NASA TM-58248

NASA Technical Memorandum 58248

NASA-TM-58248 19830003432

Medical Operations and Life Sciences Activities on Space Station

October 1982

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National Aeronautics and
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Lyndon B. Johnson Space Center
Houston, Texas

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MEDICAL OPERATIONS AND LIFE SCIENCES ACTIVITIES ON SPACE STATION

Edited by
Philip C. Johnson and John A. Mason

October 1982

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

N83-11702#

This document is for planning purposes only. It should be useful to anyone interested in planning the life sciences aspects of a NASA-space station. Present plans are to revise this document and supplement its contents as new information is made available to the working group.

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MEDICAL OPERATIONS AND LIFE SCIENCES ACTIVITIES ON SPACE STATION

EXECUTIVE SUMMARY

The operational status of the Space Transportation System (STS) opens up the utilization of space in a manner that has not been practical before now. Shuttle missions will be short (7 to 10 days). The next logical step in the evolution of space utilization is to establish a permanent manned presence in space and extend our capacity beyond what is practical with STS. This can only be accomplished by deploying a manned space station.

This JSC document assumes that the structure will consist of several modules, each being consistent with Orbiter payload bay limits in size, weight, and center of gravity. We additionally assume that the functions of a space station placed in low Earth orbit will include servicing of an Orbital Transfer Vehicle; servicing payloads for transport to higher orbits; satellite repairing, constructing, refueling, assembling, and deploying large structures for power and observation by performing extravehicular activity (EVA); processing of materials and satellites within the station; and performing physical, chemical, and biological research utilizing a microgravity laboratory environment.

Optimization of purpose and compromises will be required to accomplish the missions. These constraints provide a framework within which health maintenance, medical treatment, human research, and biological research must be viewed. Each of these functions entails the need for different equipment, training procedures, and safety considerations to prevent occupationally produced accidents. Moreover, given the number of desirable functions, there will be competition for volume, weight, power, heat rejection, and crew time.

A space station will bring NASA into a new era when space construction, long stay times, and frequent EVA will be commonplace. The station will add industrial type crew activities to the current scientific and flight test activities now in the NASA program. It will widen the types of individuals sent into orbit from the present pilot-astronauts/mission specialists to include construction workers and specialists with varied non-flight career backgrounds and scientists of all types. The varied activities bring with them the usual types of industrial accidents including trauma, burns, infections, and psychological problems which complicate the physiologic changes associated with microgravity. There is also the effect these microgravity-induced changes may have on the productivity of the space station workers and their recovery from industrial accidents and diseases. No matter what type of activities will be undertaken, considerations of health maintenance will pervade any space station concept because the term, health maintenance, includes all factors that contribute to sustaining the life and well-being of the crew. This document attempts to detail some of these considerations. The possibility exists that medical problems, for which only highly invasive surgery or prolonged medical therapy would significantly increase patient survivability, may not be treatable in the station. A health facility with capabilities to handle highly invasive surgical emergencies might not be cost-effective, since the weight and volume cost could be prohibitive. Conditions requiring complex and

prolonged therapies will not be optimally covered. Until the size and scope of long-duration manned facilities require it, the techniques and instrumentation necessary for major surgery in space will remain a research priority rather than operational requirement.

As NASA leaves the heroic era of space exploration and enters into the era of settlement leading to industrialization, the medical problems, health maintenance, and treatment strategies will change. The underlying theme and the motivation behind health maintenance is to maintain the work efficiency of the crews. As the work activity changes from the present mix of flight testing, observing, and experimenting to constructing, repairing, and manufacturing, the medical conditions encountered can be categorized as follows:

Health Maintenance: To Maintain Work Efficiency of Crew

1. Usual Medical-Surgical Conditions of Adults

   A. Nonwork Related - Medical Occurrence
      e.g., infection, heart attack, renal stone

   B. Work Related - Accidents and Exposures
      e.g., fractures, puncture wounds, bruises, toxic compounds

2. Unique to Space Occupation

   A. In Microgravity
      e.g., space sickness, sinusitis, esophagitis

   B. Return from Microgravity
      e.g., microfractures, joint injury, postural hypotension

   C. Microgravity Environmental Effect on Pharmacokinetics, Normal Ranges of Medical Testing, Recognizing Disease and Healing

   D. Radiation - Chronic and Acute

3. Psychological Factors Related to Remote Hostile Environment

   A. Maintain Productivity of Crew
      e.g., food, quarters

   B. Prevent Psychopathology
      e.g., fighting, drug dependence, sexual problems

We can expect both work related and nonwork related conditions and accidents in this new situation. The accidents caused by falling objects and personnel will be replaced by accidents related to collisions with moving objects and strains related to the hand and foot restraints. The microgravity situation causes symptoms as in space sickness, but additionally, probably affects diagnosis, treatment, and even the healing process of disease. Any industrialization taking place in a hostile, remote environment will bring out psychological problems which could have a profound effect on productivity of both the

sick and well crewmen. The three major causes of industrial death: vehicle, firearms, and alcohol, may have representation in the space station unless plans are made to avoid them.

Medical care leading toward industrialization in a space station is envisioned as passing through four stages outlined in Table 1 and the HMF section. The first stage will use the already proven Shuttle Orbiter Medical System (SOMS) with augmentation. As the number of individuals increases, the Shuttle will no longer be nearby to help sick and injured crewmen. To assure health maintenance, the space station living area will contain a sub-area dedicated to health care and maintenance. This assigned area will include a first aid station equipped for treatment of most common emergencies and an exercise area to maintain the crew's physical well-being. As the complexity of the activities expands and the number of crewmembers who stay in orbit increases, the first aid station will be enlarged to contain the supplies, diagnostic equipment, and treatment facilities of a physician's office, then a two-bed hospital. Later on, the area dedicated for health maintenance will be expanded to a point where even state-of-the-art medical research can be accomplished without interfering with the health maintenance needs of the crew. During the build up, trained medical personnel will be in the station, progressing from a crew trained in first aid to an experienced emergency medical technician, and later, a physician with surgical training.

In addition to the dedicated health maintenance area within the station, there will be a dedicated life sciences research module. This module could be added at any stage of the space station buildup and would be designed to accommodate all types of biomedical research using animals, plants, etc. (See Table 5 in Section V.) Ordinarily, the dedicated module would not be used for medical (human) research since this would be accomplished within the health maintenance facility to avoid cross contamination. Medical researchers and biological research personnel will be needed.

NASA has been in the heroic phase of space research. The craft which have housed the crew provide only basic subsistence living (except Skylab). The spacecraft design emphasizes what is best for the machine. As we change into the settlement phase of space utilization, the habitability of the station becomes very important. Attention to habitability improves and maintains work efficiency. It will help avoid disruptive interpersonal problems. If the station is inhospitable, NASA will find morale suffering followed by decreased productivity as the time in orbit increases. Additionally, the high caliber individuals needed to perform space station work will not opt for second or third trips since their memory of the inhospitable interior environment will dominate their recollections.

Even though the ultimate configuration of a space station is not decided and the character of the missions is not precisely defined, there are general medical constraints which dictate design characteristics and operations of any manned space station independent of mission plans and architecture. This document reflects the Life Sciences considerations that have appeared in past space station concepts and new ones that should be considered in any new conceptual studies being initiated by NASA. The document has been prepared by a working group appointed in the Medical Sciences Division of the Space and Life

Table 1

PROGRESSIVE MEDICAL SUPPORT AS SPACE STATION DEVELOPS

CATEGORY	MEDICAL FACILITIES[1]	MEDICAL OPERATIONS[1]
I - Single module with docked Orbiter.	Augmented SOMS (first aid kit), and exercise facility.	Observing and monitoring the crew, collecting, and storing of blood, excreta, and toxicology specimens to establish normal ranges of biochemical tests.
II - Second module on core space station. No docked Orbiter.	Equipped first aid station area, hyperbaric treatment facility, expanded health maintenance, and exercise facilities.	Initial utilization of onboard diagnostic instrumentation which has preventive medical care as its primary function.
III - All-up core space station.	First aid station expanded to dedicated medical area with expanded treatment capability, e.g., anaesthesia, minor surgery, and biochemical analysis.	Medical documentation not requiring animal specimens but including invasive studies to solve medical care problems of microgravity.
AUGMENTED III	Expansion of the medical treatment area and its laboratory equipment making it similar to a small hospital with an enclosed emergency room.	Sophisticated clinical testing and medical research.
	* * * * * * *	
ADD-ON DEDICATED LIFE SCIENCES MODULE (Added during any of the above categories.)	A dedicated separate structure of laboratory space, primarily for biologic research.	Biological research using animals and plants in a separate dedicated laboratory area, not part of the medical treatment facility.

[1]Each category includes all previous features.

Sciences Directorate of JSC. The experienced JSC civil service employee authors have been part of previous space stations planning beginning with project Apollo Extension (1963) and continuing through the JSC proposed Space Operations Center (SOC) (1980) to the present. The group includes scientists, physicians, and managers who have been part of the manned flight program starting with Mercury and who currently function in support of the operational medicine and medical research involved with Shuttle and Spacelab missions. See Appendix A.

This working group recommends that NASA prepare for the health maintenance aspects of a space station by doing the following:

a. Establish a new, broadly based working group to define and investigate the habitability requirements of a space station.

b. Begin the planning for a health maintenance facility and exercise area by implementing long lead-time projects and tasks. See Section VI.

c. Establish a working group to define personnel requirements for the non-astronaut engineers, technicians, and scientists who will operate the space station facilities.

I. BUILDUP CONSIDERATIONS FOR MEDICAL PLANNING

The space station developed and placed into orbit by the United States may well involve a sequential buildup with limited but increasing manning and operational capabilities at each phase of the buildup. To be effective and useful, the health maintenance and medical care requirements for space stations must take into account this buildup sequence.

Categories have been established by the JSC working group for planning purposes in order to define various levels of space station buildup. Each category defines a manning level and operational capability that will require an increasing level of medical support. It is believed that the categories presented will permit various levels of medical operations to be established and provide for most foreseeable space station buildup sequences. The medical operations requirements for each category are presented in this document. Table 1 summarizes the medical facilities and operations to be conducted during space station buildup.

Although the timing of the buildup is not established, some preliminary concepts have indicated that Category I activities will last only a few months and involve mainly activation of the power, communications, and support systems. Thus, there will be little time and need for health maintenance beyond that afforded by an enhanced docked Orbiter. Category II activities may last two or more years. During this period, there may be substantial time for medical research. The medical equipment in the first aid station can be used for human research but will have to be always ready for operational medical treatment. Dedicated laboratory space for medical research with animals would be available when the Life Sciences Research Module is added.

Category I - A single habitable work area is assumed with an airlock and living facilities for two persons. When this phase is in orbit, the Orbiter crew may be able to be increased to eight. This station would be utilized for short duration missions and require the Orbiter to be docked or in orbit nearby to provide for crew safety during crew occupancy. Medical equipment would consist of that available on the Orbiter with additional supplies and equipment necessary to support the habitat development. At least one crewmember would be trained as an emergency medical technician (EMT) and would have this task as one duty. The EMT will have sufficient training to use a portion of the prescription medical supplies prior to consultation with a mission control center surgeon. Depending upon training and experience, various prescription drugs and surgical supplies could not be used by the EMT until after consultation with a mission control center surgeon. The entire crew will be trained in first aid techniques. The EMT will be able to draw blood specimens for later analysis in ground-based laboratories.

Category II - Additional work areas and airlocks would be added to increase facility size and provide redundancy. A four-person crew is assumed which would occupy this configuration for stay times to 90 days. A docked Orbiter would not be needed, and the remaining Orbiter crewmembers would return to Earth. Emergency rescue capability would be fairly slow, probably 14 to 21 days. Assembly tasks would be included during EVA. Simple satellite preparation, refueling, repairing; materials processing and observational activities would occur. A dedicated exercise and first aid area would be available. Medical equipment would include a duplication of that in the Orbiter as in Category I plus the equipment and supplies necessary to care for the well-being and medical problems of the crew over a three-month period. Routine simple diagnostic equipment would be available to process specimens. One crewmember would be a trained EMT with long experience as a medical assistant. Medical care and crew health maintenance would be his primary duty, but not his only duty. The remainder of the crew will be trained in first aid techniques.

Category III - Work and habitation areas would be added to Categories I and II. It is assumed that Category III will provide for an eight or more person crew with prolonged stay times as a standard. Four or all eight crewmembers could be changed with each Orbiter visit. EVA activities could include satellite servicing and construction projects. Complex satellite repair and materials processing would be a regular activity. Emergency rescue capability would remain at 14 to 21 days. Total emergency evacuation of the facility would be a planned option. For adequate health maintenance, dedicated medical facilities would resemble those available in a physician's office clinic or in a two-bed field hospital. The sophisticated medical care facilities would then be available to be cross utilized in medical research and would be designed to solve the medical care problems caused by the interaction of industrial activities with the physiological changes of microgravity. A research trained physician would be included to take advantage of the medical operational research

have as a primary duty the health care of the crew. He will have surgical training because of the industrial activities. He would have other duties. When a physician is not available, a medical technician with extensive experience in medical care, e.g., physician assistant, would operate the medical facilities.

Add-on Dedicated Life Sciences Research Module - It is assumed that a dedicated Life Sciences Research and Laboratory module will be added to the space station at some time during the buildup. The addition of a laboratory module separated from the HMF would allow basic medical research and biological research using animals and plants. This module would include a physician when needed for the invasive medical research or/and a Ph.D. to perform biological research. This is envisioned as state-of-the-art type biological research.

General Considerations - A factor that must be considered in the planning for a space station program is the dynamic nature of life science research and how it changes the requirements of health maintenance and medical treatment. Space Shuttle and Spacelab missions will provide expanded insights into human physiological responses to microgravity, especially the early (less than seven days) responses. The space station will allow these insights to be tested and extended over longer durations. The knowledge and experience over the first years of operation will probably result in changes in the functional requirements presented in this document. The rapid advances in biotechnology and medical diagnostics will likely provide simpler, more sensitive diagnostic techniques requiring smaller space, less power consumption, and allowing multiple uses. Therefore, an overriding functional requirement of medical sciences is to provide a mechanism to accommodate these changes and to allow flexible operational procedures.

Any example of medical directions, projects, equipment, or laboratory space mentioned in this report is based on present knowledge as it exists now. Because of the dynamic nature of medical and biological research, changes can be expected between now and the time a space station is placed in orbit. This will alter the directions and tools needed to accomplish meaningful medical research. However, the examples of today are adequate guidelines for planning, provided the plans allow for flexibility of use and of equipment choice.

II. HEALTH MAINTENANCE FACILITIES (HMF)

A. INTRODUCTION

Specific requirements for medical support of a long-duration manned facility are derived from four major sources: (1) inflight medical experience, (2) projected medical scenarios having a small but finite probability of occurrence, (3) mission-related space craft and environmental hazards, (4) health maintenance and preventive medicine. Appendices B, C, and D list typical examples of hardware, medical equipment, physiological measurements, biochemical measurements, and pharmaceuticals needed in support of these medical requirements.

The evolution of the HMF should follow parallel to the sequential buildup of the Space Station. These phases are described in terms of categories relating to the modular growth of the facility.

CATEGORY I - Augmented SOMS kit both in the Orbiter and the Station plus exercise facilities. Equipment to obtain biologic specimens.

CATEGORY II

1. First Aid Station - A location in the module where a sick/injured crewman can be restrained and treated. The station will have ready access to essential equipment such as physiological monitors, intravenous fluids, oxygen, suction, defibrillator, etc. Capability to perform simple diagnostic procedures and obtain routine biologic specimens.

2. Space Station Medical Kit (SSMK) - An expanded version of the SOMS with additional drug supplies and some additional surgical supplies.

3. Hyperbaric Treatment Facility - A facility designed to withstand a minimum of 3 atmospheres (absolute pressure) for treatment of most cases of decompression sickness and able to accommodate two individuals, i.e., patient and attendant.

4. Exercise Facility - An integral part of the recreational area consisting of a treadmill, friction based exerciser, and/or bicycle ergometer, etc.

CATEGORY III - Health Maintenance and Treatment Facility (HMTF) Dedicated HMF area increased in size. All features listed under Categories I&II will be available and expanded to accommodate additional crewmen.

Expand first aid station with space and equipment similar to a one-physician clinic with several added capabilities not usually present in a small clinic. In addition to expanded treatment facilities (e.g., anaesthesia and biochemical analysis), the M.D.'s office will have laboratory and imaging equipment and record keeping and data analysis capability. The M.O. should have surgical experience, able to conduct invasive procedures, if necessary, in order to stabilize a sick/injured crewman and to develop these techniques for more ambitious missions of the future.

AUGMENTED III - Dedicated medical facilities within the station will be expanded to include the equipment of a small hospital (2 beds) with an enclosed emergency room area. By this time, a life sciences laboratory module will have been attached to the space station. While this module would have biological research activities as its most frequent use, it could, with refurbishing, be

B. MEDICAL REQUIREMENTS

1. Inflight Medical Experience

A number of medical conditions have occurred inflight in U.S. manned missions since 1961. Table 2 lists, in relative order of decreasing frequency, the medical problems observed inflight. These medical problems, except for perhaps cardiac arrhythmias and bends, require little in the way of diagnostic aids. Therapeutically, they can be handled easily with a self-help type medical kit (i.e., SOMS). Generally, these illnesses had minimal mission impact. Only space sickness has affected mission timelines and accomplishments. The remainder were irritants to the individual crewmember who was able to continue his activities and schedule until landing. The lack of psycho-social problems during the missions has been notable. This appears to be a fortunate combination of a threeman working group, good communication with Houston, learning to live and work with each other during several years of training, motivation, clearcut tasks, and esprit de corps.

2. Medical Problem Scenarios

Projected medical scenarios can only be surmised. This category includes the common medical-surgical illnesses which might be expected on longer missions with larger crews. Included are the possible industrial medical problems inherent in crew activities as they manufacture, repair, and construct. In addition, there is the response the human body must make to live and survive in a microgravity environment. It seems probable that the physiological effects of microgravity will either enhance or moderate the symptoms and healing of industrial type accidents and illnesses. Similarly, the diagnosis, treatment, and convalescence from the chance occurrence of the common medical-surgical ills of middle aged humans will be affected when these situations occur in a microgravity environment.

The occurrence of inobvious disease processes in a microgravity environment may be difficult to recognize because of changed normal ranges of responses to disease states. Treatment may need to be tailored to the environment because of different rates of drug absorption, excretion, and different distribution volumes. At present, hard facts concerning these possibilities do not exist and must be learned from clinical experience and research as man lives, works, and becomes sick in a microgravity environment.

Perhaps NASA's prior concerns for these possibilities are best illustrated by the medical support of the missions to date. To care for 2 or 4 crewmembers during launch, orbit, and landing takes 20 physicians and similar numbers of bioengineers

TABLE 2

MEDICAL PROBLEMS ENCOUNTERED INFLIGHT

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)

and EMT's. Three physicians are used to man the control console during the orbital phase with the remainder on standby for landing. It would be uneconomical to continue similar coverage and support into the space station era. How far present plans to reduce the medical coverage during Shuttle missions will have proceeded by the time of a space station is problematic. How much more coverage may be needed when activities shift from flight test, research, and observation to construction, repair, and manufacturing is still unknown and can only be surmised.

Recalling the problems of the heroic explorers of the past who had to live or die with their own miscalculations, misinformation, and inadequate medical care, one might predict similar problems in establishing a near permanent existence in the hostile microgravity-environment around a space station. Modern society demands better treatment of the explorers and workers in a new industry. To avoid highly publicized disasters or at least to be able to prevent most disasters, a medical plan will be needed. The armed services have had experience with this and generally have done a good job of selection so as to avoid medical problems during a tour of duty and a good job of training to avoid industrial type accidents. This is clearly shown in the summary of the medical problems during the nuclear submarine patrols during peace time, shown in Appendix E.

3. Hazards Assessment

Hazards assessment must consider individual mission and environmental factors. Mature operations for a long-duration manned facility will include space-based construction and satellite servicing. Such activities will undoubtedly require routine EVA. Research into new techniques for materials processing may expose the crew to potentially toxic materials. Considering these activities and ground-based medical experience in complex industrial and aerospace environments, generalizations concerning the type of medical problems having a significant probability of occurrence can be made.

Table 3 provides a general breakdown of hazards in the setting of a space station.

4. Preventive Medicine

To protect the health of the crew, both physiological and psychological problems that are caused by isolation in space must be anticipated and countered. Methods for maintaining both physical and mental health are often intertwined. Some of these procedures are:

a. Recreation - This should include a large library (perhaps computer contained), exercise equipment, videotape and music libraries, and games to be played alone or with others.

b. Work - All on board should have sufficient tasks to make their stay a challenge, yet not so much work that their tasks are burdensome and thus counterproductive.

c. Sleeping - Facilities should be comfortable, with low level noise background, and also darkened.

d. Health Monitoring - Private medical conferences, biomedical and physical testing, and self-assessment should be part of an operational schedule. The macho image must be replaced by intelligent regard to individual health.

e. Nutrition - The food should be high in nutritive value as well as appetizing. The diet should be varied enough to make the crew look forward to mealtimes. Vitamins may be needed as supplements. Food flavor may have to be enhanced. Appetite stimulation may be needed early in flight. Recreational type food may be required. It is unknown whether high or low fiber is necessary for crew health.

f. Architecture and Engineering - At least two roles are evident: First, to avoid injury and discomfort, safety and ease of operation should be considered in the layout of the station and station systems. Second, the creation of a pleasant place to live and work which would include a private space for each crewmember. Space for personal use would add to the well-being of the crew.

g. Communication - Private two-way video communication with friends and family on Earth and open communication between crewmembers on board could boost morale. Noise level should not be so high that shouting is necessary.

h. Stress Management - Crewmembers should be trained to deal with the stress of the long stay in the isolation and close quarters of a space station (e.g., training in social support techniques).

i. Clothing - Should be comfortable, abundant, and not monotonous. Keeping clothing clean should be simple and not require large amounts of water. The design of both clothing and equipment should take into account the possibilities of 1) preventing trauma (e.g., flak jacket) and 2) causing trauma (sharp corners, tight fit). These include all designs within and without the space station.

TABLE 3

HAZARD ASSESSMENT

- 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, neurologic 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

j. Normal Ranges of all physiological parameters for individuals living in microgravity must be established to aid medical personnel in the determination when disease is actually present.

Medical records, biochemical analysis lab, and other equipment listed in Appendix A should permit the implementation of long duration studies of crew health as early as Category II space station is established.

The ultimate goal of preventive medicine in space is to provide the crewpersons with a long-term safe, comfortable, and healthy environment. Table 4 lists those space station systems which have preventive medicine implications.

Table 4

SPACE STATION SYSTEMS WITH
PREVENTIVE MEDICINE IMPLICATIONS

LIFE SUPPORT

- Structure, Power and General Communications
- Environmental Control Life Support Systems, ECLSS (air, water, temperature control, etc.)
- Food and Nutrition (includes storage, food preparation, galley, consumption, taste enhancement, cleanup, etc.)
- Waste Management (wet & dry, excreta & packaging materials, etc.)
- Hygiene (hands & body washing, shaving, toothbrushing, etc.)
- Sleep Stations
- Environmental Status Monitoring (could be in HMF or in separate command station)
  - Atmospheric quality (CO_2, O_2, N_2)
  - Trace gas analysis
  - Toxic compounds
  - Water quality
  - Ambient microbial load (air, water, surfaces)
  - Temperature
  - Humidity
  - Noise level
  - Acceleration and vibration
  - Radiation
  - Odor

LIVING AND WORKING SUPPORT

- "Housekeeping" (environmental cleaning, clothes washing, etc.)
- Clothing
- EVA Equipment
- Safety Provisions (equipment and procedures)
- Hand Holds, Intravehicular Activity Mobility Aids, Foot & Body Restraints
- Crew Stations
- Man-Machine Integration (includes tools to match the job)
- Work Planning
- Quality Control
- Communications
- Hygenic Needs

HEALTH MAINTENANCE FACILITY (preventive medicine)

- Exercise (fitness - legs, arms, back)
- Physiological Status Monitoring
  - Cardiovascular condition (heart rate, blood pressure, EKG, echocardiography, etc.)

Table 4 - continued

Metabolism
Pulmonary function
Immune competence
Blood chemistry records and evaluations
Urinalysis
Microbial load
Anthropometry and mass
Bone density
Thermometry
Radiologic, ultrasonic, and nuclear imaging
Visible Light Imaging Device (high resolution color TV or equivalent)
Tonometry (fluid shift)
Audiometry (noise and fluid shift)
Health records (trend analysis)
Private Medical Communications

SOCIAL-PSYCHOLOGICAL SUPPORT (habitability factors)

Rest (Earthviewing ports, body position holders, etc.)
Recreation and Entertainment (electronic games, board/card games, physical games, i.e, library, "darts", puff ball, music, TV, hobbies, diary writing, etc.)
Work/Rest Timeline Programming (includes circadian rhythm considerations)
Private Quarters
Clothing (style, color, selection, fit)
Private Communications (family and friends)
Architecture (includes color, local vertical, volume, layout, lighting, noise minimization, stowage, etc.)
Social Support Aids (computerized library to supplement ground-training, communication with professional psychological support team, etc.)
Human Performance Measurement

RESEARCH LABORATORY AND EQUIPMENT (add-on modules assumed; not necessarily permanent)

Human Biomedical Research Laboratory
Life Sciences Research Laboratory
Vivarium
Materials Processing Lab(s)
Orbital Quarantine Facility

III. HABITABILITY

A. INTRODUCTION

Habitability has to do with the nature and quality of the environment, measured in terms of how quickly and completely people can adjust and how successfully the environment supports operational efficiency, personal well-being, and morale. In the context of space stations, the term habitability refers to those components, characteristics, conditions, and parameters of design which are beyond the basic life sustaining requirements. For example, potable water is essential for life while water for whole body bathing would be classified as a requirement for habitability.

In planning for previous space missions, the principal emphasis on vehicle design has been upon solving critical technical problems to advance functional objectives, not upon the comfort and satisfaction of the crews. In this regard, man has been perceived primarily as an extension of the machine, rather than the machine being viewed as an extension of the man. The success of future space missions of intermediate (90 days) to long term duration, however, will require a reversal towards man as a central concern.

Experience with habitation of the Orbital Workshop (OWS) of the Skylab Program provides some of the best insight into design of habitable facilities for manned space flight operations. Requirements in this JSC document are based upon this evaluation and the interpretation of these experiences.

Habitability is of concern in other Earth based situations where confinement, remoteness from normal society, unique or adverse environmental conditions, and unusual workloads are present. In this aspect, they were similar to living and working in space. However, space systems must deal with the unique responses to microgravity. These impose a variety of human adjustments which must be supported by specially designed accommodations. Mobility and restraint (anchorage) are often easier in microgravity but always different. Basic body postures and acts such as sitting, standing, walking, and lying are new experiences in microgravity. The habitability is of such importance that it should be considered as a major subsystem of the spacecraft to assure that it receives the proper emphasis in space station design.

B. DESCRIPTION

For this document, the habitability listings are based upon a mature space station (Category III) with a crew of 8 to 12 persons and nominal stay times of 90 days. Requirements are organized into nine categories or disciplines with a brief listing of the major elements of each.

Habitability Listings

1. Internal Environment
   a. temperature and humidity
   b. atmospheric composition movement and revitalization
   c. acoustic and light levels

2. Architecture
   a. volume and geometry of compartments
   b. access and egress
   c. colors and textures
   d. stowage and retrieval
   e. privacy
   f. traffic patterns
   g. observation windows

3. Mobility and Restraint
   a. locomotion restraint aids
   b. mechanical assistance

4. Food
   a. nutrition
   b. palatability
   c. stowage and retrieval
   d. meal preparation, serving, consumption, clean-up

5. Clothing
   a. duty/off-duty
   b. sleep wear
   c. protective
   d. clothes washing
   e. adjustments for changed body configurations

6. Personal Hygiene
   a. bathing - grooming
   b. body waste elimination

7. Housekeeping
   a. cleaning equipment, procedures, and schedules
   b. refuse collection and disposal

8. Communications
   a. intravehicular (within flight crew)
   b. outside (family, friends, and ground control)

9. Crew Activities
   a. work/rest schedules
   b. off-duty activities

IV. PERSONNEL

Criteria for personnel selection are categorized as follows:

a. functional abilities and skills
b. physiological qualifications
c. personality traits

Criteria for each of the above categories can be developed by an interdisciplinary working group. Criteria for the first two categories have been successfully applied in previous space flight missions. The third category, personality traits, is one which will require increased attention and development. Optimal productivity will probably entail two or three-shift operations. Selection criteria for personnel best suited for shift work need to be developed.

The effect of personnel on mission operations is indisputable. A compatible, harmonious crew will be highly productive and highly successful. The possibility of acrimony or unprofessional-like activities among crewmembers may increase, as the antarctic expeditions verify, when increased numbers of technical personnel are selected at the expense of physiological and psychological traits.

Most likely, the entire area of operations management will be delegated to the commander of the space station. The group leader will derive his/her authority from his/her own personal traits, and this will be reinforced by statutory authority vested by the NASA. Nevertheless, it is essential that these domains of group dynamics between commander and crew be given proper attention, especially for missions of long-duration and when factions amongst crewmembers can develop. This area of potential conflict could be intensified if crewmembers are required to work long or rotating shifts.

Productivity of the group assigned to the space station will be significantly affected by the personalities of the individuals. There are a variety of criteria for personnel selection of individual crewmembers. Interpersonal relationships between the crewmembers will become most important when the crew size is greater than three and mission duration is greater than 2 weeks.

In order to maximize the functional mission capability of personnel working in space, it is suggested that an interdisciplinary working group be developed consisting of at least flight operations, engineering, life sciences, and personnel interests. The rationale behind such a group is to make requirements utilizing the findings of both social and industrial psychology to produce the maximum level of productivity. Proven areas of these disciplines have provided the military and industry with successful acquisition of optimal group composition, group size, group structure, communication, lines of authority, interpersonal relationships, and psychological traits. The same could be true for NASA.

V. RESEARCH IN THE MEDICAL SCIENCES AND IN BIOLOGY

A. INTRODUCTION

Continued manned exploration of space will require the establishment of a life sciences research program to ensure that man can live and work in space for extended durations. During previous space flights, man has experienced physiological changes which could endanger the crews during longer duration space missions. Significant findings include: loss of skeletal mass and calcium, decrease of red cell mass with relative increase in abnormally shaped red blood cells, decreased plasma volume, increased leukocytes, change in blood levels of hormones, redistribution of body fluids, loss of muscle mass and nitrogen stores, and vestibular changes leading to space sickness. Studies must be conducted to determine the problems that humans will encounter during longer space flights and to suggest solutions to the problems. Invasive techniques utilizing animals will be required. In addition to the problem areas identified from previous space flights, other areas will be addressed: basic metabolic activity including glucose metabolism, reproductive activity, gastrointestinal function, central nervous activity, biorhythms, effects of space flight on aging and the development of chronic degenerative diseases, rate of drug disposition and drug efficacy, individual drug allergy, neurophysiology of vestibular system control, and radiation effects.

In addition to the biomedical areas mentioned, space biology studies will be conducted to use the microgravity environment for basic research and to determine and describe the adaptive mechanisms of terrestrial life. The basic laboratory will be supplemented by specialized equipment identified by individual investigators. Missions of increasing durations or numbers of crewmembers may require life support systems independent of resupplying consumables -- food, water, and oxygen (Controlled Ecological Life Support Systems). These substances may need to be recycled or regenerated. Research is required to establish a biologically driven regenerative life support system.

B. PROPOSED PROGRAM

The life sciences research program during space station is based on a sequential buildup of the space station with limited but increasing manning and operational capabilities at each phase of the buildup. A summary of the program is presented in Table 5. During the initial phases of the space station, the research activities will be limited to observation and monitoring of the crew and the collection and storage of specimens for analysis on the ground. As the capacity of the space station increases, the research activities will be expanded to include pilot experiments that do not use animals and the utilization and verification of instrumentation which will be used in the conduct of the research.

An isolatable life sciences research laboratory module will be required to conduct research using animals (non-human primates, rats, and mice) and plants. Laboratory procedures conducted in space will require that data be available in real time. The laboratory area will have equipment such as general purpose work stations, surgical areas, animal facilities for breeding and maintenance of animals, an aquatic facility for marine experiments, and a multigeneration plant facility. Research must be conducted on a biologically regenerative life support system. The details of the specific research efforts and requirements will be determined by panels of experts in the fields being investigated. These inputs must be generated in sufficient time to be considered in the design of a dedicated laboratory area.

Table 5

LIFE SCIENCES RESEARCH DURING SPACE STATION ERA

Space Station Configuration	Typical Research Areas	Probable Activities
Category I - single module with docked Orbiter	Cardiovascular Musculoskeletal metabolism Hematology & Immunology	Observing, monitoring, collecting, and storing specimens drawn for analysis on ground. Develop first aid techniques for use in microgravity.
Category II - second module	Same as Category I	Same as Category I, establishing normal range in microgravity of biochemical tests needed to diagnose disease.
Category III - additional modules	Category I + biology which does not require animals	Category I + verification of instrumentation for diagnosing physiological state in microgravity by invasive and non-invasive techniques. Develop surgical techniques applicable to microgravity.
* * * * * * * * * * * *		
Add-On - Dedicated life sciences laboratory module separate from HMF (added during any of the above categories)	Category I + Cardiovascular/ Respiratory Physiology Endocrine and Metabolic Physiology Neuroscience Neurosensory Physiology Biorhythms Animal Status Monitoring	Performance of experiments using non-human primates, animals (mice/ rats), and plants in addition to human subjects to determine mechanisms, etiologies, and responses of terrestial life to microgravity.
	Space Biology (animals & plants) Development Reproduction Biorhythms Plant Biology Radiation Biology	
	Life Support Systems (ECLSS)	

VI. AREAS FOR FURTHER STUDY

The working group has identified the following areas for study:

Health Maintenance Facility-Hardware	Inhouse	Contract	University
a. Diagnostic imaging	X	X	X
b. Clinical chemistry	X	X	
c. Automated hematology, urinalysis	X	X	
d. Microbiology	X	X	
e. Miscellaneous diagnostic equipment	X	X	
f. Miscellaneous therapeutic equipment	X	X	
g. Pharmaceuticals		X	
h. Rehydratable IV fluid/hyperalimentation	X	X	
j. Exercise equipment	X	X	X
i. Modularization & trade-offs of medical hardware for HMF	X	X	X
Health Maintenance Facility-Procedures			
a. Toxicology & radiation	X		
b. Physiological monitoring	X	X	X
c. Medical life support systems	X	X	X
d. Computer-assisted diagnostic/therapeutic checklist	X		X
e. Countermeasure devices	X		X
f. Cardiovascular conditioning	X		X
g. Musculoskeletal conditioning	X		X
h. Surgical procedures	X		X
i. Orthopedic procedures	X		X
j. Tissue and sample handling	X		X
Habitability - Living Space			
a. Historical review	X		X
b. Habitability data base	X		X
c. Internal environment	X	X	X
d. Spacecraft architecture		X	X
e. Mobility & restraint	X		
f. Clothing	X	X	
g. Personal hygiene	X	X	X
h. Housekeeping	X	X	
i. Communication	X	X	X
j. Crew productivity			X
Habitability-Food Systems			
a. Food preservation	X	X	X
b. Food compression			X
c. Food reconstitution	X		
d. Food preparation techniques	X	X	X
e. Emergency food supplies	X		

Habitability-Food Systems (continued)

	Inhouse	Contract	University
f. Bulk storage and dispensing	X	X	X
g. Single service containers	X	X	X
h. Materials improvement	X	X	X
Habitability-Food System Equipment			
a. Food preparation	X		X
b. Meal service methods	X		X
c. Inventory control and reporting	X	X	X
d. Food & packaging waste management		X	
e. Dish & utensil sanitizing		X	X
Habitability-Food Acceptability	X	X	X
Habitability-Nutrition	X	X	X
Personnel			
a. Personality traits			X
b. Group dynamics			X
c. Conflict theory		X	
d. Effects of group size & composition		X	
e. Communication		X	
f. Lines of authority			X
g. Interpersonal relationships-- situational testing - motivation	X		X
i. Environmental manipulation	X		
j. Man-machine interface	X		
Research			
a. Definition of experiments and identification of required facilities	X	X	X
b. Specifications of requirements for space station	X	X	
c. Delegation of research activity with health maintenance	X	X	
d. Selection of experiments	X		X
e. Identification and procurement of laboratory and diagnostic equipment	X	X	
f. Development of space station laboratory and animal handling facility	X	X	X
g. Operations plan for implementation of research	X	X	
h. Implementation of research program	X	X	X

VII. HISTORY AND BACKGROUND OF DOCUMENT

A. PREVIOUS SPACE STATION PLANNING

The first serious proposal of a space station design can be traced back to 1923. See Table 6 for a partial listing of studies.

Figure 1 shows the major space station studies conducted since the formation of NASA in 1958 up to and including the JSC/Space Operations Center (SOC) concept in 1980-1981. Most of these studies have, at least, superficial considerations of medical/life sciences aspects.

B. EVOLUTION OF THIS DOCUMENT

In early June 1982, persons in the JSC/Space and Life Sciences Directorate, learned of an Ames Research Center (ARC)/Marshall Space Flight Center (MSFC) study plan for "Near-Term Actions on the Life Sciences Space Station Module Study". The ARC/MSFC proposal for the study had been requested by Dr. William P. Bishop, Deputy Director, Life Sciences Division of NASA Headquarters with specific instruction to ARC/MSFC that "... a lab to manipulate man, a health care facility, and the human habitat itself [was to] fall outside the scope of this study".

This information together with encouragement by Dr. Arnauld E. Nicogossian, Chief, Operational Medicine Office of NASA Headquarters, induced JSC to proceed with the writing of this plan. A decision was made to proceed with a requirements document with the flavor of "input-type" scenarios that would be useful in the preparation of a NASA guidance "yellow book" for space station. Further, it was decided to identify those areas needing study, inhouse and/or by contract. Specific contract statements of work would be developed separately from this document.

C. STUDY APPROACH

A working group was established with membership mainly from the Medical Sciences Division but with a representative from the Life Sciences Project Division and from the Systems Engineering Division of the JSC/Engineering and Development Directorate. Appendix A presents a summary of the background of the working group members.

The working group has operated primarily through 1-hour weekly meetings; a total of 15 meetings have been held to date. An outline of the study plan was prepared, and the various sections were drafted by appropriate working group members. The first draft became a "living document" with many, many iterations. Between drafts, the past space station/long-duration mission study reports were reviewed by working group members. See Table 7.

Table 6

PRE-NASA MANNED SPACE STATION DESIGN STUDIES

(Partial List)

Date	Author	Description
1923	Hermann Oberth	Conceptual description only, no drawings. First serious proposal. Suggested means of supplying artificial gravity and building in orbit.
1928	Hermann Noordung	First design on paper. Heavy rotating satellite with solar powered generators. Observatory positioned away from main structure.
1948	Ross & Smith	Twenty-four-man satellite for observation, communication, and research. Rotating station provided artificial gravity while movable arm permitted entrance and exit.
1951	Werner von Braun	"Space Wheel" Concept originated in connection with "Mars Project". Originally 20-segment wheel, later changed to circular shaped rim. Largest and widest known.
1954	Kraft Ehricke	Four-Man Orbital Station. Conceptual presentation of different type of station design with mass concentrated at center for stability.
1958	Kramer & Byers	Engineering design of wheel-shaped orbital station patterned after von Braun's concept. Included design of "astrotug" for assembling station setments.

Figure 1

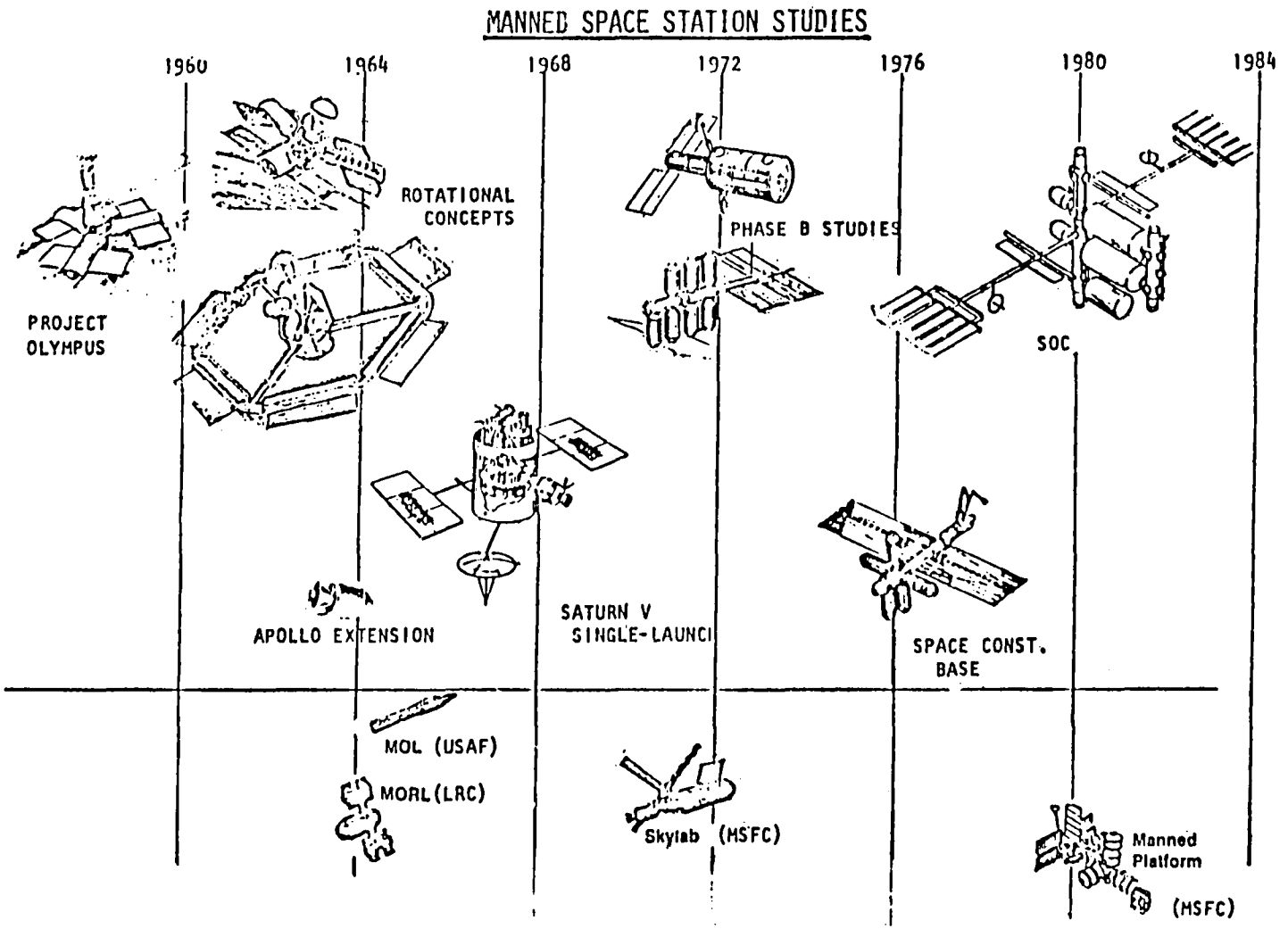
MANNED SPACE STATION STUDIES
1960
1964
1968
1972
1976
1980
1984
PROJECT OLYMPUS
ROTATIONAL CONCEPTS
PHASE B STUDIES
SOC
APOLLO EXTENSION
SATURN V SINGLE-LAUNCH
SPACE CONST. BASE
MOL (USAF)
MORL (LRC)
Skylab (MSFC)
Manned Platform
(MSFC)

TABLE 7

SAMPLING OF PAST LIFE SCIENCES REPORTS
ON SPACE STATION FOR LONG DURATION FLIGHT

Document Title	Date	Contractor	Working Group Reviewer
Medical Requirements in Support of Long Duration Manned Space Flight	Nov 1967	Bellcomm, Inc.	Mieszkuc
Saturn V Single Launch Space Station & Observation Facility (extract)	Nov 1967	Boeing Company	Dalton
A Biomedical Program for Extended Space Missions	May 1969	JSC & Bellcomm	Mieszkuc
IMBLMS/Skymed Presentation to NASA Headquarters	May 1970	General Electric	Logan
Role of the Lunar Receiving Laboratory in Post-Apollo Biological & Biomedical Activities	Jul 1970	AIBS	Smith
Space Station Study Phase B (extract)	Jul	North American Rockwell	Dalton
Space Station (extract)	1970	McDonnel Douglas	Dalton
Orbit Lunar Static Phase A Study (extr	Oct 1970	Space Division North American Rockwell	Dalton
Life Sciences Payload Definition & Integration Study Vol II & III	Mar 1972	General Dynamics	Hadley
Conceptual Design for a Biological Specimen Holding Facility	Jan 1976	MSFC/Lockheed	Greider
Space Station Systems Analysis Study - Part 1 Final Report Vol 3	Sep 1976	McDonnell Douglas Astronautics	Primeaux
Future Directions for the Life Sciences in NASA	Nov 1978	LS Advisory Committee	Johnson
Orbiting a Quaratine Facility - the Antaens Report	1981	NASA Hqs. & Colorado State U.	Harris
SOC - Life Sciences	1981		Nachtwey

The above documents (and others) are stored in bookcase, Room 162, Building 37.

EXAMPLE

Individuals with first-hand information attended the weekly meetings. Astronaut Lousma, STS-3 Commander, discussed his first-hand habitability experience, and John Annexstad, a JSC geophysicist with polar expedition experience lasting for over 9 months, described his experience in relation to habitat and interpersonal relationships.

VIII. U.S.S.R. SPACE STATIONS

In 1971, the Soviet Union launched their first "Salyut-1" Space Station. Since then, they have been aggressively pursuing the concept of permanent presence in space. However, to date, this presence was manifested by having a space station in orbit, but there were periods from a few weeks to 8 to 9 months when these stations were not manned. The Salyut 1 through 5 were mainly test articles, although some activities, primarily in the systems testing, were carried on in each station. For example, we know that in 1975 during the Apollo-Soyuz Test Project, the crew of Salyut-4, in orbit and manned at that time, was in frequent communication with Leonov and Kubasov during their flight with Apollo.

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

With the launch of Salyut-6 in 1977, the U.S.S.R. 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 unchanged. It has an essentially 0g orientation, tubular design, 15-m long and 3 m in diameter in its widest section, the workshop area. The total habitable volume of the station is approxiamtely 102 m^3 which includes the docked Soyuz spacecraft. This volume is however, greatly decreased by a large amount of 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, medical experiments, etc.

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

During manned periods by two cosmonauts, the stations (Salyut-6 and Salyut-7) were visited by 19 separate crews; 16 of them with 2 people and 3 with 3 people. Additionally, there were 17 dockings of unmanned

spacecraft (Automatic Transport "Progress" and Soyuz-T") which replenished the station with all consumables, both for the crews and for the space station operation.

The "Salyut-6 and 7" stations carry two EVA suits onboard; however, inspite of the long-duration stays of the prime crews, only four EVA's have been performed, of which two were for unscheduled, emergency repair purposes. The other two were for the retrieval of film from cameras mounted on the outside of the station and to check the progress of an externally mounted phytotronic compartment for unicellular plants. The pressure used in the EVA suits is unknown to us.

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

The last space station in orbit, the "Salyut-7", still of the second generation, is essentially identical to the "Salyut-6". The present crew manning it has been in orbit for 125 days, but there are indications that they will soon be returning to Earth. It will be important to see whether they will leave the station unmanned - as on every previous occasion - or if another crew will replace them immediately, eliminating the necessity of shutting down most of the systems. In such a case, a Soviet claim to "permanent" manned presence in space will be fully justified.

One of the visiting crews on "Salyut-7" was a woman cosmonaut, Svetlana Savitskaya. Her experience was vastly different from her predecessor, Valentina Tereshkova. According to Dr. Gazenko, she withstood the rigors of adaptation and readaptation as well 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 "Salyut-7" but on the Soyuz spacecraft as well.

To date, the Soviet manned observation in space exceeded that of Skylab on five occasions: Salyut-6 -- 96, 140, 175, and 185 days; Salyut-7 -- 125 days.

A. Life Sciences Equipment Onboard the "Salyut-6,7" Stations

Portable EKG, Microcomputer for downlink telemetry of 12-lead EKG, vectorcardiogram, echocardiogram, rheocardiogram, phlebogram, plethysmogram, pneumogram, calf volume and separate muscle group measurements. Chibis suit (portable LBNP), penguin suit (for stress on leg and lower back muscles), body mass measurement unit, bicycle ergometer, treadmill with bungees (50 kgs), individual dosimeters, two radiometers (12.5 mrad sensitivity), "Lotds" system for polyurethane spray in making casts for fractures in microgravity. Shower stall available on board, but when used (approximately every 2 weeks) it is always announced as a test measure.

APPENDIX A

WORKING GROUP MEMBERS

NAME	DEGREE(S)	YEARS NASA	SIGNIFICANT NASA EXPERIENCE/ACCOMPLISHMENTS
M. W. Bungo	M.D.	2	Mission Control Center Surgeon, cardiovascular testing STS crews.
M. C. Dalton	B. S.	19	Space station design, crew station research and development, habitability research Skylab, crew station design, orbiter habitability design-SOC.
J. Degioanni	M.S., M.D. Ph.D.	6	Board certified Aerospace Medicine (Preventive Medicine), board eligible Emergency Medicine; Ph.D. Astronomy; M.S. Public Health; JSC Medical Standards Officer, 1976-79 designed medical standards for astronaut selection, Class I, II, III; protocol for medical selection of astronauts; designed SOMS; author Shuttle medical checklist; STS-1 deputy crew surgeon; Spacelab-1 crew surgeon; principal investigator in motion sickness studies (JSC).
H. R. Greider	B.S.	18	Wrote Mercury environmental requirements; originated the conceptual design for Mercury ECS and space suit.
A. T. Hadley	M.D., M.S.	1	Certified Aerospace Medicine and Family Practice, M.S. in Public Health and Tropical Medicine, involved with decompression sickness.

APPENDIX A (cont.)

J. W. Harris	B.S.	19	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.
P. C. Johnson	M.D.	3	Specialized medical operational testing pre- and postflight Gemini, Apollo; P.I. for Skylab, SL-1; MCC surgeon, STS medical reports.
J. S. Logan	M.D., M.S.	1	Chief, Flight Medicine, MCC Surgeon, STS-3; Deputy Crew Surgeon, STS-5; Crew Surgeon, STS-6; board eligible Aerospace Medicine.
J. A. Mason	M.S., M.S.	19	Hqs. NASA-planning advanced manned missions; JSC-Deputy Chief, Preventive Medicine Division-Lunar Quarantine; Chief, Bioscience Payloads-Spacelab life science simulation; Medical Research Branch-space station planning.
B. J. Mieszkuc	M.S.	14	Virologist-Mgr. Virology Laboratory-Lunar Quarantine, Apollo and Spacelab flight support; Mgr. Bioprocessing Laboratory-Electrophoresis equipment verification test; Biomedical Laboratories Branch-manage clinical medicine support; space station planning.

APPENDIX A (cont.)

D. S. Nachtwey	Ph.D.	8	Contributor, Environmental Impact Assessment and Statement for Space Transportation System and for Solar Power Satellite (SPS) System; Contributor, Radiation Safety Assessment for SPS workers; JSC Radiological Health Officer; Manager, Radiation Effects and Protection RTOP.
G. R. Primeaux	B.S.	19	Life Science technology utilization; physiological monitoring equipment development; facilities support for crew testing/baselining-SMEAT; 1-G trainer; Skylab mobile laboratories.
M. A. Reynolds	Ph.D.	13	Contamination Control Officer of the Lunar Receiving Laboratory; Curator in charge of pristine laboratory and cleaning requirement for lunar samples; member of EEVT team-electrophoresis.
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.	10	Chief Interpreter and staff of ASTP; Space and Life Sciences interpreter/translator joint working group meetings since 1977; study of Soviet aerospace achievements in life sciences.

APPENDIX B

EXAMPLES OF EQUIPMENT FOR DIAGNOSTICS/THERAPEUTICS/PREVENTIVE MEDICINE

DIAGNOSTICS

-Exam equipment
  Stethoscope
  Blood pressure measurement device
  Otoscope
  Ophthalmoscope
  Reflex hammer
  Guaiac cards
  Thermometer

-Ocular function testing apparatus

-Laboratory capability
  See Appendix C

-Diagnostic imaging

-EKG, EEG monitoring with downlink capability

-Pulmonary function test apparatus

-Tracheostomy tray

-Paracentesis, thoracentesis trays

-Peritoneal lavage tray

-Lumbar puncture tray

-Woods light, fluorescein

PREVENTIVE MEDICINE

-Medical treatment area and equipment

-Environmental monitoring

-Exercise machinery and facilities

-LBNP

-Medical records keeping system

-Mass/center of gravity measuring device

-Anthropometry

-Physiological status monitoring

Appendix B (continued)

THERAPEUTICS

-IV fluids
  Tubing
  Catheters
  Pumps
  CVP lines
  Pressure transducers

-Respiratory equipment
  O_2, O_2 masks
  Oral airway
  Ambu-bag
  Laryngoscope
  Ventilator with positive pressure capability
  Chest tube and suction

-Surgical equipment
  Minor surgery tray and instruments
  Burr hole screws
  Bandages, tape, burn type
  Irrigation fluids
  Dentistry instruments

-Orthopedic equipment
  Splints
  Cast material
  Wraps
  Pins
  Closed reduction traction equipment

-Anaesthesia
  Local and general

-Medical support and equipment
  Urinary catheter
  Wall suction & nasogastric tubes
  Hot packs, cold packs

-Bends recompression capability to 3 ATA

-Medical checklist
  Procedures and instruction manual

APPENDIX C

EXAMPLES OF LABORATORY CAPABILITY

CATEGORY II AND SUBSEQUENT

- Hematology
  CBC - differential and platelets, reticulocytes, coagulation, erythrocyte indices sed rate, prothrombintine (PT), and partial thromboplastin time (PTT)

- Urinalysis

- Arterial blood gases, carboxyhemoglobin, methemoglobin

- Chemistry
  Serum Sodium, Potassium, Chloride, Carbon Dioxide, glucose, Creatinine, Calcium, Phosphate, Magnesium, Blood Urea Nitrogen, Liver Function Tests (SGOT, SGPT, GGTP), Alkaline Phosphatase, Bilirubin, Amylase, Cholesterol, Triglyceride, and cardiac isoenzymes

- Toxicology
  Carbon monoxide, and other atmospheric trace contaminant gases

- Microbiology
  Culture and antibiotic sensitivity, staining characteristics

- Laboratory equipment
  Microscope, centrifuge, blood drawing supplies, laminar flow workbench

APPENDIX D

EXAMPLES OF PHARMACEUTICALS

-Allergy relief

-Analgesics, antipyretics

-Anaesthetics -- injectable, local

-Antacids

-Antiasthmatics, bronchial dilators

-Antibacterials, antibiotics

-Anticoagulants

-Anticonvulsants

-Antidiarrheals, antiflatulents

-Antihistamines

-Anti-inflammatories

-Antiseptics, germicides

-Antimotion sickness, antinauseants

-Antispasmodics

-Bowel evacuants

-Cardiovascular preparations
    Antiarrhythmics
    Antihypertensives
    Digoxin
    Vasodilators
    Vasopressors

-Cough and cold preparations

-Decongestants

-Dermatologicals

-Electrolytes

-Hemorrhoidal preps

-Hemostatics

-Hormones -- glucocorticoids

-Hypnotics

Appendix D - continued

- Laxatives
- Muscle relaxants
- Nutritional aids
  - Peripheral and central hyperalimentation fluid
- Ophthalmologicals
  - Antibacterial
  - Mydriatics and cycloplegics
  - Irrigants
- Otic preparations
- Plasma expanders
  - Plasma fractions
- Radiopharmaceuticals
  - X-ray contrast media
- Sedatives
- Throat lozenges
- Psychotropic agents
- Vitamins

APPENDIX E

SUMMARY OF HEALTH DATA COLLECTED DURING 10 YEARS OF POLARIS SUBMARINE PATROL

Appendix E shows the health experience during nuclear submarine patrols, which is an analogue to a space station (Ref. Analysis of health data from 10 years of Polaris submarine patrols, W. A. Tansey et al, Undersea Biomedical Research, Submarine Supplement, 1979). It may be seen that, in 20,960 man-years of experience, 1,685 cases requiring at least one day of lost time have occurred. In addition to the cases treated on-board, 37 cases were of such severity as to require immediate medical evacuation at sea. These cases represent a risk of 1.8×10^{-3}/man-years. However, this submarine experience involved only patrols and routine maintenance, no battle experience is included. Major repairs were done in Navy yards and at the time the problem was noticed. In a space station, major maintenance activities would have to be undertaken on orbit, and the purpose of the space station includes construction and hazardous duty, e.g., EVA. We can anticipate much higher rates of serious injuries because of these activities.

It should be noted that the 20,960 man-years of experience with Polaris is far greater than the 2.65 man-years of experience to date in U.S. manned space flight. But the submarine experience may not be directly applicable to potential risks in a space station because the age distribution of submarine crews (25 to 35) is likely lower and because fluid, electrolyte, and blood changes resulting from microgravity and radiation exposure may lead to additional physiologic stresses on various organ systems (e.g., the cardiovascular system) and produce decreased resistance to disease. Moreover, space crews will be subjected to additional hazards. See Hazards Assessment.

APPENDIX E (continued)

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

Disease/ Condition	No.	Rate Cases[b]	No.	Transfer per MY	Deaths	Comments Cat. At Sea
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.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM:58248		

4. Title and Subtitle	5. Report Date
Medical Operations and Life Sciences Activities on Space Station	October 1982
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Philip C. Johnson, Jr., M.D. and John A. Mason	S-518
	10. Work Unit No.
9. Performing Organization Name and Address	199-99-00-00-72
Lyndon B. Johnson Space Center Houston, TX 77058	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Technical Memorandum
National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This Johnson Space Center document presents current life sciences thinking concerning space station: health maintenance facilities, habitability, personnel, and research in the medical sciences, and in biology. It is assumed that the space station structure will consist of several modules, each being consistent with Orbiter payload bay limits in size, weight, and center of gravity. Present plans are to revise the document and supplement its contents as new information is made available or developed.

17. Key Words (Suggested by Author(s)

Toxicology	Radiation Hazards
Acoustic Noise	Environmental Effects
Medical Science	Nutrition
Management, Planning	Crews (Health)
Medicine	Motion Sickness
Cardiovascular System	Water
Training Simulators	Hematology/Immunology
Biochemistry/Endocrinology	Microbiology
Food	

18. Distribution Statement

Unclassified - Unlimited
Subject Category: 51

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	44	

*For sale by the National Technical Information Service, Springfield, Virginia 22161

JSC Form 1424 (Rev Nov 75)

NASA — JSC

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1983—669-013/2226