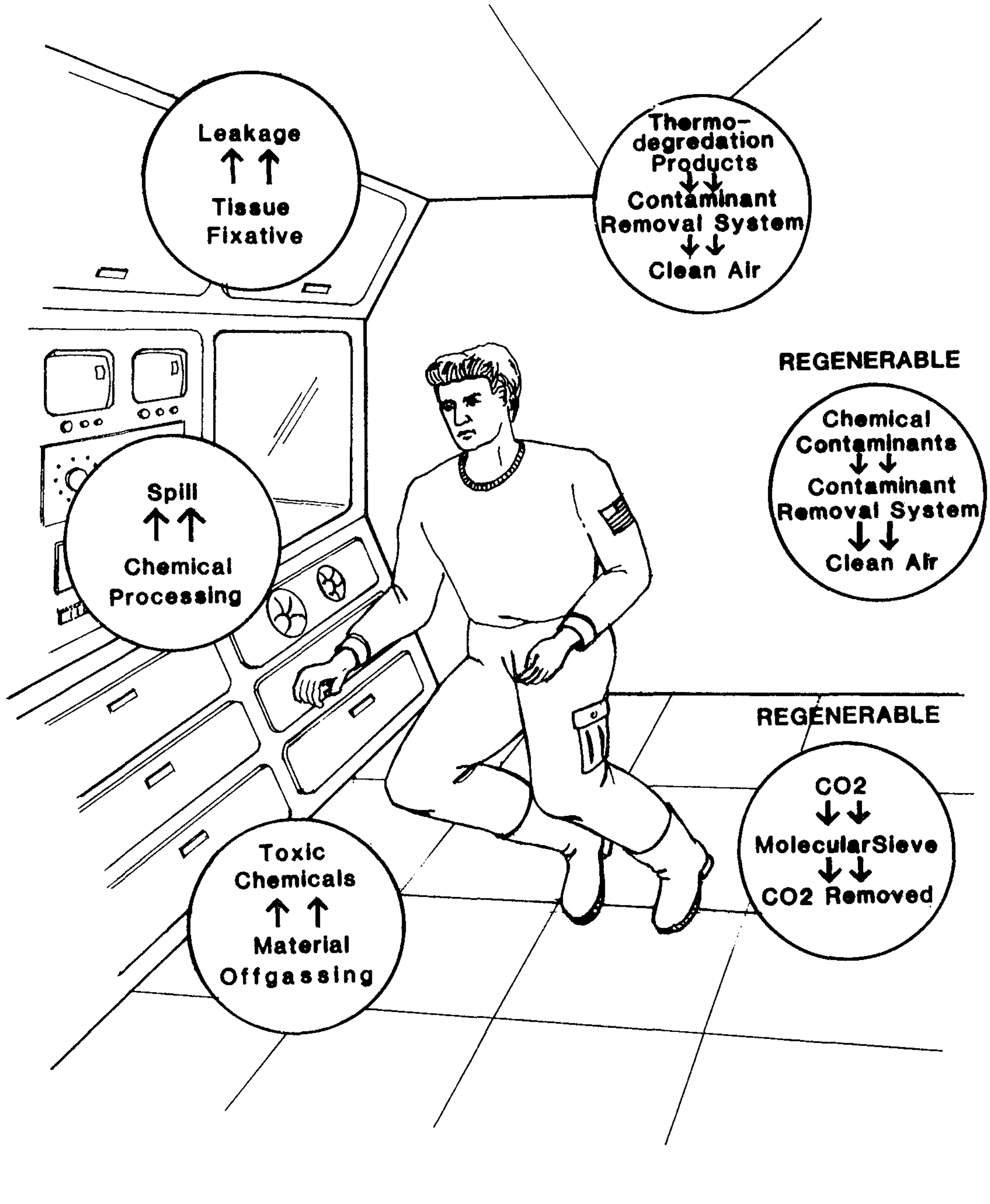
safe job (e.g. teaching) leads to an average 30 days life expectancy loss; the average "less safe" job (e.g. construction and mining) leads to a 300 day loss. Coal mining leads to a 1100 day loss. If work in a Space Station is considered as a "less safe" occupation, then the radiation exposure problem should be viewed in this context.

Heretofore, NASA's Astronaut Radiation Exposure Limits (see Table) were predicated, in part, on the high risks involved in space missions. With experience, the risks of equipment failure are declining. Moreover, since 1970 when the limits were recommended, more has been learned about radiation effects. It is not unreasonable to expect that space crew radiation limits may be revised downward toward the career limits for terrestrial workers, which is 235 rem (equivalent to 235 rad of low LET radiation). This is particularly true if large numbers of individuals will be exposed to the environment.

The few virtually unshieldable, galactic cosmic heavy particles/day contribute very little to the overall dose. However, these heavy, charged particles are so energetic that they can produce a densely ionized track through the entire body with a consequent track of dead and damaged cells. The biological consequences of such heavy particles are poorly understood, but recent evidence suggests that they can be very effective in inducing cancer at a later time. Therefore, although rare, they should be given special consideration and at least measured separately from the proton belt dose in order that the true biological significance for human can be calculated.

Recommendations

Should the above discussed consequences of space radiation be unacceptable, potential countermeasures could be employed: The overall shielding of the Space Station could be increased, either through dead mass or judicious stowage of water, wastes, equipment, and non-expendable items. (To reduce the bone marrow dose to half, i.e., 75 mrad/day, requires the equivalent of an additional 20 g/cm^2 of structure.) Partial body shielding of the lower abdominal area (e.g., with a lead-loaded girdle) could be utilized for individuals likely to conceive after their Space Station tour. Otherwise sheilding of the bone marrow and lens of the eye should be considered. To protect against a catestrophic exposure bone marrow banking on Earth could become useful. The Station could be maintained in a lower altitude orbit. (At STS orbits of about 300 km, the dose-rate is about 6 mrad/day). Radiation exposure of the crew could be budgeted to a predetermined acceptable level by restricting number of tours. All of these potential countermeasures require tradeoff studies to determine the impacts on missions, mass-to-orbit costs, and operational flexibility. An optimization appears readily achievable. Potential population of proginey and age at the time of exposure could be included in the allowable limits if lifetime radiation exposure becomes too high for the regulating authorities to readily accept for the population in general.



ATMOSPHERIC CONTAMINATION CONTROL

Atmospheric contaminant sources and removal in the Space Station.

ATMOSPHERIC CONTAMINATION CONTROL

Martin E. Coleman

Introduction

Toxic chemical contamination of the breathing atmosphere has been recognized as a potential hazard to crewmembers since the earliest days of manned space flight. Considering the long period of time that atmospheric contaminants could accumulate and the great diversity of materials and equipment projected, the Space Station could present a greater toxicological hazard from atmospheric contaminants than was seen during any of the earlier orbital missions. The principal sources of atmospheric contamination in the Space Station would be as follows:

a. Continuous release (offgassing) of trace amounts of contaminant chemicals from most types of nonmetallic materials used such as plastics, electric wire insulations, and paints.

b. Escape from containment of liquid or gaseous chemicals from material processing facilities, cooling coils, and propellant systems.

c. Combustion, thermal decomposition, or heat vaporization of various materials.

d. Metabolic products released by the crewmembers themselves.

Discussion

The consequences of toxic levels of atmospheric contaminants might include an increased incidence or severity of space sickness, because many types of chemical fumes increase susceptibility to nausea. The most likely adverse effect would probably be discomfort caused by eye and respiratory tract irritants. Some potential chemical contaminants would cause mental impairment during high level continuous exposures, perhaps interfering with the performance of complex tasks. Long-term exposure to chemical contaminants could cause an increased susceptibility to diseases such as respiratory infection or damage to organs such as the liver and kidneys.

Control of released contaminant chemicals into the Space Station atmosphere would begin with the selection of flight materials that release minimal amounts of toxic chemicals through offgassing. Liquid and gaseous chemicals used in chemical processing facilities, heat exchangers, and other applications would, as much as possible, be maintained in fail-safe containment systems. To the extent possible, areas where these chemicals are used would be isolated from the remainder of the habitable areas of the Space Station.

Gaseous containment levels in the Space Station would be monitored in several different ways. Excessive atmospheric levels of carbon dioxide (CO_2), carbon monoxide (CO), and certain other chemicals would set off alarms. Crewmembers should have eye and respiratory protective devices readily available at all times for use in the event of excessive atmospheric contaminant buildup.

A gas chromatograph-mass spectrometer (GC-MS) system for the analysis of atmospheric contaminants would be essential to the Space Station. There would either be a crewmember in the Space Station who was trained in the use of this system, or the output from the GC-MS system would be telemetered back to Earth for evaluation. The GC-MS system would be capable of detecting very low levels of thousands of different atmospheric contaminants. It would perform atmospheric analyses in the Space Station compartment in which it was located or in atmospheric samples brought in from other compartments.

Atmospheric contaminant removal would be important in maintaining a safe breathing atmosphere in the Space Station. Most, if not all, of the decontaminant materials should be renewable, if possible, since this would eliminate the necessity of resupplying them at intervals.

An effective way of removing CO_2, a contaminant that would be produced in large quantities by the crewmembers themselves, is by molecular sieves. The molecular sieves take up CO_2 from the air flowing through them, and can then be regenerated by heating in the space vacuum to drive off the CO_2. These molecular sieves were used successfully in CO_2 removal during the Skylab missions of the 1970's.

Large activated charcoal filters would probably be the primary means of removal of most organic chemical contaminants from the Space Station atmosphere. Charcoal has a high affinity for most organic chemicals, and like the molecular sieves, could be regenerated by heating in the space vacuum. Special chemical-treated charcoals would be required for the removal of certain contaminants such as ammonia and formaldehyde.

Still another means of toxic contaminant removal would probably be through oxidation. The ambient temperature catalytic oxidizer (ATCO) system is currently used in manned spacecraft to oxidize CO to CO_2. It probably also oxidizes a number of other organic chemicals to CO_2. An oxidation system may be the method of choice for removing many chemical contaminants that are not absorbed by charcoal.

Recommendations

Considering the anticipated wide diversity of activities and the long mission times by individual crewmembers, adequate toxicological control of Space Station atmosphere will be extremely important. Air quality will be controlled in several ways. Alarm systems will warn of release from containment and of excessive atmospheric levels of certain chemicals. A GC-MS system will analyze atmospheric samples taken from each compartment of the Space Station on a regular basis and immediately after a suspected chemical spill.

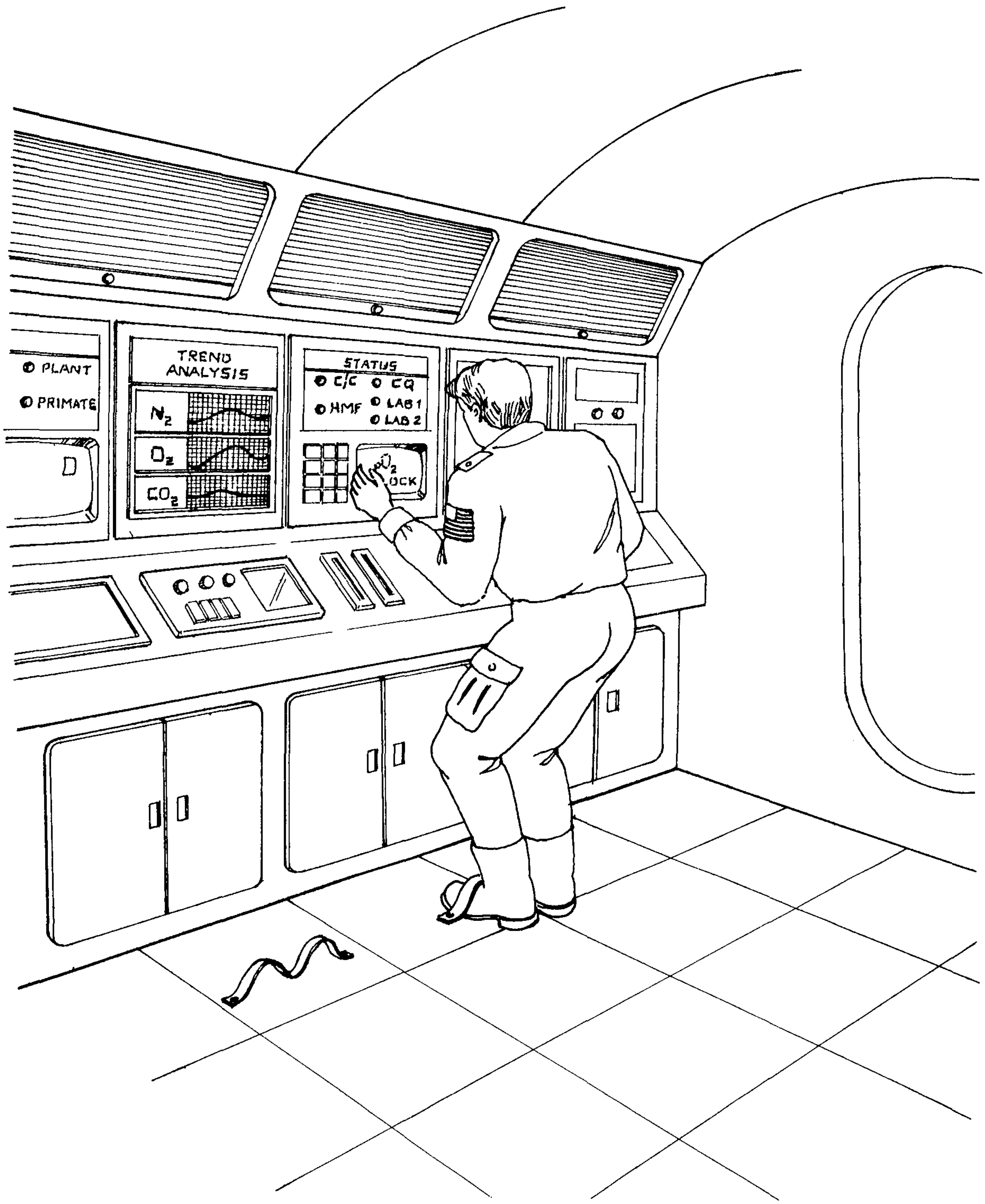
Examples of chemical contaminants that might be released into the Space Station atmospheres, the means of their removal, and the means of regeneration of several removal systems are summarized in table 1.

The measures discussed should ensure a safe, clean breathing atmosphere over a long period of time, even in the event of unexpected accidents or equipment failures, for the inhabitants of the Space Station.

TABLE 1 - ATMOSPHERIC CONTAMINANT SOURCES AND REMOVAL

Contaminant source	Examples of contaminants	Present day means of removal	Means of regeneration of decontaminant system
A. Offgassing of nonmetallic materials	Organic chemicals toluene methylethylketone ethylbenzene isopropyl alcohol	 Activated charcoal molecular sieves oxidation (ATCO system)* dehumidifer system	 Heat in space vacuum Heat in space vacuum Heat in space vacuum Charcoal filtration of water
B. Chemical reactor or leaks	Organic chemicals styrene cadium telluride	 Activated charcoal HEPA filter	 Heat in space vacuum -
C. Biological tissue fixatives	Glutaradelhyde formaldehyde	Activated charcoal special chemical treated charcoal	Heat in space vacuum -
D. Combustion or thermodecomposition of materials	Carbon monoxide hydrogen cyanide smoke particles	ATCO system activated charcoal HEPA filter	Heat in space vacuum Heat in space vacuum -
E. Normal respiration of crewmembers	Carbon dioxide carbon monoxide skatole	Molecular sieves oxidation (ATCO system) activated charcoal	Heat in space vacuum Heat in space vacuum Heat in space vacuum
F. Toxic Metals	Cadmium vapor or dust mercury vapor	HEPA filter activated charcoal	Heat in space vacuum Heat in space vacuum
G. Chemical components of flight hardware	Freons Ammonia	Activated charcoal(freons) phosphoric acid treated charcoal (ammonia)	Heat in space vacuum -

*Ambient temperature catalytic oxidizer, consisting of platinum-coated charcoal. The platinum catalyzes the oxidation of many chemicals.



ATMOSPHERIC COMPOSITION

The atmosphere within the Space Station will be controlled to provide the proper environments for crewmembers and research activities.

ATMOSPHERIC COMPOSITION

Herbert R. Greider

Introduction

For the last five years the Space Shuttle program management has been aware of the possibility of an extravehicular activity (EVA) crewmember developing the bends when going from a cabin pressurized at one atmosphere with 23% oxygen to an EVA suit at 4.2 psia and 100% oxygen. The requirement that the EVA crewmember breathe 100% oxygen for several hours at cabin atmosphere has not solved the bends problem and causes unsatisfactory operational procedures.

Since the Shuttle atmosphere was selected over ten years ago, a fresh look at Space Station atmosphere selection is needed using the Shuttle experience. The goal must be an atmosphere combination (cabin/suit) that does not cause bends and has simple operational procedures with no oxygen prebreathe requirement. Of course, the decision cannot be made without considering the fire hazard, waste heat removal, structural weight, and equipment complexity.

The main discussion concerns the amount that the partial pressure of nitrogen can be reduced, which translates into the amount the total pressure can be reduced. Probably, the partial pressure oxygen can be reduced from the equivalent of sea level (pO_2=160 mm.Hg) to something like the pressure in Denver (5000 ft: pO_2=133 mm/Hg). The only problem that must be considered is that the Space Station will have a less stable pressure control than Denver. To compensate for this instability, two factors must be considered: the low side of the cabin pressure regulation and the added reduction required to activate the warning system.

Discussion

Altitude bends are caused by a reduction in total atmospheric pressure which reduces nitrogen partial pressure. The reduction of nitrogen partial pressure by replacing nitrogen with oxygen will not cause bends when total pressure is kept constant. Therefore, the best solution is to select a Space Station atmosphere at an intermediate altitude--such as 1/2 atmosphere--and use a suit pressure of approximately 4.0 psia, with less loss of hand dexterity compared to the much-discussed 8.0 psia suit.

During World War II the United States flew 25,000 to 30,000 crewmembers per day in unpressurized cabins to altitudes between 21,000 ft (6.5 psi-335 mm) and 27,000 ft (5.0 psi-258 mm) with no apparent operational bends problem and no need for hyperbaric chambers. Flights of 4- to 7-hours duration at over 21,000 ft were often made on three and four successive days with no ill effect. Assuming that the oxygen partial pressure remained at sea level normal, the nitrogen partial pressure was reduced from between 433 and 510 mm.Hg.

From this experience, it seems safe to say that the Space Station crews will be able to go from the sea-level environment of the Shuttle to a one-half atmosphere Space Station, where the nitrogen partial pressure is reduced by 372 mm.Hg, with no bends problem and no oxygen prebreathe requirement. The crew would reach equilibrium with this atmosphere in a short time, and then would be available to go EVA with 4.0 psia suit as frequently as necessary with no oxygen prebreathe. This would give another change in nitrogen partial pressure of 228 mm. Hg. The important factor here is that the crewmembers will make the large change in nitrogen partial pressure (Shuttle to Space Station) only once, at the beginning of their tour. During the 3 to 6-month tour of duty, small changes in nitrogen partial pressure (Space Station to suit) can be made many times with no ill effect.

Recommendations

A cabin pressure of 7.4 psi/60% N_2 is highly recommended. The key is the use of intermediate pressure between Shuttle's sea level pressure and the 4.3 psia suit pressure. The intermediate is selected so that the transition between Shuttle and Space Station is larger (7.4 psia) (table 1). However, this transition will be made only once, at the beginning of each tour of duty. Once the body has reached equilibrium with the Space Station atmosphere of 7.4 psi/60% (ca. 24 hrs.), then the crewperson is available to make a second smaller transition to the suit pressure of 4.3 psi/100% O_2.

The 8 mm CO_2 is selected so as not to put too stringent a requirement on the CO_2 scrubbers. No ill physiological effect is expected because of this selection. The first 24-hour limitation in the Space Station before going EVA is an estimate of the time required to reach near equilibrium for N_2. Some research is required to determine the equilibrium time. The hyperbaric chamber is of questionable need, but if it is considered necessary, one atmosphere above Space Station pressure would meet this need (see table).

Other Considerations

Fire hazard is always a serious consideration whether it is a ship at sea or a Space Station. A 40% oxygen at 7.4 psia will require a somewhat more rigid material selection than a 1.0 atmosphere cabin. It should not be an overwhelming problem considering that Mercury, Gemini, and Apollo missions were flown with 100% oxygen at 5.0 psia. Lyndon B. Johnson Space Center (JSC) and Lewis Research Center (LERC) are looking at the problems with a 7.4 psia cabin and 40% oxygen. LERC has a Research and Technology Objectives and Plans (RTOP) on Reduced Gravity Combustion Science and is having a workshop early in 1984 on fire problems in this atmosphere.

Space Station gas leakage and airlock gas losses would be reduced by one-half compared to a 1.0 atmosphere cabin. This is a very important consideration because all makeup gases must be carried into orbit. The airlock losses with many EVA's will be significant. The gas leakage from the EVA suit at 4.3 psia, of course, would be approximately half of an 8.0 psia suit. This must be one of the considerations in selection of Space Station suit pressure.

Structural weight would be lessened by reducing the pressure to 7.4 psia. This is not important in a small station but becomes more important as the stations get larger. This proposed pressure of 7.4 psi must be given serious consideration as it may affect the space program for many decades. Lower pressures also reduce the decompression risk.

TABLE 1 - RECOMMENDED CABIN ENVIRONMENT AND CONSTRAINTS

Cabin Pressure	7.4 psia (18,000 ft)
EVA Suit Pressure	4.3 psia (30,000 ft)
Partial Pressure CO_2	8 mm - maximum
Cabin Temperature	65° to 80° F - controllable
Time from Sea Level to 7.4 Station Cabin	One hour minimum and no prebreathe O_2 required
Time in Station before First EVA	24 hours minimum
Time from 7.4 Station to 4.3 Suit	30 minutes and no prebreathe O_2 required
Repeat EVA's	No limitation
Hyperbaric Chamber	One atmosphere over Station pressure

TABLE 2 - ALVEOLAR PO_2 AND PCO_2 VS ALTITUDE IN AIR

	Avg pO_2	Avg pCO_2
Sea Level	102	38
5,000 ft.	79	37
8,000 ft.	70	36
10,000 ft.	61	35

TABLE 3 - OXYGEN EQUIVALENTS FOR 18 000 FT TO SIMULATE SELECTED ALTITUDES

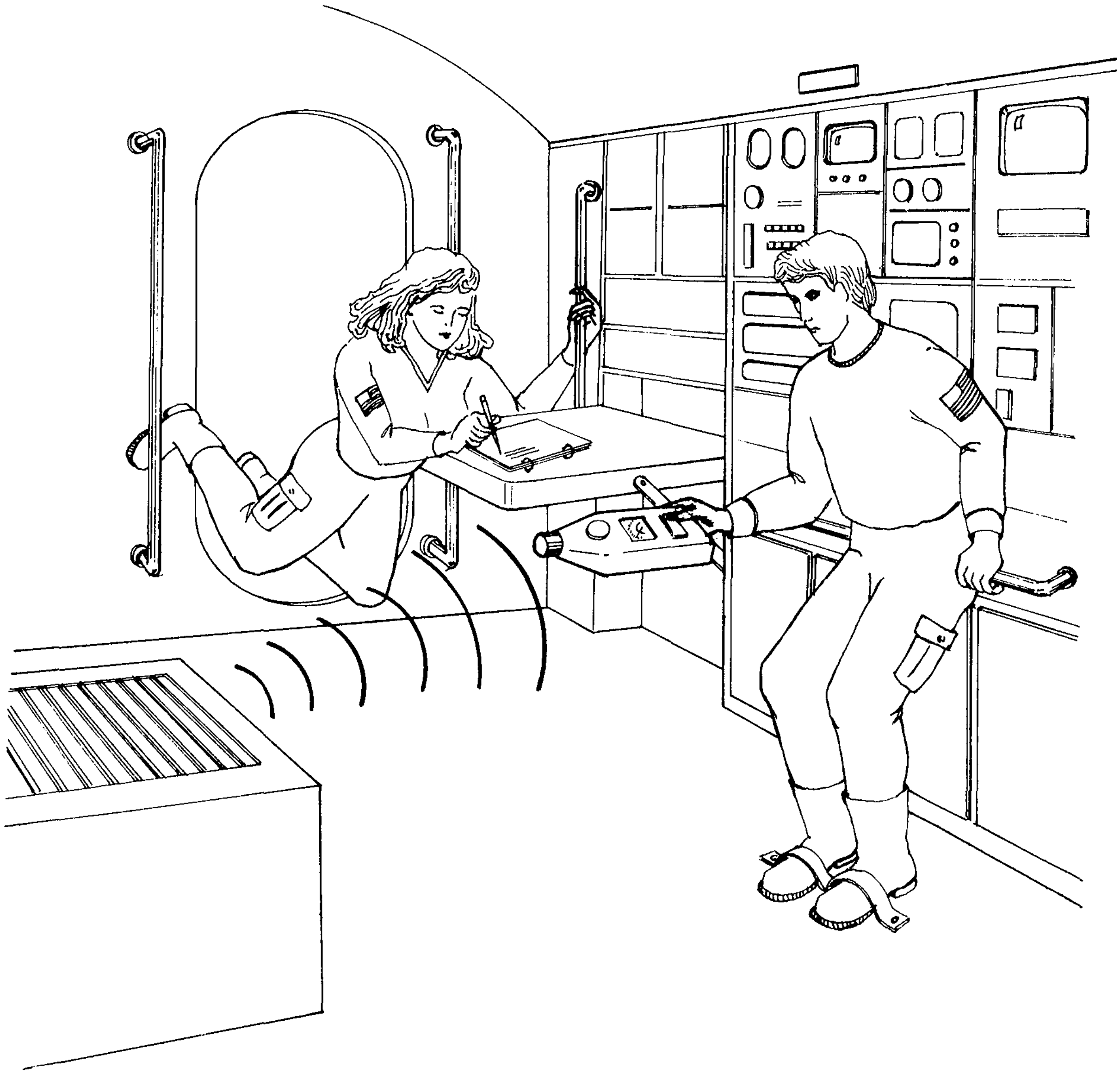
	Oxygen Concentrations
Sea Level	44%
5,000 ft.	37%
8,000 ft.	33%
10,000 ft.	30%

TABLE 4 - ALVEOLAR PO_2 AT 18 000 FT FOR TABLE 2 ABOVE

O_2 PERCENTAGES FOR NOMINAL CABIN REGULATION AND FOR LOW RANGE REGULATION (-20 mm/-0.4 psi)

	Nominal pO_2	Low Range pO_2
Sea Level	102	94
5,000 ft.	79	71
8,000 ft.	70	63
10,000 ft.	61	55

It is possible to reduce the percentage of oxygen and simulate a higher altitude as noted in table 2. Airlines fly with an 8000-ft cabin. Table 3 shows that to simulate the 8000-ft condition in an 18 000 -ft cabin, oxygen is used. It is possible to go to a higher equivalent altitude and depend on crew acclimatization. The cabin pressure will deviate approximately ±0.2 psi around nominal. Another 0.2 psi must be subtracted to activate the low pressure warning alarm. Table 4 shows these effects on the alveolar oxygen partial pressure.



NOISE POLLUTION

Although Space Station systems must be designed to ensure that acoustic noise levels generated will be within specified limits, periodic noise surveys will be conducted on-orbit. Illustrated above is a crewperson using a portable sound level meter to measure noise produced by a mechanical device. A second crewperson is entering the data into a log which will be returned to the ground.

NOISE POLLUTION

Jerry L. Homick

Introduction

During the past 10 to 20 years, an increased awareness of the effects of noise on man has influenced the design and development of manned spacecraft systems. Where cost, weight, and size are critical factors, a compromise must often be reached between the desirable and the practical. Nevertheless, in the future, with the use of more sophisticated vehicles that are intended for long-duration habitation by a larger number of people, acoustical noise must be given due consideration as a potential detriment to safety, functional efficiency, and physical and psychological well-being.

Discussion

Permanent Threshold Shifts (Hearing Loss)

Brief exposure to very high intensity noise or long-duration exposure to moderately intense noise can cause permanent damage to the human auditory system. Well-established damage risk guidelines exist for wide-band and narrow-band noise for exposure up to 8 hours. However, in attempting to establish physiologically safe levels for long duration, continuous noise exposure, certain assumptions and extrapolations must be made. Using the best available sources of information, it has been determined analytically that continous exposure to noise levels greater than 76 dBA for periods longer than 24 to 28 hours could cause permanent hearing damage in some individuals.

Temporary Threshold Shifts

A temporary threshold shift is a temporary hearing loss, the magnitude and duration of which depends on the duration, intensity, frequency content, and periodicity of the offending noise. Temporary threshold shifts can cause difficulty with signal detection and speech communications. Available data indicate that temporary shifts reach asymptotic levels after the first 24 to 36 hours of exposure. If the offending noise is removed for a sufficient period of time complete recovery will occur. However, the literature indicates that if the temporary shift exceeds about 40 dBA, then complete recovery may never occur. That is, some residual permanent loss will be present.

Sleep Interference

The results of laboratory studies indicate that subtle alterations in EEG activity occur with noise exposure. Also, as expected, large individual variations in subjective reactions occur. Some individuals have no difficulty with sleeping in loud noise environments while others are easily affected. It is widely recognized that intermittent noises are more disruptive of sleep than are steady-state noises. Large individual variations exist with regard to the time required to habituate to noisy sleep environments. This is an important consideration for Space Station. Most crewmembers may become accustomed to sleeping with excessive noise after a few nights; however, in the

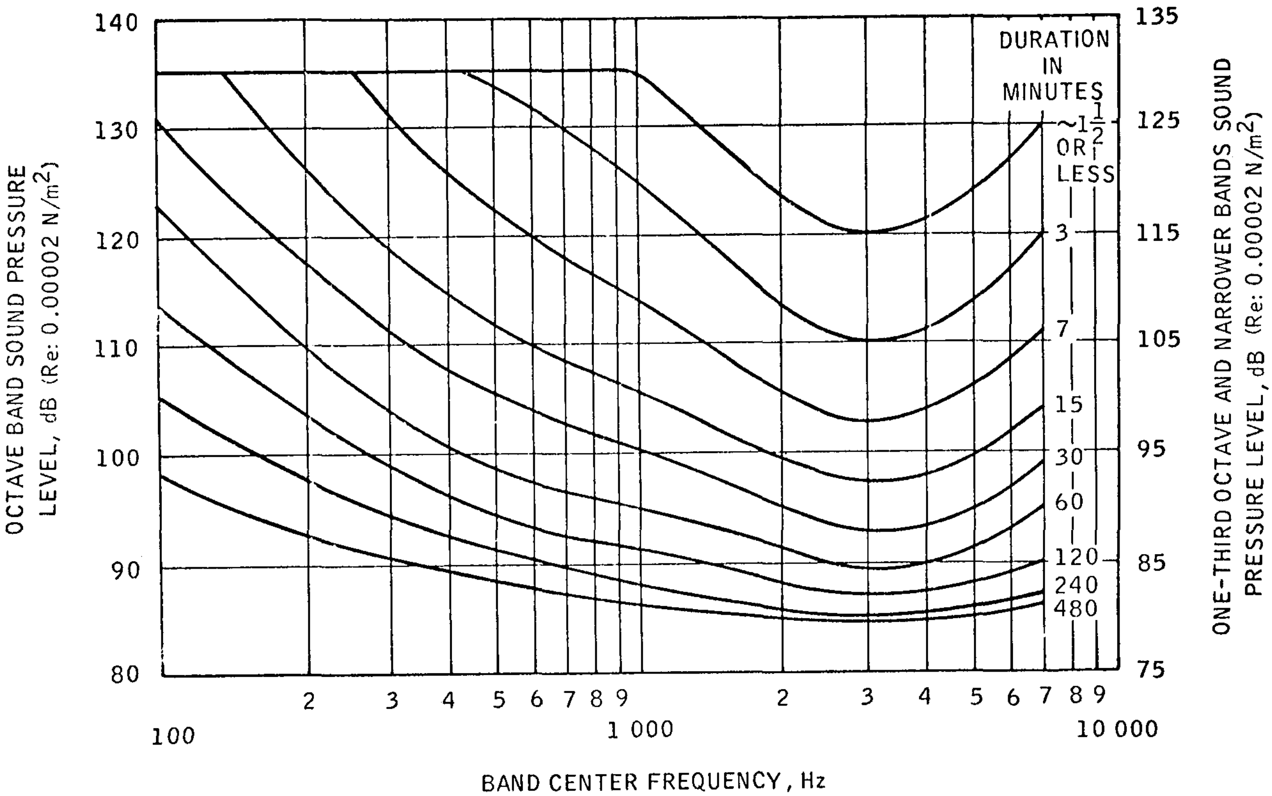


Figure 1. - Damage risk contours for One Exposure Per Day to octave (left-hand ordinate) and one-third octave or narrower (right-hand ordinate) bands of noise.

This graph shall be applied to individual band levels present in broad band noise.

meantime, their performance and well-being may suffer due to fatigue from the loss of sleep. Finally, the problems of noise-induced temporary threshold shifts and potential permanent hearing loss cannot be minimized. A period of relative quiet must be provided during the sleep period to ensure adequate recovery from temporary threshold shifts during the work day.

Annoyance

Annoyance caused by noise is a highly subjective response which can be influenced by a variety of factors including individual attitudes, motivation, the situation in which the noise occurs, and the physical characteristics of the noise. The last mentioned variable is the most sensitive region of hearing, and excessive narrow-band noise in the 1-4 KHz range is to be avoided.

Performance Decrement

Limited quantitative data available in the literature indicate that direct noise-induced performance decrements occur only with noise levels greater than 90 dBA. However, indirect noise related performance decrements can result from degraded ability to detect accurately and discriminate auditory information (speech and nonspeech), fatigue resulting from sleep loss, and irritability. As with annoyance, efforts must be made to reduce spacecraft noise levels which may affect, even indirectly, the performance of some crewmembers.

Recommendations

Preliminary recommendations for Space Station acoustical noise limits are based in part on JSC Design and Procedural Standard 145, "Acoustic Noise Criteria." The varied operations and habitability modules that will compromise the Space Station were considered in these recommendations.

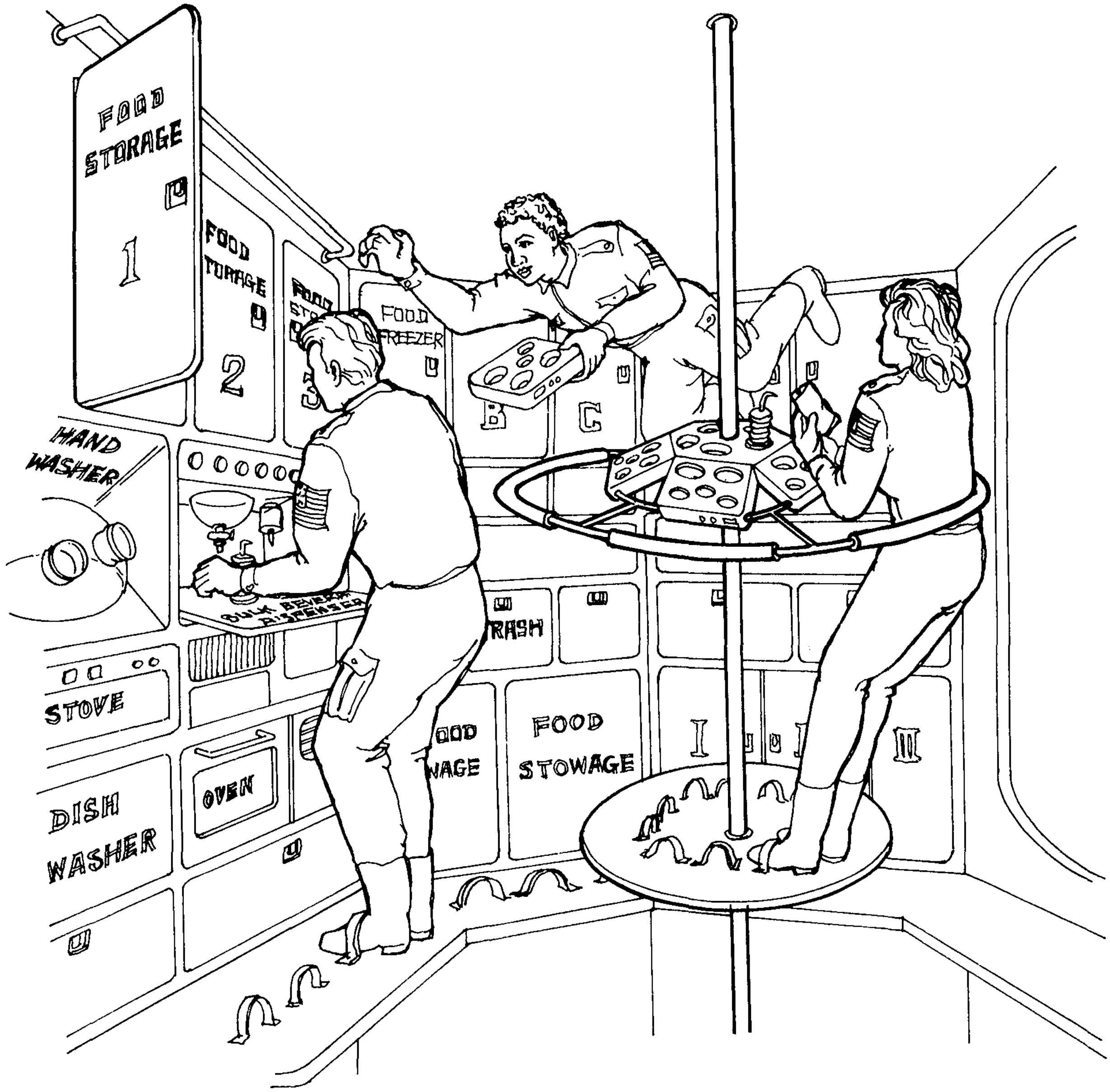
Maximum allowable sound pressure levels at an individual's unprotected ear during relatively short-duration exposures (e.g., launch) are defined in the accompanying figure. No single octave band may exceed the contour for the time period cited.

The maximum allowable continuous sound pressure levels produced by normal operating equipment on systems within work and sleep areas should be as follows: (1) Crew sleep compartment noise should be limited to 50 dBA; and (2) Crew work compartment noise should be limited to 60 dBA.

To avoid potentially annoying (continuous) sounds or disruptive (intermittent) sounds, the maximum sound pressure level of any narrow band component should be at least 10 decibels less than the sound pressure level of the octave band which contains the component.

Ear plugs, muffs, or other personally worn hearing protection devices should not be used as a means of achieving acceptable exposure limits except in the case of high intensity, short duration exposures such as launch.

A vigorous effort should be made to develop acoustic noise criteria during the early design stage of the Space Station, and to ensure that the criteria are met during the development stage. Routine on-orbit monitoring of acoustic noise will verify that crewmembers are not being exposed to hazardous levels.



FOOD SUPPLY AND SERVICE

The food supply and service system incorporates food storage, preparation, and dining facilities. Fresh and frozen food and snack items provide a variety and insure continuing acceptability. System design provides particular attention to human factors and incorporates congregate feeding capability.

FOOD SUPPLY AND SERVICE

Richard L. Sauer and Malcolm C. Smith

Introduction

The Space Station food supply and service system will entail a major development effort. Food technology developed for previously manned space flights was designed for relatively small crews on flights of limited duration. Much of this technology is inappropriate for Space Station application because the human aspects of the habitability and the food system effects on the general well-being of the users received minimal consideration. The development and provisioning of a Space Station system will require a new and comprehensive effort which considers the biological, operational, and engineering requirements listed in table 1.

Discussion

Historically, food system weight and volume have been prime drivers in the design of space flight food systems. This has resulted in the compromise of certain palatable aspects of the food system and limited the availability of foods to primarily precooked intermediate moisture or reduced water content and dehydrated foods. While previous food systems have provided the minimum daily nutrient requirements, the form in which the food has been presented has been more in the nature of a "camp out" or of combat rations. This can severely affect the psychological acceptability of the food system for extended missions.

The nature of space flight to now has also limited the types of food storage, preparation, and production equipment available. This has resulted in a limited availability of fresh foods and no capability for providing inflight prepared foods. Hence, it has not been possible to provide astronauts with familiar types and varieties of foods.

The Skylab missions are a partial exception to the characteristics discussed. The nature of these missions did permit the availability of a limited amount of frozen items and some human engineering of the dining facility. These factors contributed significantly to the acceptability of the Skylab food system. Of particular delight to the Skylab crews was the availability of ice cream and frozen precooked steaks.

The projected multimission, permanent Space Station inhabited by up to 16 persons for long periods of time offers a challenging but unique opportunity in food system design. The long-term functional life of the station and its subsystems will require the inclusion of food storage, production, preparation, and service equipment not previously considered cost-effective in manned space flight. The new hardware and procedure possibilities include the items and equipment listed in table 2. A definition of how the equipment might appear is shown in the sketch introducing this chapter.

TABLE 1 - SPACE STATION FOOD SYSTEM REQUIREMENTS

Biological	Operational	Engineering
Safety	Vehicle interface	Weight
Nutrition	Stability	Volume
Sensory qualities	Packaging	Water for rehydration
Personal hygiene	Storage	Pressure
Ingestion	Preparation	Temperature
Digestion	Servicing	Relative humidity
Absorption	Habitability	Acceleration
Gastroenterology	Maintenance	Vibration
Crew idiosyncracies	Schedules	
Nutritional monitoring	Crew Time	
Sanitation	Cost	
Human factors	Schedules	

TABLE 2 - SPACE STATION FOOD SYSTEM HARDWARE

Freezer: -10°F including icemaker
Refrigerators: 40°F
Ovens (convection, microwave, and radiant)
Dishwasher
Food preparation and servicing equipment: trays, tables, mixers, etc.
Capability for culture and harvest of fresh salad greens
Trash management/trash compactor
Hot water supply: 180°F
Cold water supply: 35°F
Capability for baking bread items
Bulk beverage dispenser
Ice cream maker/freezer
Accessories (disposable and recyclable)

Recommendations

The design and operation of the Space Station food system will be critical to the physiological and psychological well-being of the Space Station crews. To this end, the food system must meet the nutritional requirements of the crew-members and also provide for the recreational and human acceptability aspects of food preparation and dining.

In order to meet the overall objectives of the food system, the following goals should be adopted:

1. To develop, test, and provide food service procedures which meet overall mission objectives.

2. To ensure crew safety together with effective and productive performance of the food service system.

3. To assure that applicable human engineering principles are incorporated into the design and function of the system.

4. To develop a food service operating posture which is cost effective in launch weight, launch volume, operating efficiency, and inflight maintenance.

To achieve these goals, the Space Station food development objectives are the following:

1. To manage the technology base so that required system availability matures consistently with the Space Station schedule.

2. To provide a capability from the technology base to select system options compatible with the planned Space Station growth stages.

3. To conduct the research and development necessary to effect a maximal operating capability to satisfy crew and mission needs.

CLOTHING AND FURNISHINGS

A typical private accommodation for a Space Station crewmember will provide a sleep-restraint for the individual's comfort and security, and stowage for clothing and personal items.

CLOTHING AND FURNISHINGS

Maynard C. Dalton and John B. Charles

Introduction

The continued motivation of Space Station personnel over their tours of duty will require careful attention to the "little things", the background aspects of everyday living. Their work and off-duty environments should be pleasant, and with enough variability to remain interesting. Especially amenable to these considerations are the areas of clothing and furnishings. An unimaginative wardrobe and spartan living conditions were cited by the Skylab astronauts as factors requiring more attention for long stays in space. Through careful design and planning, these aspects of the crewmembers' personal environments can play a large part in the maintenance of each crew's productivity and efficiency.

Discussion

Clothing

It is anticipated that standard flight clothing will be supplied to the crewmembers for the exclusive use of each person (see table 1). The apparel should provide the appropriate thermal environment for the wearer, considering the inefficiencies in air conditioning and physiological temperature regulation to be expected in microgravity. A choice of colors and styles, including leisure and sportswear, would provide visual variety and personal expression. The clothing should also have many pockets, to minimize the nuisance of having the numerous small items a person carries escaping in weightlessness.

A multigarment system consisting of a shirt, trousers, and a jacket would give the crewmembers flexibility in achieving thermal comfort as well as providing a large range of sizes and style options. Consideration should be given to the wide variations in body size and habitus to be expected in the population of Space Station crewmembers. Common clothing articles will be utilized for both male and female crewmembers to the greatest possible extent. But, these should be adjustable to provide for a good fit and to accommodate the changes in body measurements that occur in weightlessness. Furthermore, all clothing should be aesthetically pleasing, allow unrestricted mobility, and allow the efficient use of the waste management systems.

Wearing comfort with adequate body protection should be emphasized in the design and materials selection for the clothing. Cotton, with its comfort, absorbancy, and wearability, is the preferred material. Operational considerations will require some sort of chemical treatment for flame proofing, which should not affect its comfort or its cleanability in the onboard laundering or dry-cleaning facilities.

In addition to the standardized clothing to be provided, provision should be made for some personal clothing items. These items could be supplied by the crewmember, as long as they meet the established compatability requirements.

Footwear will be an important factor on the Space Station. It will provide protection from injuries caused by the unusual forms of locomotion likely to

Table 1 - STANDARD CLOTHING SUPPLIES

- Shirts
- Trousers
- Underwear items
- Sleep/exercise shirts and shorts
- Socks
- Slipper socks
- Light-weight footwear
- Jacket
- Gloves
- Handkerchiefs

These items would be provided in sufficient quantities to ensure that each crewmember would always have clean clothing available.

Table 2 - FURNISHINGS APPROPRIATE TO A MICROGRAVITY LIVING ENVIRONMENT

Bed -- Hammock or netting, with bedding materials

Tables and Workbenches -- Elevated work surfaces inclined toward user,
Restraints for equipment, loose papers
Plenty of drawers and storage compartments

Restraint Systems -- Hand holds
Foot restraints
Waist harnesses

Lockers and Drawers
Draperies and Wall Hangings -- Aesthetically pleasing, sound absorbing

Comfort Fixtures -- Designed to ease the discomfort of physiological adjustments to weightlessness, such as lower back pain

Personal Items -- Pictures, sculptures

Other Items -- Yet to be defined

be used in weightlessness. It will be an important comfort factor, since the redistribution of blood volume inflight may leave some individuals with cold feet. The footwear must also incorporate a versatile restraint system, since the legs and feet will be used primarily for fixing the individual at a work site. The shoe-sole triangles and cleats used on Skylab are a possibility, as are the use of velcro and foot-loops on the floor at commonly-used work stations. Underwear can be standard, commercially available items to suit individual tastes, subject to the appropriate operational safety considerations.

Furnishings

The furnishings in the Space Station will necessarily be quite different from those in use on Earth. In table 2, for example, chairs and sofas will not be needed for relaxation. An appropriate substitute might be simply a means of mooring the person in the desired area, and allowing nearly complete relaxation in "mid-air".

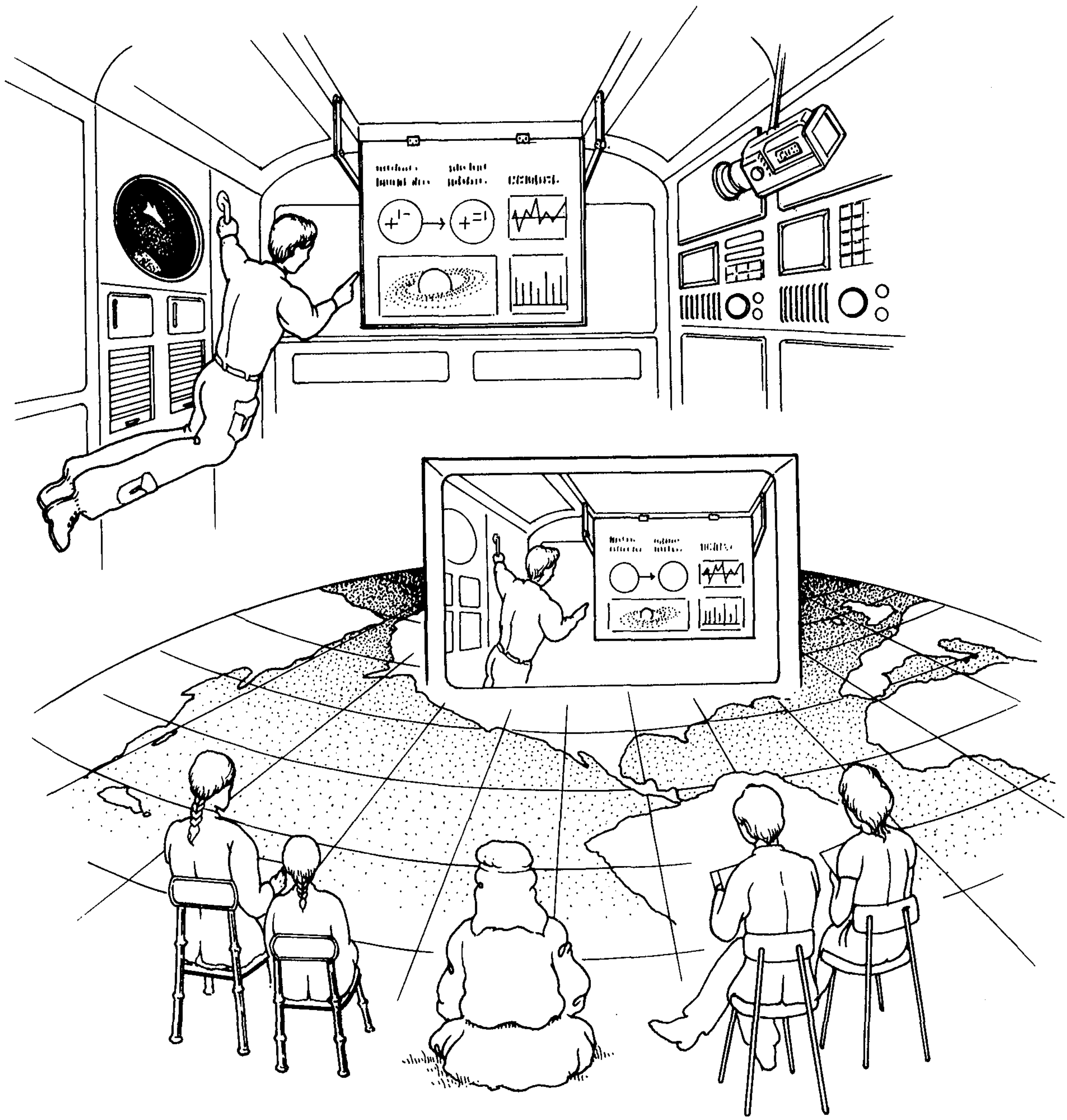
Beds may be hammock-like in that they merely restrain the sleepers from floating freely about their quarters, and should incorporate provisions to hold bedding, blankets, and pillows around the users. They might be fastened to a wall at night, and either left in place, as shown in the figure, or stowed in a locker when not in use.

Work stations and dining areas will also need to be designed for the wide range of body sizes among the Space Station population, and for the pecularities of working in weightlessness. A system of foot restraints and waist harnesses might prove useful for fixing the individual at a work site. Jobs requiring some mobility around that site could use a waist-restraint system which slides along a fixed bar. It is anticipated that some of these restraint devices will be permanently mounted at heavy-use locations, some will be moveable as necessary, and some will be incorporated into the clothing and footwear of the crewmembers.

Instrument consoles, work benches, and tables must be designed to accommodate the "microgravity slump", the posture that the body assumes in the apparent absence of gravity. Chairs and stools will not be required. Work surfaces should be elevated and inclined toward the worker, who will not have the usual assistance of gravity in bending over a horizontal surface. Several forms of restraint to hold equipment, papers, and tools must be provided, and storage compartments for loose items will be located near the place of maximum usage.

Recommendations

Careful planning can eliminate design shortcomings which will blossom into major annoyances and aggravations under the potentially stressful circumstances of long stays in orbit. The analysis of similar situations in the Skylab and Salyut orbital stations, and the testing of habitability and housekeeping features in short-term Space Shuttle flights, will provide a data base from which to work. It should also be recognized at the outset that, inevitably, some proposed solutions will be found to be less than optimal in use. Accordingly, provisions should be made for a degree of on-orbit modification of work and rest areas, as practical experience reveals more appropriate solutions.



EDUCATIONAL IMPLICATIONS

World-wide participation in education of and by Space Station personnel.

EDUCATIONAL IMPLICATIONS

John Harris

Introduction

To adequately discuss the educational implications of a Space Station, it is necessary to first define the meaning of education in this particular context. We are looking at the way inhabitants of a Space Station can enhance learning on Earth and provide new concepts in the sciences, especially astronomy, life sciences, and social sciences. Obviously, at this point, we cannot enumerate specific subjects that could be taught or even classroom situations. What is needed first is an education of the public, through available methods, to gain long-term support for a Space Station as well as development of new concepts regarding working and living that will carry forward into the now traditional educational systems to help prepare future citizens for a rapidly changing life in the 21st century. As this process is occurring, specialized groups will begin to utilize Space Station as a valuable resource and formal learning situations can take place. These could include university courses, public service broadcasts, and science for laymen.

Discussion

The mass media, especially television, can bring the events that occur in a Space Station to Earth on a daily basis via newscasts. This is the first and highly necessary step in educating the general public about the many advantages of a permanent human presence in space. Through this medium, public interest will be piqued and people will learn what it is like to live and work hundreds of miles above the Earth, how Space Station inhabitants react to their environment, what type of work is being done and how this will eventually affect life on this planet. Once public interest is triggered, it will hopefully manifest itself into continued support of Space Station, a necessary commodity in a democracy. In addition, a realization will develop that in a changing world a great deal of knowledge can be gained through interaction with the Space Station population. As a result of the scientific studies on Space Station, investigators will gain knowledge in many areas of science that can be shared with other scientists throughout the world. Also, inhabitants of Space Station will probably develop a more global perspective of the world than their earthbound peers which could lead to, among other things, new thinking in the areas of geopolitics and sociology.

NASA can also educate the public through literature, displays, speakers, and films devoted to various aspects of Space Station. Emphasis should be placed on the potential of Space Station to enhance learning at all levels and to become a forum for the exchange of scientific information on a global scale. As interest increases, a special Space Station Office can be created to arrange and structure interactions of specific groups with those aboard Space Station. While at the same time, it could be used as a clearing house for all information originating from Space Station.

Mass media has been capable of rapidly building up interest in a news event. Their tendency for the spectacular encourages the editors to choose the dire event for coverage on the front page. Press reporting of Skylab was heavy during launch, recovery, and during the EVA repair of the laboratory. During the long Skylab IV (84 days), coverage was relegated to the inside stories of the newspapers and commentators tended to barely mentioned it in TV newscasts. Most of the public forgot that crewmen were orbiting overhead. Space Station will suffer a similar fate unless its communications are not limited to the commercial press but are expanded into the educational system generally. From this the public will realize that it is their Space Station, and that besides industrial processes, it is a worthwhile source of information for the United States student body from grammer school through college into adult postgraduate education.

When the public is aware of the many possibilities for increased knowledge as a result of Space Station, then specialized groups will begin to utilize it as a resource and many different types of learning situations will be developed. For instance, world leaders in the sciences and social sciences will be able to hold discussions with their peers who are working aboard Space Station. Earthbound coinvestigators can discuss an experiment with the principal investigator aboard Space Station. Other scientists in the same field could also participate in the discussion. On the other hand, an investigator could make a formal presentation of his/her work to the scientific community directly from the Space Station laboratory. Students at all levels can join an investigator for a discussion or demonstration of the type of work in which he/she is engaged. For example, students could interact with an expert in bioprocessing who is separating cells by electrophoresis in order to use them to manufacture pharmaceuticals. They could also question someone who specializes in physiology and the changes that occur in the body as a result of weightlessness. On a more selective basis, outstanding students in a given subject area could be chosen to participate in a one-on-one learning experience with a Space Station investigator.

Recommendations

In order to have continued public support and eventual use of Space Station as an educational resource, it is important to inform the public now of its potential to expand our knowledge in many diverse areas. Prior to the actual construction of the Space Station, NASA can mobilize its resources to keep the world informed as to the importance of this effort. During and after the building phase, NASA should keep the public abreast of Space Station activities through regular announcements and conferences with the news media as well as publications, films, and speakers. PAO should expand its emphasis from the news media into the educational system in general.

A Space Station information office should be created to handle all information originating from the Station. As operations mature, the office can keep the public informed regarding Space Station activities as well as coordinating and structuring learning situations between earthbound investigators and students with those aboard Space Station.

CONCLUDING REMARKS

The goals of this technical memorandum have been several. It has acted as a platform for individual NASA life scientists to express viewpoints and consider what has been done in the past in relationship to a Space Station. It has focused attention on the unique needs of a Space Station and encourages the development of new ideas. In addition, by using the technical memorandum as a forum, it records today's ideas in a manner which can be used by those who follow. It will be used to communicate with management as well as with interested scientists, educators, aerospace contractors, and fellow NASA workers the perspectives and ideas of the Life Sciences Space Station Working Group during its deliberations during late 1983 and early 1984.

It is planned to publish a second technical memorandum in late 1984 to further present concepts that are just now being developed.

APPENDIX A

WORKING GROUP MEMBERSHIP

NAME	DEGREE(S)	YEARS NASA	SIGNIFICANT NASA EXPERIENCE/ ACCOMPLISHMENTS
M. W. Bungo	M.D.	3	Cardiovascular Section, Medical Resarch Branch and consultant for Medical Operations Branch; CV Physiologic Research RTOP Manager; Mission Control Center Flight Surgeon for Shuttle OFT Series; design, implememtation, and evaluation of cardiovascular deconditioning countermeasures in Shuttle flight program; Board certified in Internal Medicine and Cardiovascular Disease.
J. B. Charles	Ph.D.	1	Physiologist; research into cardiovascular effects of weightlessness deconditioning countermeasures.
M. E. Coleman	Ph.D.	3	Toxicologist, responsible for evaluation of toxicity of contaminants in spacecraft atmospheres; evaluation of toxic hazards in spacecraft payloads; and development of concentration limits for spacecraft atmospheric contaminants.
G. R. Coulter, Lt Col, USAF	Ph.D.	2	Director, Aerospace Medical Division Space Biotechnology Programs Office (JSC); Clinical Research Associate, JSC Biomedical Branch; Associate Professor of Biology USAF Academy.
M. C. Dalton	B.S.	20	Space Station design; crew station research and development; habitability research Skylab; crew station design; orbiter habitability design-SOC.

NAME	DEGREE(S)	YEARS NASA	SIGNIFICANT NASA EXPERIENCE/ ACCOMPLISHMENTS
J. C. Degioanni	M.S., M.D., Ph.D.	7	Board certified Aerospace Medicine (Preventive Medicine), Emergency Medicine Specialist; Ph.D., Astronomy; M.S. Public Health; JSC Medical Standards Officer, 1976-79 defined medical standards for astronaut selection Class I, II, III; designed protocol for medical selection of astronauts; designed SOMS; author Shuttle medical checklist; STS-1 deputy crew surgeon; principal investigator in motion sickness drug studies (JSC).
W. J. Frome	D.D.S.	17	Provides all astronaut dental care; developed provisions for inflight care--Apollo, Skylab, ASTP, STS Dental Resarch Skylab; developed dental selection standards; member of Space Medicine Board.
L. Gardner	M.S., Ph.D.	1	Aerospace Clinical Neuropsychologist, Universities Space Research Association, Division of Space Biomedicine, NASA Space Biomedical Institute; space adaptation syndrome research and countermeasure training; operational applications of biobehavioral medicine; Space Station planning.
H. R. Greider	B.S.	19	Wrote Mercury environmental requirements; originated the conceptual design for Mercury ECS and space suit; lunar surface equipment handling problems; environmental planning for Space Station.
J. W. Harris	B.S.	20	Established radiation and meteoroid environment standards for Apollo; editor, 1969 lunar science working group; manager, Lunar Sample Office; member lunar sample curatorial staff; radiation biology; Space Biomedical Institute.

NAME	DEGREE(S)	YEARS NASA	SIGNIFICANT NASA EXPERIENCE/ ACCOMPLISHMENTS
P. C. Johnson	M.D.	4	Specialized medical operational testing pre- and postflight Gemini, Apollo; P.I. for Skylab, SL-1; MCC surgeon, STS medical reports; Space Adaptation Research Branch Chief.
J. S. Logan	M.D.	2	Chief, Flight Medicine; Mission Operations Control Center, STS-3,7,9; Deputy Crew Surgeon, STS-5,11; Crew Surgeon, STS-6,8,12; board certified in Aerospace Medicine.
J. A. Mason	M.S., M.S,	20	Hqs. NASA-planning advanced manned missions; JSC-Deputy Chief, Preventive Medicine Division-Lunar Quarantine; Chief, Bioscience Payloads Office-Spacelab life science simulation; Medical Research Branch-Space Station planning.
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R. L. Sauer	M.S.	16	Project Manager for Shuttle Food and Orbiter Medical System; Manager for Advanced Life Support Systems RTOP; Project Engineer for Skylab Water, Personal Hygiene, and Waste Management System; licensed professional engineer.

NAME	DEGREE(S)	YEARS NASA	SIGNIFICANT NASA EXPERIENCE/ ACCOMPLISHMENTS
C. G. Smith	M.S.	22	Physiologist; human ecologist; remote sensing studies of Earth environment; Associate Fellow, Aerospace Medical Association; aerospace technology for the disabled; member, Air Transport Committee of the Aerospace Medical Association; member, Foundation for Science and the Handicaped; air travel for the disabled.
M. C. Smith	D.V.M., M.S.	16	Subsystem Manager for Apollo Food and Personal Hygiene (1967-70); Subsystem Manager for Skylab Food (1970-71); Chief, Food and Nutrition Branch (1970-75).
N. Timacheff	M.A.	11	Chief Interpreter and staff of Apollo Soyuz Test Project; Space and Life Sciences interpreter/ translator joint working group meetings since 1977; study of Soviet aerospace achievements in life sciences.
J. M. Waligora	M.S.	20	EVA and environmental requirements on Gemini through Shuttle; EVA liquid cooling systems; development and testing of procedures to prevent altitude decompression sickness; EVA monitoring and measurement of metabolic rate.

APPENDIX B

SOVIET SPACE STATIONS

Nicholas Timacheff

In 1971, the Soviet Union launched their first space station "Salyut-1". Since then, they have been aggressively pursuing the concept of permanent presence in space. To date, this presence has been manifested by having a space station in orbit, although there have been periods of from a few weeks to eight to nine months when these stations were not manned. Salyuts 1 through 5 were mainly test articles, although some activities, primarily in the systems testing, were carried out in each station. For example, in 1975 during the Apollo-Soyuz Test Project, the crew of Salyut-4, in orbit at that time, was in frequent communication with Leonov and Kubasov during their flight with Apollo.

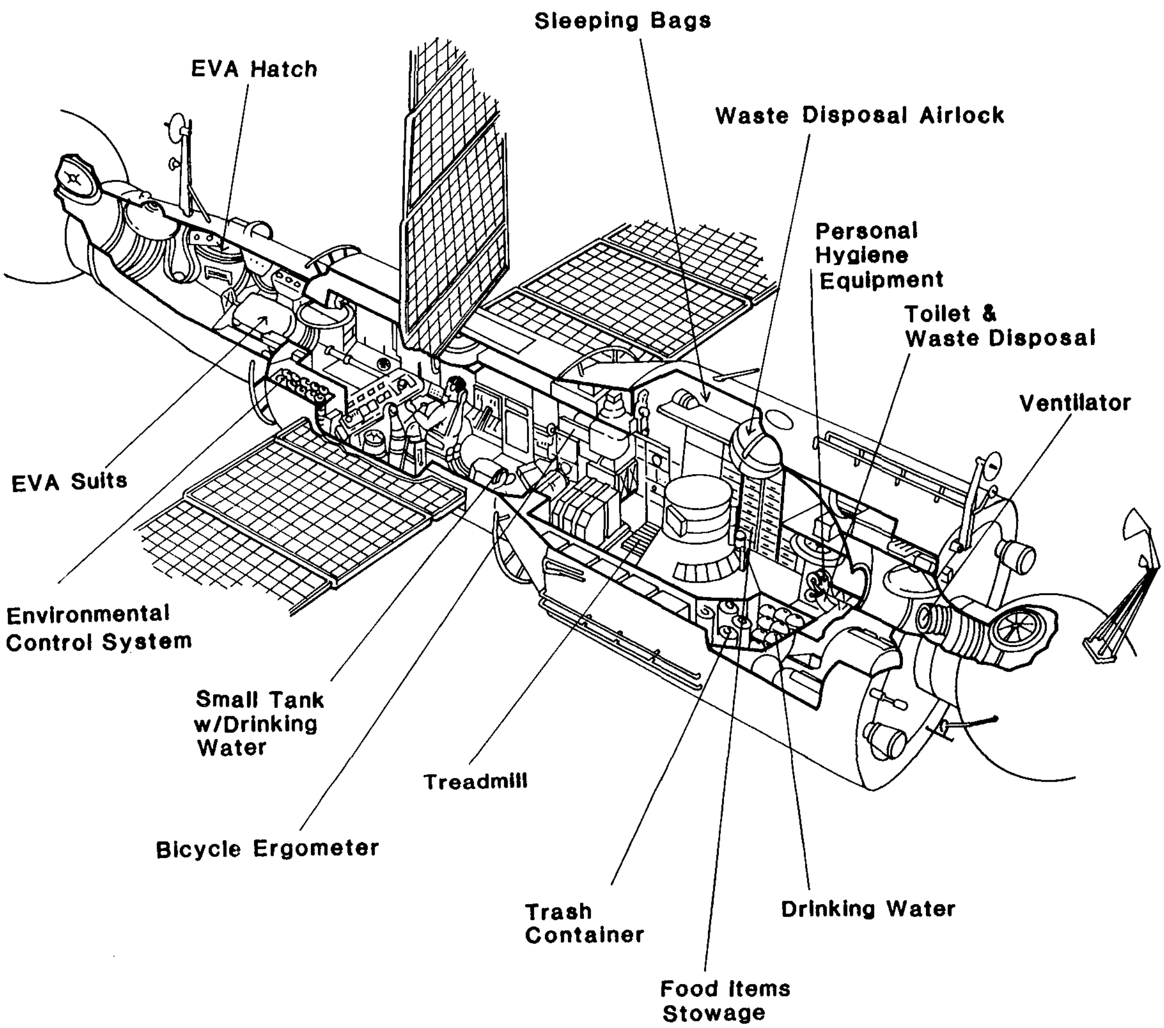
Salyuts 1 to 5 were first-generation stations with only one docking port. The atmosphere in these stations, just as in Salyut 6, 7, and all of the Soyuz spacecraft, was always maintained at 14.7 atm $\pm$ 10%, with an "Earth-like" gas mixture, which the Soviets always emphasize.

With launch of Salyut-7 in 1977, the USSR engaged in operating their second generation space station. With the exception of an additional docking port (at the instrument module, or aft) and several changes in the interior architecture, the configuration of the station remained the same. It has essentially a 1-g orientation and is of tubular design: 15m long and 4m in diameter in its widest section, the workshop area. The total habitable volume of the station is approximately $102m^3$, including the docked Soyuz spacecraft. However, this volume is greatly decreased by equipment of various types which has allowed the Soviet cosmonauts to perform a very large number of experiments such as materials processing, Earth observation, astrophysics, geodetic surveys, and medical experiments.

In some respects, the space station design leaves much to be desired. For example, ventilation is provided from the Soyuz spacecraft docked at the instrument module. The air first attacks the personal hygiene and toilet areas, then the drinking water tanks and food items storage. This has allegedly caused the finding, in the cosmonaut's oral and nasal cavities mucosa, of an "inordinate" (sic) amount of <u>Enterococcus bacilli</u> and <u>Streptococcus faecalis</u>.

The Soviet manned expeditions in space exceeded that of Skylab on six occasions: Salyut-6 -- 96, 140, and 185 days; Salyut-7 -- 211 and 115 days.

During the periods when they were manned by the "permanent" crews made up of two cosmonauts, the stations Salyut 6 and 7 were visited by 20 separate crews: 16 of them with two people and four with three people. Additionally, there were 18 dockings of unmanned spacecraft (automatic transports "Progress" and Soyuz-T) which replenished the station with all consumables, both for the crew and for the space station operations.



"SALYUT-6" SPACE STATION

Showing some of the principal life support system items on board.

One of the visiting crews on Salyut-7 was a woman cosmonaut, Svetlana Savotskaya. Her experience was vastly different from her predecessor, Valentina Tereshkova. According to the Soviets, she withstood the rigors of adaptation and readaptation as well as or better than her fellow crewmembers. In a departure from their traditional attitude, the Soviet designers even made provisions for private women's personal hygiene areas, not only on the Salyut7, but on the Soyuz spacecraft as well.

The Salyut 6 and 7 stations carry two EVA suits onboard; however, in spite of the long duration stays of the prime crews, only five EVA's have been performed, of which two were for unscheduled, emergency purposes. The other three were for scheduled scientific operations. The most recent EVA from the Salyut-7 lasted 2 hrs 33 min in spite of the fact that the EVA suits are rated for a maximum of two hours activity in open space. The Soviet EVA suits are pressurized at 5.2 to 5.8 PSI, with an emergency capability of 3.8 to 4.1 PSI. Prebreathing is done for a period of 25 to 30 minutes of 90% O_2, at 10.6 PSI.

The work/rest schedule is based on Moscow time to avoid "jet lag" and simplify work for ground personnel.

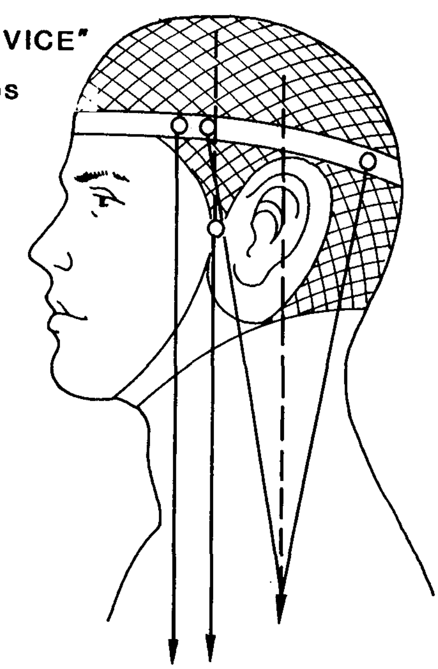
In June of 1983, the Soviets launched the "Kosmos-1443", an unmanned transport craft, which docked with the Salyut-7. This multipurpose spacecraft (of which we have no picture, or sketch, as yet) has a different configuration from the Salyut or Soyuz. It has a mass of 20 m/tons, is over 13 meters in length, and 4 meters in diameter, and has an inside volume of 50 m^3, which doubles the previous work/habitability area for space crews. With the Kosmos-1443, which has 40 m^2 of solar panels, the power capability of the complex has been increased to 7 kw. Kosmos 1443 can take up to 3 metric/tons of cargo to the Salyut (2.5 times that of "Progress"). It also has a return module which can take down a maximum 500 kgs of any type cargo. On its first turn-around, it returned 350 kgs of various items, i.e., results of scientific experiments, materials processing, and equipment to be repaired.

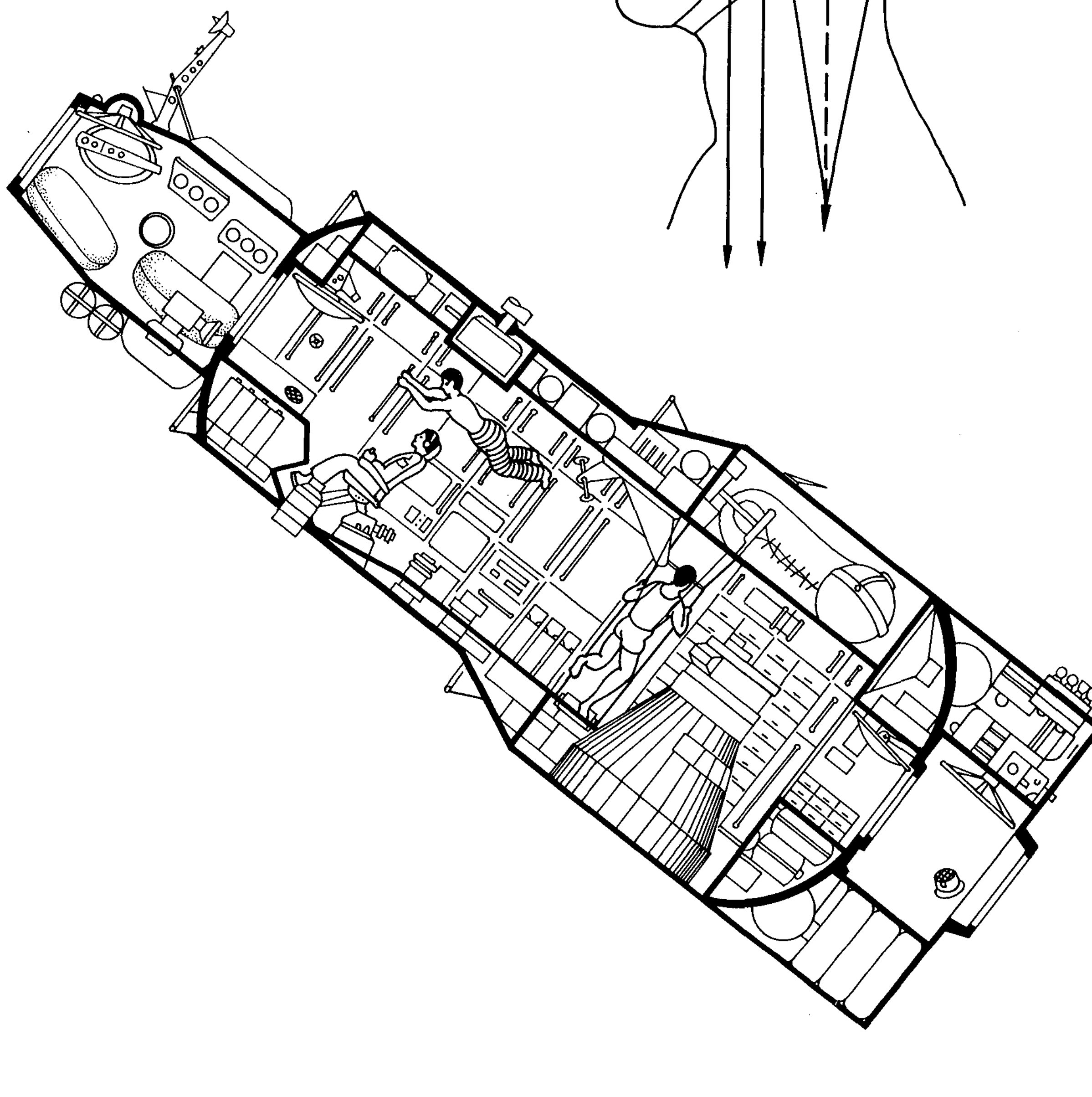
TABLE I - LIFE SCIENCE EQUIPMENT ONBOARD THE SALYUT-6 AND 7 STATIONS

Portable EKG, Microcomputer for downlink telemetry of a 12-lead EKG, vectorcardiogram, echocardiogram (also a Doppler Echocardiograph, supplied and flown by a French cosmonaut, Jean-Loup Chretien), rheocardiogram, phlebogram, plethysmogram, pneumogram, calf volume and separate muscle group measurements. Chibis suit (portable Lower Body Negative Pressure), penguin suit (for stress on legs and lower back muscles), body mass measurement unit, bicycle ergometer, treadmill with bungees (50 kgs), individual dosimeters, two radiometers (12.5 mrad sensitivity). A shower stall is available on-board, used every two to three weeks. The taking of the shower is always announced in connection with other health maintenance activity. Otherwise, washing and brushing of teeth is done with a cloth soaked in an antiseptic solution.

"ANTIMOTION SICKNESS DEVICE"

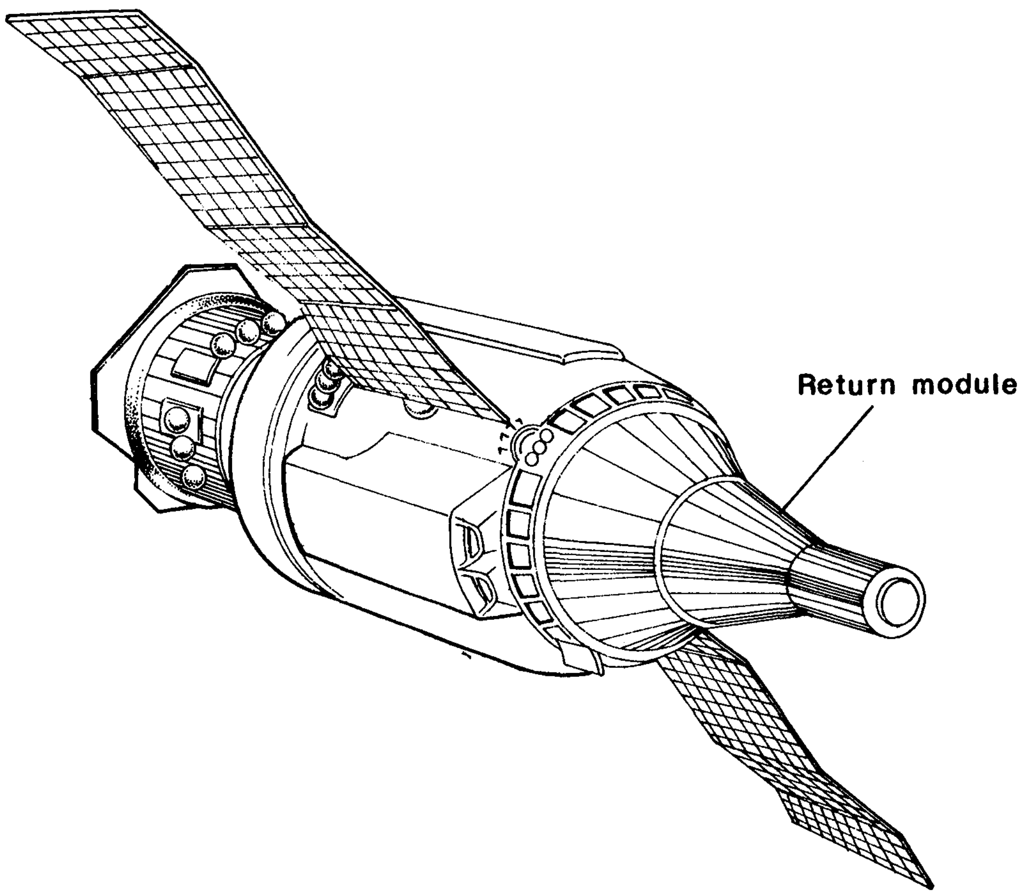
Headcap With Restrain Straps





"SALYUT-7" SPACE STATION

Essentially the same as "Salyut-6". Three crewmembers are shown to give an approximate idea of inside proportions. Permanent crew usually consists of two cosmonauts.



"KOSMOS-1443"

Automatic cargo transport, doubling the capacity of the "Salyut" Space Station. Also has a remote controlled return module allowing the return to earth of processed materials, completed experiments, etc.

APPENDIX C

PHYSIOLOGICALLY ACCEPTABLE SPACE STATION AND PRESSURE SUIT PRESSURES

James M. Waligora

The choice of a cabin atmosphere pressure for Space Station is influenced by a number of considerations. Several of these factors are related to human physiology. In light of an increased emphasis on extravehicular activity (EVA), and considering the results of our recent tests at JSC on decompression sickness prevention, it may be useful to restate the requirements for acceptable cabin and suit pressure combinations.

Oxygen Pressure: The nominal O_2 pressure in the cabin should be normoxic, that is, it should provide O_2 pressure normally available to the alveoli of the lungs.

Because of a dilution effect of water vapor and CO_2 in the lungs, the higher the O_2 concentration, the higher the ambient O_2 pressure must be to provide a normoxic level. At 3.7 psi (100% O_2), 3.7 psi is the normoxic O_2 pressure. At 14.7 psi (20% O_2), 3.1 psi is the normoxic O_2 pressure.

The band width of O_2 controllers and O_2 sensors will be within physiologically acceptable variation in O_2 pressure. Contingency O_2 pressure in the worst case should not provide less O_2 in the alveoli than available at an 8,000 ft equivalent altitude.

Pressure Change Ratios: A simple predictor of the threshold of decompression sickness incidence is the ratio of tissue nitrogen (as reflected by ambient N_2 pressure in saturation situations) to the final reduced pressure. Our best current estimate of a zero-prebreathe threshold from a 14.7 psi air saturation environment is a reduction in pressure to no less than 8.00 psi. This pressure reduction results in an N_2 ratio of 1.45. Years of exposure to these ratios in aviation indicates there will be no problems with symptoms at this level. However, because of the specific requirements of Space Station EVA, long periods (up to 6 hours) of substantial physical activity, the possibility of daily exposure and the need to be able to move freely from cabin to suit pressure, we are currently verifying that the 14.7 psi to 8.00 psi decompression can be done three days in a row with representative EVA times and activities without problem. There will be worst cases that involve a greater decompression than the 1.47 nominal case as a result of worst case ranges of control bends in both the cabin pressure and the suit pressure. However, variations in these control ranges also will be experienced in test verification data, and the nominal pressures should be the design pressures. This does not apply to significantly lower contingency pressures of either the cabin or the pressure suit which must be considered at their own nominal values. For instance, if a 14.7 psi cabin has an 8.00 psi contingency pressure mode, the impact of this decompression must be considered in planning for subsequent EVA from this cabin pressure. In a like manner, a lower contingency pressure in a pressure suit must be evaluated in terms of duration of exposure and possible increased incidence of symptoms.

Nitrogen Washout Procedures: Where required changes in pressure exceed the allowable N_2 ratio, prebreathing with O_2 or a reduced N_2 pressure atmosphere has been used to reduce tissue N_2 pressure. In assessing the effect of prebreathing, we use a half-time decay equation to estimate the reduction in tissue N_2 pressure prior to decompression. Both 240 min and 360 min tissues were used in the analysis for Shuttle. Our two current EVA preparation procedures involve some period of prebreathe to reduce tissue N_2 concentration. In our Shuttle planning, we used certain operationally successful O_2 prebreathing procedures as benchmarks rather than an R value of 1.45. The results of our bends tests indicate that our assumptions were not conservative enough to completely preclude decompression sickness.

Certainly for Space Station, where it might take two weeks to return a crewmember to Earth, we would want to be conservative regarding the incidence of decompression sickness.

Our current recommendation for calculating acceptable bends prevention protocols for Space Station would be to use a maximum N_2 ratio of 1.45 and to use tissue half-times of from 360 min to 720 min to account for N_2 tissue loss from prebreathe. Research needs to be done to establish which of these half-times would be most appropriate. The Lambertson committee has recommended that we use a 720 min half-time, and this conservative approach should be used until the use of a shorter half-time can be verified as appropriate by test.

Procedures Involving Multiple Decompression: Where more than one reduction in pressure is involved, the guidelines already stated for N_2 ratios and calculation of tissue N_2 pressure from assigned half-times will not provide adequate protection. There is empirical evidence that where multiple decompressions are involved, an initial decompression involving a N_2 ratio of less than 1.45 can potentiate the appearance of symptoms during a second decompression at a much later time. There is radiographic and animal indwelling Doppler data indicating that bubbles of a size below that which can be heard with a precordial Doppler sensor can form after a decompression from 14.7 psi to 11.5 psi. This is an N_2 ratio just in excess of one.

One theory is that micro-bubbles form or increase in size at any level of supersaturation, but it is only when the N_2 ratio exceeds some critical value (1.45?) that bubbles will continue to grow and cause symptoms. A corollary of that theory is that once micro-bubbles have formed or increased in size, it is difficult to reduce them with O_2 prebreathing. They act like tissue with a very long half-time for N_2 washout.

With these considerations in mind, supersaturation should not be allowed to occur on any but the final decompression in a multiple decompression exposure. That is, a N_2 ratio of 1.0 should be limiting on these decompressions.

Equations Used in the Calculations:

1. Equation for calculation of alveolor O_2

$$Pa\ O_2 = F_iO_2\ (P_b - 47) \left[- PCO_2\ X\ (F_iO_2 + \frac{1 - F_1,O_2)}{(0.85)} \right]$$

Where $Pa\ O_2$ = alveolar partial pressure of oxygen
$F_i\ O_2$ = oxygen fraction in breathing atmosphere
P_b = barometric pressure of the breathing mixture
0.85 = on assumed respiratory exchange ratio
PCO_2 = partial pressure of CO_2
PAO_2 at sea level = 104 mm
PAO_2 at 8000 ft = 68 mm

2. Pressure Change Ratios

$$RNs - \frac{TN_2}{Pf}$$

Where TN_2 = tissue N_2 in saturated environments nominally assumed equal to ambient N_2

Pf = the pressure after the final decompression

3. Tissue N_2 Calculation

$$PT = Po - \left[(Pa-Po)\ (1-e^{-kt})\right]$$

PT = final tissue N_2 pressure
PO = original tissue N_2 pressure
PA = ambient (breathing) N_2 pressure
K =
t = time of exposure to breathing gas
$K = \frac{0.693}{T\ 1/2}$

Application to Space Station Pressure Suit Pressure Combinations

Figure 1 is a plot of Station pressure and minimum suit pressure consistent with free movement from one pressure to another. These conditions are calculated to be equivalent to a 14.7 to 8.00 pressure combination and also provide normoxic O_2 levels with the indicated maximum O_2 concentrations. The combinations only apply after saturation at the Space Station pressure. To avoid bubble formation in cabin pressures of less than 11.6 psi, either several stages of decompression would have to be used or prebreathe with O_2 would have to be accomplished prior to decompression to cabin pressure.

Space Station Scenarios Assuming 720 minute 1/2 time

Cabin Pressure	Suit Pressure	Max O_2%	Constraints
14.7 psi	8.0 psi	26	None.
11.6 psi	5.75 psi	34	Stay at 11.6 psi 72 hrs. prior to EVA.
10.2 psi	4.8 psi	38	Prebreathe 130 min prior to going 10.2. Stay at 10.2 psi 72 hrs prior EVA.
9.4 psi	4.3 psi	40	Prebreathe 220 min prior to going to 9.4. Stay at 9.4 psi 72 hrs prior to EVA.
7.5 psi	4.3 psi	48	Prebreathe 460 min prior to going to 7.5. Stay at 7.5 psi 8 hrs prior to EVA.

ACCEPTABLE CABIN AND SUIT PRESSURE COMBINATIONS
AS SAFE AS A DECOMPRESSION FROM 14.7 PSI TO 8.0 PSI

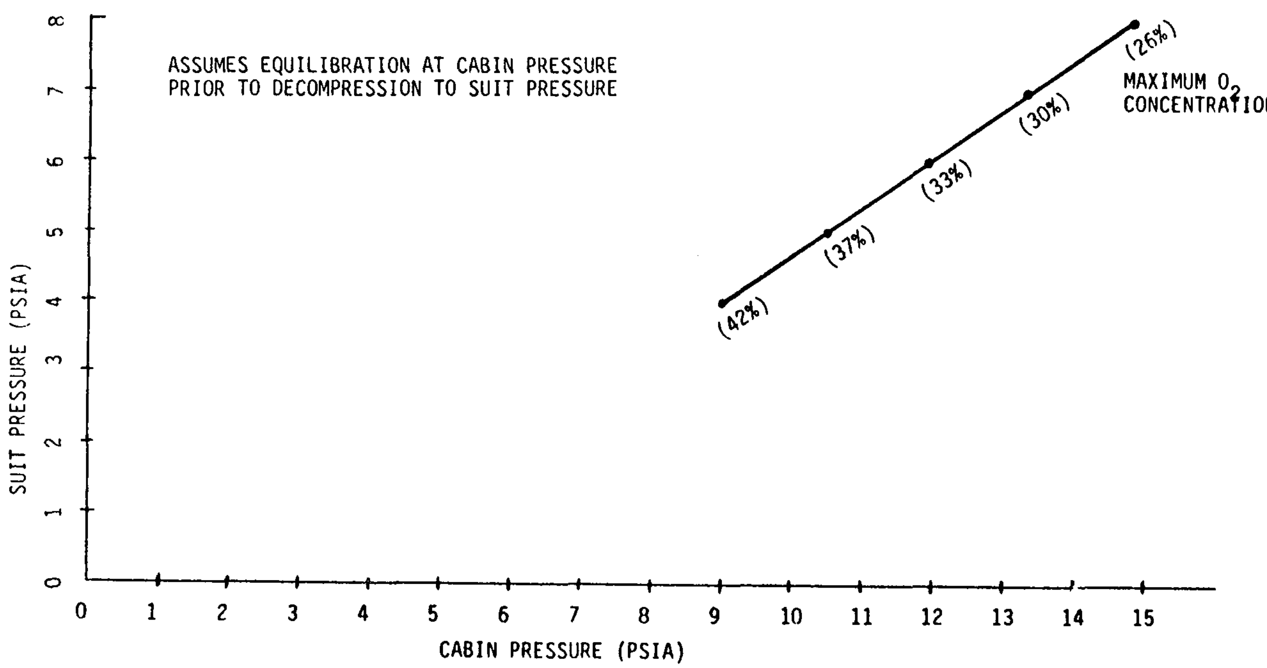


FIGURE 1

APPENDIX D - SUPPORTING HEALTH MAINTENANCE DATA

REVIEW OF PAST MEDICAL PROBLEMS ENCOUNTERED INFLIGHT (REF. NASA TM 58248)

Anorexia (loss of appetite)
Space Sickness
Fatigue
Insomnia
Dehydration
Flatulence (gases in stomach or intestine)
Dermatitis (skin inflammation)
Back Pain
Upper Respiratory Infection
Conjunctival Irritation (eye irritation)
Subungual Hemorrhage (bruises under fingernails from EVA suit gloves)
Urinary Tract Infection
Cardiac Arrhythmia (abnormal heart beat)
Headache
Muscle Strain
Diarrhea
Constipation
Barotitis (ear problems from atmospheric pressure difference)
Bends (decompression-caused limb pains)
Chemical Pneumonitis (lung inflammation)

CLASSIFICATION OF EMERGENCY SERVICES ACCORDING TO THE JOINT COMMISSION ON ACCREDITATION OF HOSPITALS (1984)

Level I — Emergency facility offers comprehensive medical care 24 hours a day with at least one physician experienced in emergency care. There shall be in-house physician coverage with specialties in medicine, surgery, orthopedics, obstetrics-gynecology, pediatrics, and anesthesiology. The hospital offers definitive care capabilities in these specialties and other specialty consultations are available within 30 minutes.

Level II — Emergency facility offers comprehensive medical care 24 hours a day with at least one physician experienced in emergency care. Specialty consultation is available within 30 minutes. In-hospital capabilities, otherwise, are similar to the level I facility.

Level III — Emergency facility is staffed by a nurse or medical technician. A physician is available within 30 minutes. Specialty consultations are available by request or transfer to a definitive care facility.

Level IV — First aid station with the availability of personnel capable of rendering life saving measures, then transfer to another facility. No call roster is required.

SUMMARY OF HEALTH DATA COLLECTED DURING 10 YEARS OF POLARIS SUBMARINE PATROL[a]---20,960 MAN-YEARS

Disease/ Condition	No.	Rate Cases[b]	No. per MY	Transfer Cat.	Deaths At Sea	Comments
Gen'l Surgery Referral	269	0.0238	32	6		70 appendicitis; 45 pionidal abscess; 23 burns.
Bone & Joint	264	0.0126	52	1		66 lumbosacral strain; 34 fractures; 2 amputations.
Gen'l Medical	240	0.0115	30	0		134 flu; 31 mononuc; 13 viremia.
Gastro-Intestinal	229	0.0109	19	6		155 gastroenteritis; 17 gastritis; 14 hepatitis.
Respiratory	185	0.00883	9	6		80 pneumonis; 43 URI; 36 acute bronchitis; 11 pneumothorax.
Ear, Nose, and Throat	165	0.00787	14	1		96 pharyngitis; 23 tonsilitis.
Urinary Tract	115	0.00549	19	3		39 ureteral calculi; 26 epid; 23 pyeloneph.
Psychiatric	58	0.00277	15	3	1	25 anxiety reaction; 13 neurotic depr.
Neurologic	53	0.00253	18	4	3	18 headache; 9 concussion; 8 migraine.
Dental	50	0.00239	9	1		28 periapical abscess; 13 pericoronitis+.
Eye	48	0.00229	16	3		18 corneal abrasions or foreign body; 16 conjunctivitis; 5 burns.
Cardiovascular	9	0.00043	5	2	1	3 hypertension; 2 chest pain.
TOTAL	1685	0.0804		37	5	

a. Compiled from data in: Tansey, W.A., J.M. Wilson, and K.E. Schaefer. 1979. Analysis of Health data from 10 years of Polaris Submarine Patrols. Undersea Biomedical Research, Submarine Supplement, S217-S246.

b. Excludes transfer at sea and death; includes only cases resulting in 1 or more days lost from work.

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16. Abstract

The medical operations report for the Orbital Test Flights (STS-1, 2, 3, and 4) includes a review of the health of the crews before, during, and immediately after the four Shuttle orbital flights. Areas reviewed include health evaluation, health stabilization program, medical training, medical "kit" carried in flight, tests and countermeasures for space motion sickness, cardiovascular profile, biochemistry and endocrinology results, hematology and immunology analyses, medical microbiology, food and nutrition, potable water, Shuttle toxicology, radiological health, and cabin acoustical noise. Also included is information on environmental effects of Shuttle launch and landing, medical information management, and management, planning, and implementation of the medical program.

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Cardiovascular System	Water	
Training Simulators	Hematology/Immunology	
Food	Microbiology	
Biochemistry/Endocrinology		

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