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Space Station Crew Safety Alternatives Study—Final Report

Volume III—Safety Impact of Human Factors

L. A. Rockoff, R. F. Raasch,
and R. L. Percy, Jr.

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Volume III—Safety Impact of Human Factors

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and R. L. Peercy, Jr.

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Langley Research Center
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In addition to assessing risks, this report aggregates related data that has been in preparation by the aerospace community since 1968. The report surveys broad areas of interest and calls on reference data to support concept development and risk assessment. Rather than footnoting individual references, each reference is identified by a parenthetical number that correlates with the entry number in the Literature Search print-out, appendix A of volume IV of this report.

The co-monitors of Contract NAS1-17242, Bob Witcofski of NASA-Langley Research Center, and Marc Cohen of NASA-Ames Research Center supported the development, data input and direction for this study report. Their guidance and support during this effort is deeply appreciated.

Personnel in the Rockwell-Downey Operations Safety Group (D/294-400) contributed to this report within their respective areas of expertise.

FOREWORD

This report is one of five documents covering the results of the Space Station Crew Safety Alternatives Study conducted under Contract NAS1-17242. The study documentation is designated as follows:

- Vol. I - Final Summary Report (NASA CR-3854)
- Vol. II - Threat Development (NASA CR-3855)
- Vol. III - Safety Impact of Human Factors (NASA CR-3856)
- Vol. IV - Appendices (NASA CR-3857)
- Vol. V - Space Station Safety Plan (NASA CR-3858)

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1. INTRODUCTION

BACKGROUND

The U.S. manned space program has concerned itself with the engineering technology required to place a man on the moon, with the medical requirements for survival being an important allied part. However, basic biological research has played only a secondary role and the social sciences have been comparatively ignored. By comparison, the U.S.S.R. space program has placed a great emphasis on the biological, psychological and sociological aspects. They have developed a training program that includes learning to handle stress and isolation through survival missions, anechoic chamber isolation, and parachute jumping. The Soviets also utilize a Group of Psychological Support that monitors the cosmonauts during the missions; looking for signs of stress and then providing ways to reduce this. (173)

The behavioral and psychological factors of the astronauts involved in long-duration space missions are extremely important and must be investigated in future flights. Kubis and McLaughlin have expressed this need: "It is well known that energies can be mobilized, stress can be adapted to, and discomfort can be tolerated for short periods of time. But under conditions of continuous long term mobilization of effort against unrelenting stresses, there may well be a degradation of the resistance and adaptability of the astronaut despite conditioning which they have acquired in training." (096) The U.S. traditional on-orbit workloads have been heavy with clearly defined tasks and goals. Most crewmembers have been highly motivated test pilots accustomed to stress and danger. Space Station crews will be comprised of a majority of members with less extensive training than the traditional astronaut corp. However, as crew mixtures change and duration of the missions extend, stress will increasingly impact upon safety.

SAFETY IMPACTS OF HUMAN FACTORS ASSESSMENT

To approach the problem of human factors and safety interaction, several approaches were used. The Rockwell approach identified discrete subelements that relate to safety and placed these elements in a personal/habitability matrix. Independently of this, NASA Ames researchers, Marc M. Cohen and Maria Junge approached the identification of these subelements through the stressor route. The Human Stressors, i.e., noise, confinement, task assignment, etc., were identified as part of a Human Factors interaction model involving Space Habitation and Working. This interaction model is presented in Section 2 of this volume.

Discrete subelements identified as stressors in the NASA interaction model and also as the human factors safety issues identified in the Rockwell matrixes were compared for correlation. The correlation factor was high. The funding and schedule constraints on this study limited selection of the stressors that could be assessed for safety impact. Rockwell, together with NASA Ames, agreed on a listing of stressors to be reviewed. These stressors are listed below and discussed in this volume in the sections noted.

<u>STRESSOR</u>	<u>SECTION</u>
Crisis Management	3
Confinement/Isolation	4
Acoustics	5
Territorial Issues	6
Behaviorial Protocols	7
Scheduling	8
Cleaning/Disinfecting	9
Hygiene	10
Recreation	11
Violation of Safety	12

Approach

Each of these stressors were addressed to determine what safety issues evolved. Once these issues were identified, strategy options for their control were sought. A summary of these strategy options follow each section. These are options not requirements. The purpose is to allow the Space Station planners flexibility in implementing the Space Station program.

AREAS OF FURTHER STUDY

In some cases, strategy options may indicate selecting a resolution approach that pushes the state-of-the-art. One of the overall objectives of this study was to identify areas needing further study either with or without today's technological capability. These areas are summarized at the end of every section.

ANALOGUES (352)

Next to atmospheric conditions, living space and privacy have the greatest influence upon morale, performance and general well being on long term missions. Excessive demands on man's ability to endure adverse environmental factors can result in deterioration of his capabilities, information intergration, problem solving, decision making, etc.

The habitabilty of the crew's living quarters can affect the capability of the crew to perform missions. Some factors that are known to cause great annoyance on long duration activities are: insomnia, lack of exercise, lack of privacy, crowding, poor food and noise levels.

Psychological problems become more imposing with duration of the mission and deserve increased consideration. Some of these problems are unique with isolated confined environments such as reaction to prolonged periods of sensory and social isolation, reaction to unfamiliar environment, etc. These stresses when combined with others could threaten the successful completion of any mission.

Space Station Stressors

Investigation of analogues isolated environments included submarines, Antarctic stations, communication stations, drilling rigs and fixed underwater habitats. The first two, submarines and Antarctic stations, appeared to incorporate the significant stressors of the other environments. Figure 1-1

summarizes those stressors of the submarine and Antarctic environments that could relate to the space station environment. It appears that the noted stressors, in addition to micro-gravity, began to describe the environmental stressors to be expected in a long term space station occupancy.

The environments of the three scenarios above are novel and unique and involve potential danger from both individual accidents and the failure of life support systems. Once established, the daily routine, in each case, can be monotonous. Due to the nature of these environments, individuals may be required to suddenly shift from a state of boredom into their highest level of physical and mental activity and cope with an emergency. A certain type of individual is required to successfully meet these requirements. The presence of socially nonadaptive crewmembers in a closed, isolated group can significantly decrease the group's efficiency.

Included in this section are analogues which discuss the conditions present in the Antarctic, submarine and Skylab scenarios. Parallel stressors begin to emerge from the comparison.

Antarctic Research Stations (352)

Of the several nations maintaining permanent Antarctic research stations, the U.S. Antarctic Research Program is unique in its organization and heterogeneity of personnel. The U.S. Navy provides the facilities, maintenance, and support personnel; the National Science Foundation provides the scientific staff. There has been a permanent American presence in Antarctica since the International Geophysical Year, 1957.

Size of Group - The size of groups wintering-over at the four U.S. stations has ranged between eight and 30 personnel in recent years. The average size is 16, and the median is 20. During the four summer months, as many as 1,000 Americans live and work in Antarctica; during the eight-month winter, fewer than 100 remain in isolation and confinement.

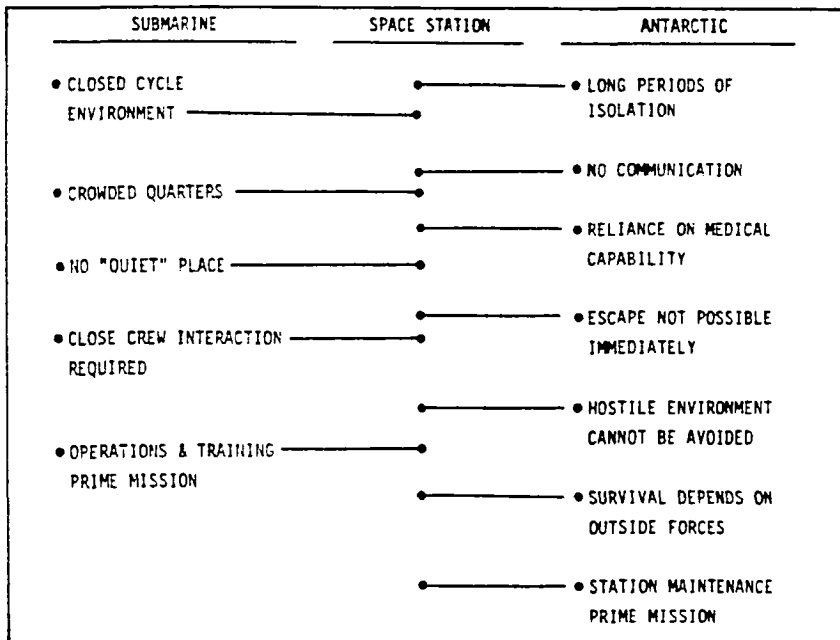
Composition of Group - Approximately one-half of those wintering over are civilian scientists (meteorologists, geologists, and biologists) and one-half are Navy personnel. The Navy group is composed of about equal numbers of Seabees (construction, logistics, and maintenance responsibilities) and administrative/technical positions (coordination and communication responsibilities). The educational backgrounds range from high school to advanced degrees. The range of participants' ages is 18 to 45 years; most are in their 20s or 30s.

Although several women participate in summer activities at McMurdo Station, only a few have wintered over since the first women did so in 1979.

Form of Social Organization - There is a Navy and a civilian group leader at each station.

Duration of Tour - A total of 13 months: one month in transit, four months of summer, and the eight-month winter-over.

Types of Tasks - Work activities include habitat maintenance (generators, heating and ventilation, etc.) scientific laboratory work, brief field trips in winter gear, housekeeping, food preparation, and administrative tasks.



NOTE:
 MOST SEVERE ISSUES FROM EACH ENVIRONMENT DIRECTLY APPLY TO SPACE STATION

Figure 1-1 Space Station and Analog Stressors

Preparedness for Mission - Each group usually includes a few men with polar experience. Most participants have never experienced anything like an Antarctic winter. Also, Navy personnel receive some technical training, and scientific staff receive an orientation concerning conditions to be expected. The Navy is responsible for psychological screening of potential winter-over personnel.

Personal Motivation - The prospect of scientific discovery is a paramount motivation for scientific staff. Navy personnel frequently cite the opportunity to earn and save money as their primary reason for volunteering for Antarctic duty.

Hostility of Outside Environment - The average annual temperature at the South Pole Station is -60°F . Under normal wind conditions at this temperature, exposed flesh freezes in 30 seconds or less. Temperatures drop to -112°F during the winter.

Perceived Risk - The primary sources of danger are accidents while working outdoors. Accidental deaths are not uncommon among those participating in Antarctic research.

Physical Isolation - During the eight-month winter, Antarctic stations are totally isolated from outside contact. There are no visitors, no supplies, and only very infrequent radio contact is possible.

Psychological Isolation - The feeling of psychological isolation is nearly complete. Sporadic radio contact is established with support base and occasionally with ham operators. News of the outside world is a scarce commodity.

Amount of Free Time - Because little work can be conducted outdoors during the winter, free time is abundant. It is estimated that 8-10 hours per day are available for self-maintenance and recreation.

Quality of Life Support Conditions - The temperature within a room frequently ranges from 0°F near the floor to 85°F six feet above the floor. Humidity is low except in the galley, where meals are taken. There it reaches 80%. Saunas and hot water showers are provided.

Food is abundant and of excellent quality. Most men spend a disproportionate amount of time eating and lingering over their meals; most also gain several pounds during the winter. Copious quantities of alcoholic beverages are also consumed: a daily average of approximately 9 ounces of distilled liquor and 5.4 beers per day among the group.

Physical Quality of Habitat - The stations are small and usually crowded. The current South Pole Station consists of ten buildings, including homemade versions of a sauna, basketball and racketball courts, and a bar. A geodesic dome covers the station and protects it from drifting snow.

Privacy and personal space are at a premium; this is especially true for the Seabees. While the scientific and technical people usually each have a laboratory or work station they can occupy, members of the maintenance staff are limited to their bunks and the common areas. Much use is made of the galley, however, at all hours for snacking, playing cards, and conversing. Reading is a favorite pastime and all personnel appreciate weekly films and special theme dinners.

Submarines (352)

The evolution of submarine technology provides a model of the development of complex systems involving human performance under adverse conditions. The following paragraphs summarize the conditions aboard a modern nuclear-powered ballistic missile submarine. Fortunately for submariners, conditions have improved dramatically.

Size of Group - Crew size of ballistic missile submarines ranges between 133 and 168 personnel depending on vessel class; 140 is most common.

Composition of Group - Approximately 14 officers and 126 enlisted personnel are required; no female crew. Composition is mixed in terms of educational background.

Form of Social Organization - Hierarchical, military command structure.

Duration of Tour - Each submarine is assigned two alternating crews designated "Blue" and "Gold." Each crew mans the vessel during a 60-day patrol and partially assists during the intermediate 28-day refit alongside a tender.

Type of Tasks - Tasks include administration, equipment maintenance, monitoring, standing watch, radio operation, housekeeping and food preparation functions.

Preparedness for Mission - Potential submarine crewmen must pass at least six selection and training hurdles before they are qualified for active duty. These include preselection (eliminating 10-50% of volunteers), physical exams/aptitude screening (10-20% attrition), escape training (1-5% attrition), basic s/m school (5-20% attrition), advanced s/m school (0-2% attrition), submarine qualification (5-12% attrition).

Personal Motivation - The reported reasons for volunteering for the submarine service are (in decreasing order of frequency mentioned by a large group of enlisted men), "pay, good food, and opportunities to learn interesting skills." It is also understood that men volunteer and later reenlist largely because of the personal satisfaction of belonging to a closely-knit, high-status group and because of the privilege of wearing the dolphins, the coveted emblem of the submarine service.

Hostility of Outside Environment - Sixty days of each tour are spent submerged.

Perceived Risk - Submarine service is considered to be hazardous duty. In addition to the hostile outside environment, crew are exposed to potential injury and death from both human error and equipment failure. The presence of a nuclear reactor and nuclear missiles on board is a concern to many crew personnel.

Physical Isolation - During 60-day submerged cruises, crew are isolated totally from the world.

Psychological Isolation - Psychological isolation from normal society is equally complete. No calls are allowed. Occasionally, periscope leave is scheduled (a peek through the periscope for crewmen to obtain a glimpse of topside activity, normally waves).

Amount of Free Time - Approximately three hours are available each day for self-maintenance and recreation. The Navy provides much to occupy this time: self-paced educational opportunities, films, arts, crafts, and physical exercise equipment.

Quality of Life Support Conditions - Air quality aboard modern submarines is generally good; tobacco smoking is allowed, rendering certain areas unpleasant to nonsmokers. Toilet facilities are adequate; hot showers are available. Food is excellent and served at cloth-covered tables in pleasant, paneled rooms; three seatings are usually required to feed the entire crew. It is an open mess, and an ice-cream locker, soft drinks, and snacks are available at all times.

Physical Quality of Habitat - Even though the size of the modern submarine has increased since World War II, the overall space per man has actually decreased as a result of increased crew size and the introduction of additional instrumentation necessary to propel and navigate the vessel and to fire its weapons. It has been estimated that there are about five cubic yards of space provided for each crew member of a nuclear submarine. Each man has a relatively large berth, equipped with a lamp, draw curtains, and built-in lockers for personal gear. Although most submariners adapt to the environment, "confinement" was the most frequently mentioned aspect of submarine life disliked, while "general living conditions" was the second most disliked aspect.

Skylab 4 (352) Third Manned Mission

Skylab, constructed of surplus hardware from the Apollo program, was launched on May 14, 1973. In addition to the unmanned launch, there were three manned missions conducted between May 1973 and February 1974.

Size of Group - Three-man crew.

Composition of Group - The crew consisted of one Marine Lieutenant Colonel, one Air Force Lieutenant Colonel (both pilots), and one civilian physicist (Ph.D.).

Form of Social Organization - Skylab had a hierarchical organization: mission commander, pilot, and science pilot. Direction was received from ground control personnel.

Duration of Tour - The duration of Skylab 4 was 84 days. Missions 2 and 3 were 28 and 59 days, respectively.

Type of Tasks - Tasks included biomedical experiments, life sciences experiments, earth resources monitoring, visual inspection, photography, astronomical observation, communications, maintenance, housekeeping, food preparation, and administration. Astronauts ventured outside the spacecraft only during Missions 2 and 3.

Preparedness for Mission - All personnel were professional astronauts. Each had undergone extensive training and simulation in preparation for the mission.

Personal Motivation - No references to the personal motivations of Skylab astronauts have been located in the literature. It is assumed that crew motivations were other than financial and were probably similar to those of current astronauts.

Hostility of Outside Environment - The void of space.

Perceived Risk - Exposure to risk was substantial. Although the Apollo systems had proven reliable, Skylab was a new venture. In addition to the risks of system failures, crew were exposed to the potential for meteorite collision, solar flare danger, and critical human error.

Physical Isolation - Skylab occupied a low earth orbit, approximately 269 miles above the earth's surface.

Psychological Isolation - The crews of Skylab were in nearly continuous radio contact with ground control personnel. Also, astronauts frequently used the B channel to record their observations, experiences, and interpretations; B channel recordings were "dumped" at high speed at regular intervals.

Amount of Free Time - The two hours between 8:00 and 10:00 p.m. each day were supposed to be the astronauts' own to use as they pleased. In reality, however, Mission Control typically found some additional task to occupy some or all of that time. They probably averaged less than one hour per day of free time.

Quality of Life Support Conditions - The atmospheric pressure aboard Skylab was about one-third that of earth. At low pressures, sounds do not travel readily (15 feet for a loud speaking voice); consequently, astronauts were hoarse most of the time. An oxygen rich mixture was used, with filters keeping it fresh to the crew's satisfaction. Food quality and variety were better than on previous space missions.

Water quality was good, but bubbles in the line, combined with the lower pressure of Skylab, resulted in severe flatulence. Showers were available only once each week. Toilet facilities were repeatedly criticized by the astronauts.

Physical Quality of Habitat - Skylab was an enormous structure. It was sometimes called "the cluster" or "the can." In fact, it appeared to be a cluster of cans of varying shapes and sizes. The largest can, the workshop, was a converted Saturn rocket booster left over from the Apollo program. It was 48 feet long and 21 feet in diameter. At the forward end was a shorter, thinner can (about 17 feet longer), at the tip of which the command and service modules docked.

Skylab was certainly big enough to qualify as a space station by any definition; when the command-and-serve module had docked and become part of the cluster, it had the volume of a three-bedroom house, weighed (had it still been on earth) almost a hundred tons, and was as tall as a six-story building. It was the biggest structure any astronaut had ever seen in space.

The three astronauts of the third crew floated head first out of the conical command-and-service module; through the docking adapter; through a hatch into the smaller airlock module; through another hatch into a tunnel that passed through a ring of gas tanks and other ventilating equipment; and on into the cavernous workshop, which filled what would have been a huge fuel tank inside the booster. (A smaller tank to the rear was used for garbage.) The workshop tank was divided into an upper and lower deck, the upper one being by far the bigger; the lower, which they floated into last of all, was only a little higher than a man; and it was here, the furthest inside Skylab, that the astronauts' bedrooms and living quarters were.

Many items were provided to occupy the astronaut's leisure time. These included books, games, darts, playing cards, and taped music. However, what little leisure time they had they spent either reading or looking out the 18-inch diameter window in their living quarters.

Midway through the 84-day mission, the third crew refused to conduct assigned tasks. This one-day "strike" was imposed to protest the overloading of time by mission controllers. The crew spent the day in individual pursuits, mostly looking out the window.

See Figure 1-1 for parallel space station and analogue stressors to draw correlations.

2. HUMAN FACTORS INTERACTION MODEL (367)

This section, in its entirety, has been prepared by NASA ARC co-monitor, Marc M. Cohen and Maria K. Junge, also of NASA-ARC. This model was presented at the Proceedings of the 28th Annual Meeting of the Human Factors Society, October 21-26, 1984 in San Antonio, Texas. This section bridges Space Stressors to discrete human factors issues.

"As NASA prepares plans to develop a space station, one of the major Human Factors study tasks is to develop an approach to Crew Safety. NASA has always been a paradigm of safety consciousness and recognizes that safety will be a key to reliability and human productivity on the space station.

In evaluating safety strategies, it is also necessary to recognize both qualitatively and quantitatively how this space station will be different from all other spacecraft. During the initial phase of this study, it was recognized that the major difference between space station and previous spacecraft is the role of human factors and extra-vehicular activity (EVA). In this project, a model of the various human factors issues and interactions that might affect crew safety is developed.

The first step addressed systematically the central question: How is this space station different from all other spacecraft? A wide range of possible issues was identified and researched. Five major topics of human factors issues that interacted with crew safety resulted: Protocols, Critical Habitability, Work Related Issues, Crew Incapacitation and Personal Choice.

Next, an interaction model was developed that would show some degree of cause and effect between objective environmental or operational conditions and the creation of potential safety hazards. The intermediary steps between these two extremes of causality were the effects on human performance and the results of degraded performance. The model contains three milestones: stressor, human performance (degraded) and safety hazard threshold. Between these milestones are two countermeasure intervention points. The first opportunity for intervention is the countermeasure against stress. If this countermeasure fails, performance degrades. The second opportunity for intervention is the countermeasure against error. If this second countermeasure fails, the threshold of a potential safety hazard may be crossed.

An example of how this interaction model works can be demonstrated. Under Critical Habitability, the primary environmental stressors include confinement, isolation and separation from earth. There are two subgroups within the first countermeasure against these stressors: social and architectural interventions. The social factors are communication with family and friends, visitors to the station, and recreation. The architectural factors are design, station geometry and "local vertical" reference orientations, and windows. When these social and architectural design level countermeasures against stress are not effective, crew performance may degrade in the form of morale deterioration, impaired judgement or faulty perceptions. The second set of countermeasures against errors are operational or group social activities plus personal existential actions. These social subset countermeasures include group activities, hobbies and time for personal interests. The design/physical countermeasure subgroup includes color coding on interior functions, lighting and video systems. To the extent

that this second defense of countermeasures is not successful, the threshold of potential safety hazards may be crossed. In this instance, potential safety hazards include a breakdown in group process and teamwork, and mistakes occurring in judgement, perception or action.

The third step, which will require further research, is to apply a system of weighting to the various stressors and countermeasures in order to be able to evaluate their relative importance. This weighting will also require an element of time duration to identify which stressors or countermeasures are relevant at the beginning, middle or end of missions, and which are short-lived or chronic in nature."

The following table, Table 2-1, describes and presents this interaction model.

TABLE 2-1

**SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL**

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TABLE 2-1 (CONT'D)

**SPACE STATION CREW SAFETY
HUMAN FACTORS CONCERNS**

1. PROTOCOLS
 - AUTONOMY FROM GROUND
2. CRITICAL HABITABILITY
3. TASK RELATED ISSUES
 - TASK ASSIGNMENT
 - ROLE DEFINITION
4. CREW INCAPACITATION
5. PERSONAL CHOICE
 - INDIVIDUAL SCHEDULE CHANGES
 - OPERATIONAL CHANGES
 - WORK PROCEDURE CHANGES

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TABLE 2-1 (CONT'D)

SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL

1. PROTOCOLS

STRESSORS	COUNTER-MEASURES AGAINST STRESS	DEGRADED PERFORMANCE	COUNTER-MEASURES AGAINST ERRORS	SAFETY HAZARD
A U T O N O M Y F R O M G R O U N D				
SCHEDULING OVERLOAD	SCHEDULING CHANGES CREW ROTATION	SCHEDULING CONFLICTS	DAILY SCHEDULING STAFF MEETINGS	LACK OF COORDINATION MISUNDERSTANDING
FAMILY PROBLEMS	FAMILY INTER-ACTION/SECURE COMMUNICATIONS	ABNORMAL BEHAVIOR DEPRESSION	DISCIPLINE COUNSELING	DELIBERATE CONFLICT INABILITY TO WORK
DISAGREEMENTS WITH GROUND CONTROL	AUTONOMY FROM GROUND	CONFLICTING OBJECTIVES	CHANGES IN MISSION OBJECTIVES	VIOLATION OF SAFETY CRITERION
TERRITORIALITY	ACCESS/ NON-ACCESS	TURF CONFLICTS	NEGOTIATIONS	IMPROPER ENTRY OR INADEQUATE ACCESS
INCOMPATIBILITIES	CREW SELECTION CREW TRAINING	INCOMPATIBILITIES	TRAINING GROUP PROCESS	LACK OF COOPERATION

2. CRITICAL HABITABILITY I

STRESSORS	COUNTER-MEASURES AGAINST STRESS	DEGRADED PERFORMANCE	COUNTER-MEASURES AGAINST ERRORS	SAFETY HAZARD
VOLUME LIMITATIONS	ARCHITECTURE: DESIGN PRIVACY, WINDOWS	FEELINGS OF CLAUSTROPHOBIA LACK OF PRIVACY	PRIVACY OR EVACUATION	IRRITABILITY PARANOIA
NOISE	VIBRATION, ISOLATION AND CONTROL	SLEEP DISTURBANCES POOR COMMUNICATION	EARMUFFS, HEADSETS, DRUGS COMMUNICATION DEVICES	FAILURE TO RESPOND FAILURE TO COMMUNICATE OR COORDINATE
HOUSEKEEPING (OR LACK OF)	ROUTINES AND TRAINING	ENVIRONMENT QUALITY DETERIORATION	ASSIGNMENT OF RESPONSIBILITIES TEAMWORK	BREAKDOWN IN LIFE SUPPORT
HYGIENE CLEANLINESS	PERSONAL PRACTICES TRAINING	DISCOMFORT TO OTHERS ILLNESS DISEASE	GROUP STANDARDS	PERSONAL ILLNESS INABILITY TO PERFORM TASKS

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TABLE 2-1 (CONT'D)

CRITICAL HABITABILITY II

STRESSORS	COUNTER-MEASURES AGAINST STRESS	DEGRADED PERFORMANCE	COUNTER-MEASURES AGAINST ERRORS	SAFETY HAZARD
THERMAL/HUMIDITY CLOSED ATMOSPHERE	ENVIRONMENTAL CONTROLS	DISCOMFORT IRRITABILITY	AIR MOVEMENT GAS COMPOSITION CONTROL TEMPERATURE AND HUMIDITY CONTROL	INCREASED ANXIETY IMPAIRED RESPONSE
CONFINEMENT ISOLATION SEPARATION	COMMUNICATION WITH FAMILY AND FRIENDS VISITORS SOCIAL EVENTS RECREATION COUNSELING ARCHITECTURE GEOMETRY STOWAGE	LONELINESS MORALE DETERIORATION IMPAIRED JUDGMENT PERCEPTION UNDER STRESS CLAUSTROPHOBIA	GROUP ACTIVITIES HOBBIES PERSONAL INTERESTS JUDGMENT CHECKS COLOR CODING LIGHTING MULTIPLE ACCESS MOBILITY AIDS	BREAKDOWN IN GROUP PROCESS, TEAMWORK MISTAKES IN JUDGMENT, PERCEPTION OR ACTION PARANOIA
ARTIFICIAL LIGHTING	LIGHTING DESIGN, "NATURAL LIGHT"	FATIGUE IRRITABILITY BLURRED VISION	SPECIAL TASK LIGHTING	MISTAKEN PERCEPTION

3. TASK RELATED ISSUES

STRESSORS	COUNTER-MEASURES AGAINST STRESS	DEGRADED PERFORMANCE	COUNTER-MEASURES AGAINST ERRORS	SAFETY HAZARD
TASK ASSIGNMENT / ROLE DEFINITION				
WORK ENVIRON- MENT PROBLEMS	STATION ORGANIZATION/ DESIGN	FATIGUE FACTORS	WORK STATION DESIGN	MISTAKE/ INADVERTENT ACTION
WORK ORGANIZATION/ LEADERSHIP	LEADERSHIP TRAINING CONSENSUS	CONFLICTS WITH LEADERSHIP	CRISIS RESOLUTION/ CHAIN OF COMMAND	CONFLICTING ACTIONS
TASK ASSIGNMENT	TASK SELECTION	MONOTONY BOREDOM	TASK ROTATION	"FAMILIARITY BREEDS" CONTEMPT LACK OF CAUTION
PHYSICAL LIMITATIONS	CREW SELECTION PHYSICAL ENDURANCE	STRAIN ON ENDURANCE	MANDATORY PHYSICAL EXER- CISE REGIMEN	"CUTTING CORNERS" PHYSICAL INABILITY TO PERFORM TASKS
SCHEDULING AND COORDINATION CONFLICTS	GROUP ACTIVITIES AND MEETING	LOW MORALE AND MOTIVATION	CREW/BUDDY CHECKS AND DRILLS	LACK OF EFFECTIVE CREW INTER- ACTION

TABLE 2-1 (CONT'D)

4. CREW INCAPACITATION

STRESSORS	DEGRADED PERFORMANCE		SAFETY HAZARD	
	COUNTER-MEASURES AGAINST STRESS	COUNTER-MEASURES AGAINST ERRORS		
SPACE SICKNESS GAS BUBBLES IN WATER	SELECTION/ ADJUSTMENT MAINTAIN/CHECK WATER SYSTEM	POOR TASK PERFORMANCE GAS PAINS	TREATMENT IMPROVE WATER SYSTEM	CREW FAILURE TO RESPOND
ILLNESS	EXAMINATIONS AND HEALTH MAINTENANCE PROGRAM	SHORT TERM INCAPACITATION	TREATMENT	CONTAGION?
INJURY	SPACE INDUSTRIAL SAFETY	LONG TERM INCAPACITATION	RETURN TO EARTH? STABILIZE ON ORBIT?	DISTRACTION OF OTHER CREW MEMBERS
EMOTIONAL/ MENTAL PROBLEM	CREW SELECTION AND TRAINING	LACK OF TRUST AND COOPERATION	RELIEF FROM DUTY	ABNORMAL BEHAVIOR DETRIMENTAL ACTIONS
FAILURE IN LIFE SUPPORT SYSTEM	ABANDON, EVACUATE ONE MODULE	CONFINEMENT, TRAUMA	REPAIRS, REPLACE- MENT	LOSS OF ACCESS TO CRITICAL FUNCTIONS
DEATH OF CREW, FAMILY OR FRIEND	COUNSELING	TRAUMA TO CREW DISRUPTION OF TEAMWORK	COUNSELING	PRESERVATION OR DISPOSAL OF BODY INABILITY TO WORK

5. PERSONAL CHOICE

STRESSORS	DEGRADED PERFORMANCE		SAFETY HAZARD	
	COUNTER-MEASURES AGAINST STRESS	COUNTER-MEASURES AGAINST ERRORS		
COOKING/EATING HABITS (RESTRICTIONS)	SHARED MEALS ACCOMMODATION FOR INDIVIDUAL CREW PREFERENCE	IRRITATION DEPRESSION	ADEQUATE TRAINING	FIRE ODORS OUTGASSING
INDIVIDUAL PROPERTY (RESTRICTIONS)	EDUCATION MONITORING AND CONTROL CREW TRAINING	PERSONAL AUTON- OMY DIMINISHED LOW MORALE	MONITORING AND CONTROL	OUTGASSING CONTAMINATION FLAMMABILITY
BOREDOM, MONOTONY	ENTERTAINMENT CREW SELECTED ACTIVITIES	LACK OF VIGILANCE	ADEQUATE CREW ACTIVITIES PLANNING AND SCHEDULING	PRACTICAL JOKES DISTRACTION ACCIDENTS
CLOTHING	VARIETY, LAUNDRY CREW PREFERENCE	IRRITATION, DISCOMFORT LESS PERSONAL FREEDOM	CLEAN FILTERS	LINT PROBLEM CONTAMINATION FIRE
PERSONAL HABITS: ALCOHOL DRUGS	CREW SELECTION CREW TRAINING	EFFECTS OF OVERUSE WITHDRAWAL SYMPTOMS	COUNSELING EVACUATION	FIRE IMPAIRED JUDGMENT

3. CRISIS MANAGEMENT

BACKGROUND

The application of work station design employing state-of-the-art display and control technology will improve the performance of man in space. Advanced technology has been developed for input and display of information at crew stations in aircraft, ships, power generating control rooms, and other applications which could be used in Space Station.

The current Orbiter cockpit contains approximately 1,500 switching devices, 3000 communicators, and 40 meters and other electromechanical displays, many of which are used only during very short periods of the mission. Multipurpose displays and controls will enable more efficient crew/vehicle interaction. Table 3-1 implies a possible problem when considering the number of controls/displays for Space Station.

It is widely recognized that human operators do not passively respond to increased levels of mental workload or stress. Instead, considerable evidence suggests that they tend to adjust the strategies of information processing that they employ in an effort to minimize or optimize psychological cost. Such strategic variation could present problems where high workload, fatigue and boredom are likely to confront crewmembers. Strategies that may be adopted by the stressed operator can be maladaptive with respect to system goals. For example, a contributing factor in the Three-Mile Island accident was that the station engineer, at one time, had over one-hundred annunciators (lights, bells, alarms, etc.) actuated.

Coupled with all the other factors that can contribute to the lack of effective crew coordination in emergency situations is that group members generally tend to be more dependent on leaders under stressful circumstances. As a result, the captain is likely to bear even more responsibility for monitoring and orchestrating the actions of the crew. Hence, the selection of a commander's leadership style or characteristics is particularly important.

Table 3-1 indicated the trend of increase in numbers of controls and displays expected in the normal evolution of man's short-to-long term stays in space. The crisis management impact is based on how many of the projected space station controls and displays relate to emergencies.

More sophisticated annunciator systems are a direct outgrowth of computer and cathode ray tube (CRT) technology capabilities. The overall data management architecture approach selected for the space station data processing will define the ability of crewmen to effectively manage crisis. Incorporating inherent data edit functions, multi-color displays, split-screen capability and interactive annunciate/activate scenarios within the space station data system would be a step in the right direction. In programming data management systems for dynamic functions, the specifier of function tends to require annunciation of too much data per element. This, when added to the annunciation requirements of other elements in a multi-element system, inundates the crew with information. Trends to assimilate and edit data in the Maintenance and Data Recorder (MADAR) systems, used on Air Force cargo aircraft, and the Central Integrated Testing Subsystem (CITS), used on the B-1 aircraft, are an approach to alleviating the tasks of the crisis manager.

TABLE 3-1 PROLIFERATION OF CONTROLS AND DISPLAYS

SYSTEM	DURATION	CONTROLS & DISPLAYS
APOLLO	14 DAYS (NOMINAL)	1,300
SKYLAB	84 DAYS (EXCEPTIONAL)	3,000
SHUTTLE	7-8 DAYS	4,540
SPACE STATION	90 DAY (PROJECTED)	?

ISSUES

Anthropometrics

It is essential to note that the physical man-machine interface is substantially different under zero-g conditions. In order to optimize crew station design and operations planning, models of human movement and "neutral body posture" are needed. The neutral body position of a crewmember in micro-gravity relates neither to the one-gravity sitting or standing position. Rather, the neutral body position is a semi-crouching/semi-fetal position. Neutral body position anthropometric standards need further development, definition and dissemination for the space station design community. Once this anthropometric information is available, placement of critical controls and displays in the crew "ease see/ease reach" sector can improve crisis management capability.

Inability to Communicate

In zero gravity the face becomes puffy from the collection of blood in the upper body area causing alterations in the features of the face. With this facial distortion, the Russians have reported that the discontinuity between the verbal message and the facial message caused confusion about the real intent of the message. (155) A series of commonly understood phrases and hand signals will have to be devised to address emergency situations. Drills, though a nuisance, imprint the action/message so that response is automatic.

Automation

Automation offers benefits of increased productivity, safety, and control of large complex, interrelated systems. However, while automation can perform some tasks more precisely than humans, there are drawbacks. Many questions must be asked prior to making decisions on automation, such as:

- o What is the function under consideration?
- o What are the tasks involved in this function?
- o What is the total hypothesized human operation participation for the function?
- o What is the total hypothesized equipment participation for the function? (373)

In NASA-MSFC TM-82510, Tiesenhausen further identifies seven core performance areas: 1) Monitoring, 2) Sensing, 3) Information Processing, 4) Interpreting, 5) Decision Making, 6) Information Storage, and 7) Controlling. (373) These core performance areas are basic to any function or activity. To be noted is that all but number 6 above are key to crisis management under high stress, fast reaction conditions. Crisis management activities, as with critical functions in the space station, should be a candidate for automation trade studies. Basic to these studies is the need to postulate as many contingency scenarios that could realistically occur.

Recognizing that man's procedural inclusion cannot be reduced to preset procedures, identifying contingency operations allows the total manual interface to be reduced if the related crisis management functions can be automated. The trade study should include reasonableness of the stated contingency, costs to automate as opposed to risk of manual operations, costs to maintain and checkout automated system element vs. the manual element, and costs to change procedures within the system.

Training

Human performance is another factor to be considered in achieving efficient use of humans with automated systems. Proper crew training is essential. Particularly as noted under communications, emergency procedure training must be stressed.

All major automation functions are subject to the critical question, "Is this function best assigned to the human operator to the equipment"? These key functions include sensing, interpreting, information processing, decision-making, controlling, monitoring and information storage.

STRATEGIES

1. Ensure that critical and emergency controls and displays are in core reach and sight volume
2. Screen crew for abilities to handle sensory overload
3. Train crew to handle crisis. Develop and implement emergency procedure scenarios.
4. Identify contingency operations to support emergency procedure development
5. Identify who is in charge

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items, in no way, comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Determine degree of automation needed and/or desired for interactive crisis management
2. Expand and disseminate anthropometric data on the micro-gravity "neutral body" position
3. Further develop the software architecture and approaches to allow editing, recombination and understandable annunciation of many data elements to support real time decision making under conditions of stress
4. Develop testing/screening techniques that can identify or relate subject's ability to function under high stress conditions

5. As a part of space station systems engineering and integration, develop a "crisis management" overlay of all space station signals and data interchange networks to help coordinate aggregation of annunciations/controlling signals necessary for crisis management (emergency or contingency operations)

4. CONFINEMENT/ISOLATION

BACKGROUND

The human factor in isolated realms such as long-duration spaceflight, Antarctic service and submarine duty has received steadily increasing attention as more men and women venture into these new areas. But problems remain. The usual candidate who enlists for this kind of mission knows very little in advance about what is likely to be experienced psychologically during the long period of isolation. The same can apply when returning home to a world that has grown and changed.

The word isolation has meanings as varied as its effects. One common denominator stands out: Isolation separates the individual or group from important parts of the normal environment. This separation must be accounted for when planning or anticipating extended ventures into space.

The four main components of isolation are:

- 1) Confinement, usually protected from a threat, by physical enclosure or encapsulation.
- 2) Aloneness or separation from familiar surroundings, with feelings that one is miles from nowhere in a vast expanse, often accompanied by feelings of relief and exhilaration in some, but fear and depression in others.
- 3) Sensory deprivation, which occurs during an absence of sensory impressions or lack of variety.
- 4) Stress, encompassing the overall effects of time, pain, danger and annoyance, perceived both personally and professionally, either imagined or real.

To date, only a handful of scientists have drawn comparisons between the psychological effects of life in Antarctica and long duration spaceflight. Kirmach Maturi elaborates on some of the similarities:

Both environments are novel and unique, and involve potential danger from both individual accidents and the failure of life support systems. Once established, the daily routine in both may become monotonous. However, due to the nature of these environments individuals may be required to suddenly shift from a state of boredom into their highest level of physical and mental activity to cope with an emergency. A certain type of individual is required to successfully meet these requirements to remain alert to potential hazards over an extended period of time and to maintain psychological adaptability under the influence of environmental stresses. (086)

Studies conducted in an isolated and confined environment have identified a number of physical and psychological effects as well as individual and group behavior changes (176). Elements include (177):

- o Boredom
- o Irritability
- o Depression
- o Anxiety
- o Mood Fluctuation
- o Fatigue
- o Hostility
- o Social Withdrawal
- o Vacillating Motivation
- o Tension
- o Sleep Disorders
- o Sensory Deprivation

ISSUES

Boredom

Some tasks do not require a great attention span nor do they require any degree of concentration but must be carried out with consistency and accuracy over a prolonged period of time. Tasks of this nature may be hazard generators. The premium of automated versus the costs of each man-hour in space may be a gauge to judge which task should be candidates for automation.

Another facet of this issue is the make-up of the individual. To some, boredom sets in when external stimuli cease. Consideration in psychological screening should be given to selecting a space station crew with people whose lives do not require much external stimuli but who can provide their own mental and recreational stimulation.

Irritability

Causes of irritability are found in stressors that constrain the individual, either real or habitual. These can include:

- Unwanted Direction
- Inability to Perceive Extended Space
- Limited Personal Interfaces
- Over Familiarity From Co-Workers
- Abrasive Habits of Others
- Inability to Get Along

Unlike boredom, irritability is engendered by an excess of specific external stimuli. Although the tendency toward irritability exists to varying degrees the prime stressors should be controlled so that a space station crewman should be able to remove himself from the stressing environments. The safety issue is that irritability engenders aberrant actions that could precipitate a hazardous situation.

Depression

Psychologists have described the difficulty of the Antarctic winter as "the absence of customary sources of gratification". (258) In other words, being stuck without much to do. The obvious stresses are parallel with those of space: no grass, no trees, no living things, but there are the unseen stresses that lend to the problems associated with depression. The apparent stresses that begin the depression are the social isolation and the on-going monotony. "You've heard everybody's favorite story, you know their good habits and bad habits" (258) But the normal way of dealing with things when one is fed up are not available; for example: going outside for a walk or seeking other people.

The way that people eventually respond is called "depressed affect" a sort of mental shifting into neutral. This affect also takes place in submarine crews and other people in confined situations with little stimulus. A person who "turns himself off" can be liability within the station, unable to accept, give or execute orders.

Anxiety

Confinement/Isolation is a major stressor to people with claustrophobia. This is a discernible trait. Aside from fear of enclosed spaces as an anxiety generator, the crewman's anxiety may be founded in concern for personal safety and survival in a hostile environment. Antarctic area anxieties were sometimes traceable to the fact that the available medical facilities did not alleviate a person's fear of untreatable illness or injury. This subject is treated separately in Section 4 of Volume II. In confined areas, anxieties appear to be directed toward ability to survive and capability to perform under conditions of stress. The former may be addressed by providing a comprehensive orientation of the space station and the system provided to counter threats. The latter, performance under stress indicates a need for more comprehensive training and cross-training in primary and peripheral skills.

The other anxiety issue is actual and perceived volume. Physical factors may determine module size initially. Within these constraints the judicious use of interior design (color, light, spacial arrangement) may give the space crewmember a feeling of greater openness than exists. The growth station may consider inflatables or fabricated spheres to realize a larger single volume for a crew wardroom.

The safety issue is possible physical/psychological illness driven by anxiety.

Mood Fluctuations

Socially non-adaptive individuals may be particularly disruptive to the efficiency of a group working in an isolated condition. The socially competent individual adjusts his or her behavior to be consistent and compatible with the microculture of the group. Open expression of personal values or aesthetic tastes may generate conflict within the group. Non-adaptive individuals presenting a dissenting value system may have an especially difficult time in maintaining their self-esteem under the continual pressure to conform to the standard group. Individuals may then respond with mood fluctuations which can lead to ineffective job performance. Such fluctuations noted in Antarctic situations include: sulking, temper tantrums, behavior abuses, chronic complaints and series of ups and downs that parallel with visitors during the summer months.

The Russians have a manned capsule that visits every other month. Frequently, videotapes of the cosmonaut's families, friends, and co-workers are sent up to them. They have reported that communication with their families served as the source of "a most powerful emotional charge". (160) Issues of screening communication between the family and crew need to be addressed. Should ground control have any say about what a family member says to a crew member? How often should they be allowed to communicate? This issue could be a key factor contributing to mood fluctuations.

The Russians have utilized several methods to stabilize their cosmonaut crews and carry them over the long periods of isolation. The following are examples of how the Russians have accomplished this.

Typical Russian Cosmonaut "Up's"

- o Visits of other cosmonauts every other month helped ease the psychological stress of the long flight
- o Allowed some vodka
- o In the sixth week of the flight, cosmonauts talked with movie stars, musicians, poets and artists to keep their spirits up during the long stay
 - o The program of talks with celebrities was arranged by a psychological support group that completed a study on the preferences and moods of the cosmonauts
- o Toward the end of the 211-day space mission, the crew complained of irritability toward each other and requested and received permission to extend their sleep periods from 8 to 12 hours
- o About a week before return to earth, Soviet medical personnel stated that they were paying increased attention to the physiological condition of the crew - watching the crew's every move
- o Send up surprise packages in the resupply module every other month
 - o Tulips (smell of earth)
 - o Letters from friends, family
 - o Presents
- o Russians use as preventive measures:
 - o Tape and videotape recorders
 - o Assembled in accordance with the preferences and tastes of the unique crew
 - o Foreign movies, stage productions
 - o Video library supplemented with new material by the visiting mission crews and progress cargo craft
 - o Includes tapes of families, co-workers, friends
 - o Crews receive diversified information
 - o News
 - o Science/Technology
 - o Cultural events
 - o Sports
 - o Functional music (reproductions of the sounds and noises of earth)
- o Russian scenario now allows Saturday and Sunday off
 - o This allows them more time for their personal needs
 - o Allots time to catch up on the paperwork
- o Work on a 9-to-5 basis
 - o On Saturday/Sunday allowed an extra hour of sleep
- o Found that tasty/favorite foods ease the tension of the cosmonaut's work

- o It was observed that the cosmonauts made more frequent requests for transmission of rhythmic music starting with the second month of the mission
 - o Shortage of social contacts compensated by organizing communication sessions with the participation of representatives in different areas of public life (political, sports, artists)
- o A total of 118 such communication sessions involving about 100 people was organized during the four long missions aboard the Salyut-C orbital station
- o Independent importance
 - o Use of results of the cosmonaut's work
 - o Use of crew's recommendations

Mood fluctuation is similar to irritability in that it may be the precursor for aberrant actions or critical tasks.

Fatigue

Factors affecting fatigue are physical as well as psychosomatic. The counter measures are identifiable as ability to work (proper rest and nutrition), knowledge of job (proper education and training) and reasonable scheduling demands. The non-physical issues are more subtle. As in the Antarctic, fatigue following mood swings may be tour of duty related. Initially, the challenges of a new environment and new job fend off fatigue. Once routine sets in, however, signs of fatigue may show. Boredom may be a precursor to fatigue. Toward the end of a tour, fatigue would tend to be put aside by planning for post flight activities.

Additional fatigue issues are discussed in Section 6 of this volume.

Hostility

Clash of incompatible personalities can generate hostility - either suppressed or patent. Irritability usually is a precursor to open hostility. The direct safety issue with hostility is the possibility that a critical task may not be done to support a timely requirement. It is not beyond comprehension that open hostility may require active control measures. One issue is - "Who's in charge?" Another issue is - "What is he going to do about it?" The Polaris submarines carry whole body restraint suits called "Polaris Pajamas". The difficulty in dealing with hostility in a closed environment is that one can't go out for a walk/run to blow off steam. Crews may need to be taught group process skills to resolve conflicts.

The safety issue here is physical violence, followed by injury or damage to equipment/crew. This safety hazard can be manifested also in subtle ways that may be hard to identify before, during or after the creation of a safety hazard!

Social Withdrawal

The type of individual chosen for isolated duty is important in terms of personal health and well-being, individual job performance and over-all group effectiveness. Individuals who tend to withdraw into their own world are likely to become non-productive.

In a study conducted by the U.S. Army Research Institute for the Behavioral and Social Sciences (249) it was found that a decline in problem solving skills were related to environmental invariance. Lack of opportunity to "get out" of the barracks, along with less than challenging job requirements interacted to produce a decline in the thinking process, which lead to social withdrawal.

Certain individuals may be less susceptible to the tendency of social withdrawal than others. For space station long-duration, a program must be maintained to keep individuals in a state of readiness and to prevent this social withdrawal syndrome. With this in mind, additional burdens may occur in a case of an emergency situation.

Vacillating Motivation

This issue, together with boredom and fatigue, are probably tied to the tour of duty in space. Task scheduling diversity may be worth investigating to address this issue. Universal in-task assignment may help to keep the job interest quotient high. A degree of routine tasks may help to stabilize a crewmember in any diurnal period. The safety issue here is in attention to duty or related critical tasks and the ensuing consequences.

Tension

All the stressors of confinement and isolation tend to build tension in the person if relieving de-stressors are not available. Adaptability within a normal work environment usually transcends the tension builders. Concentration on providing a compatible crew and a reasonable task and living environment would tend to forestall precipitating tension generating issues.

The safety issue is the physiological tendency of a person toward symptoms caused by tension (headache, gastro-intestinal disturbances, etc.), or related illness.

Sleep Disorders

Confinement sometimes adversely affects the ability to sleep soundly. Sleep disorders may provide a basis for irritability, depression, anxiety, fatigue, hostility, etc. Essentially, without reasonable rest, nutrition and exercise, the human person deteriorates. Both visual and aural masking to induce sleep, may be an approach to alleviate the anxiety caused by confinement that would prey on the individual to prevent sleep. Interviews with the present astronaut core could shed light on some simple approaches to avoiding this issue. Lack of sleep may impair the ability to perform.

Disorientation

In habitats where normal sensory feedback is not possible, the body systems do not work together properly. Vertigo, a motion dynamics issue, relates to coordinating diverse visual-cochlear stresses. It is speculated that visual-motion discontinuities may contribute to the high incidence of motion sickness in space. Controlled visual cueing may help alleviate the problem; for instance, providing a private television monitor that always, or on call, presents a picture that is "up" or "in the direction of flight". Tactile issues and dealing with restraints may provide an artificial simulation of g-forces to shave off this issue.

Soviet Experience

Following the 140 day Salyut-6 flight of 1978, the space flight director reported that the only barrier to long space flights seemed to be psychological conditions; "man finds himself in a small collective, extremely far away from home, relatives and friends. It is more difficult to solve psychological loads". (174) The lack of stimuli, restriction of living space and monotony remains areas of concern to the Soviets.

The safety issue involves the inability of the sensory deprived person to respond to a time sensitive emergency situation.

STRATEGIES

1. Develop plan for variety benefiting from Soviet approach.
 - a. Set up of private video-communication for astronauts would tend to foretell boredom.
 - b. Provide library of videotapes to span interest of crew.
 - c. Provide personal motivation/growth courses/lectures.
 - d. Include provisions to link-up (tape record) on demand for videos that would support the crew.
2. Provide a "quiet place" for each astronaut that can include the personal items of decor photos, cartoons, books, etc.
3. Provide a space station vital statistics - MET (Mission Elapsed Time) clock, altitude, cabin pressure, etc. - readout panel in astronaut habitability area and/or stateroom.
4. Ensure medical capability consistent with expected threat. See Volume II, Section 4.
5. Consider including an architect and interior designer in developing habitability design solutions.
6. Establish UP/DOWN space station orientation consistent with free form/fetal body position in orbit.
7. Entertain the option of a single, large volume module (possibly an inflatable, or an erectable sphere) for a common room to provide an open environment.
8. Investigate possibility of including transparencies (replaceable without depressurizing module) for common and private viewing including variable polarizing or opaque shades.
9. Provide a chemical or physical astronaut restraint system similar to the "Polaris Pajamas".
10. Begin crew training on the ground a considerable length of time before mission.
11. Develop a screening/behavior modification program derived from submarine and Antarctic developed parameters to ensure crew compatibility.

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Polarized shades vs. opaque shades
2. Allow personalization of cabins or work areas (photos, cartoons, books, etc.) including decor options
3. Define crewmember psychological and physiological screening elements to support functioning in a long term confined/isolated environment
4. Include architectural/interior design consultation in habitable module design
5. Consider possibility of single, large-volume space (inflatable or structurally built-up to provide "open" environment for crew on growth station

5. ACOUSTICS

BACKGROUND

Past manned space flight programs have dealt loosely with acoustical requirements within vehicle cabin enclosures. Part of this happened for reasons of economy and part because the acoustical requirements may have had no champion in the procurement agency. Figures 5-1 and 5-2 summarize the "before" and "after" situation of the planned and actual acoustical profiles for the Apollo and Shuttle programs. These data concern perceived sound in the crew compartments. The curves show the NC-50 and NC-40 curves that were targets for programs at their inception. The actuals are indicated. It appears that when the design objectives were not achieved, the specification values became the actual achieved. Table 5-1 relates the NC50 number to typical noise environments. For the most part, noise control of assembled sub-systems is usually addressed after the fact, and inter-element synergies are not considered. Space station apportionment of allowable noise to subsystems should be mandatory so that component suppliers know what their individual noise design allowables are. Then the integrator can apply isolation/insulation techniques to augment those actually taken by the suppliers to control noise.

On STS-3 there was a crew module noise anomaly. The measured value at the frequency noted peaked between STS-2 and STS-3. An actual noise measurement isolated the source to a noisy fan motor bearing, which when replaced eliminated the noise peak. See Figure 5-3.

Sleep on Apollo 13 was affected by the cold, coolant pump noise from the lunar module, and frequent communications with ground control. Psychological stresses were commonly causes of sleeplessness. Results of the Skylab program have indicated that previous loss of sleep was caused by the restricted conditions rather than any physiological effect of weightlessness.

ISSUES

Figure 5-4 summarizes the acoustical impacts and the stressors affected.

Noise consistently affects astronauts physically, psychologically and functionally, and comes high on the list of irritating environmental pollutants on spacecraft. The irritant effects of noise are well documented. It can cause stress and pain, disorientation, vertigo, nausea, fatigue, loss of appetite and interfere with sleep and normal speech communication. (174)

The efficiency and well-being of the crew are affected adversely if the crewmembers' sleep patterns are constantly disturbed by the environment within the spacecraft. Spaceflight experience to date has indicated that many crew members experience difficulties in falling asleep, and have needed to take medication. No clear evidence exists that all astronauts are affected or that crew members who are affected suffer the same disturbances. Some complain that sleep was inadequate or that there was a considerable shift in sleep periods from expected home sleeptime.

Many factors have been postulated to cause sleep disturbances and it is difficult to show conclusively, to date, which factors are of greatest importance. Main causes cited are: cyclical noise disturbances from thruster firings, communications or movement within the spacecraft, staggered sleep periods, significant displacements of the astronauts normal diurnal cycle, the unfamiliar sleep environment and excitement.

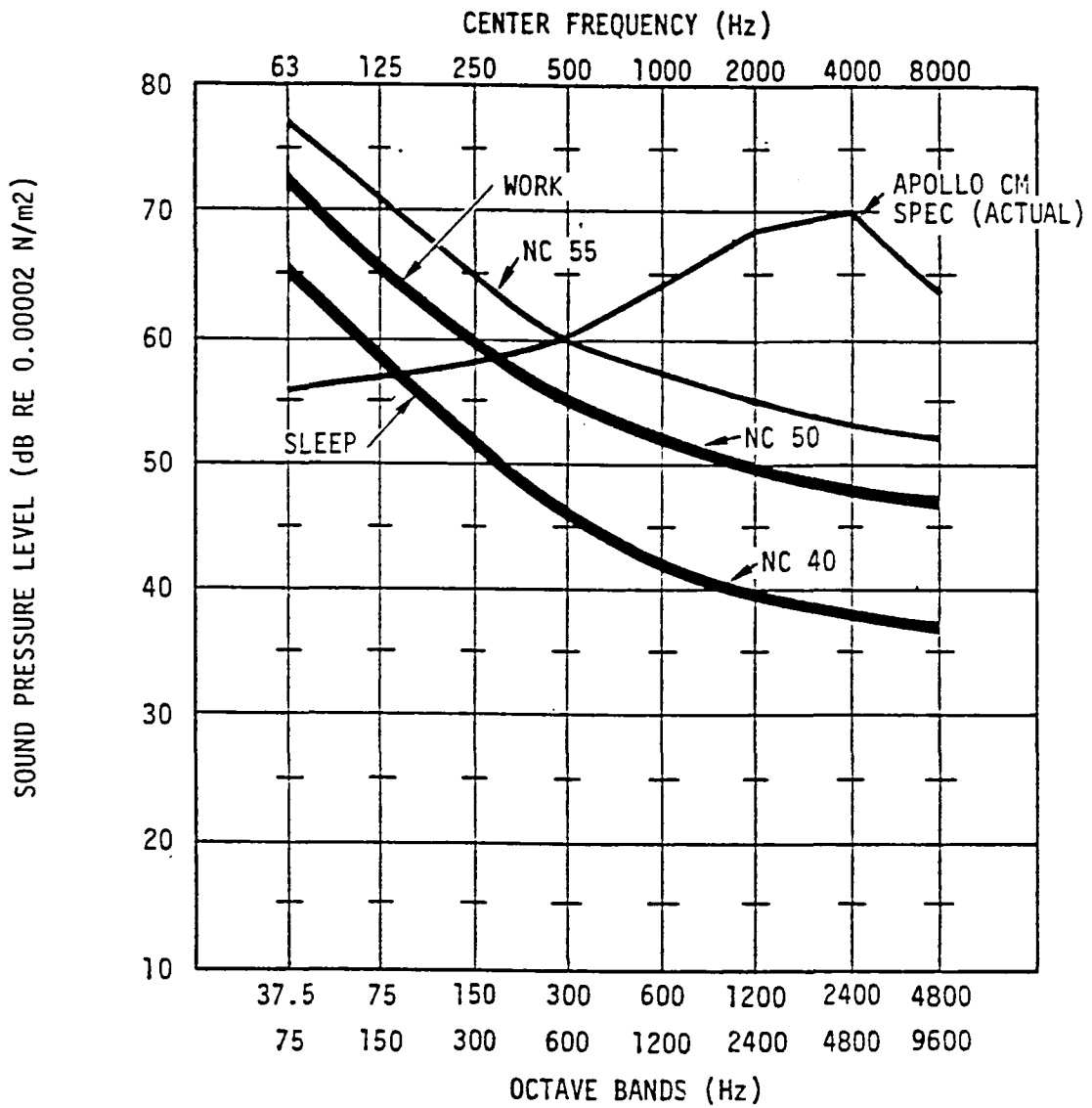


Figure 5-1 Apollo Acoustics

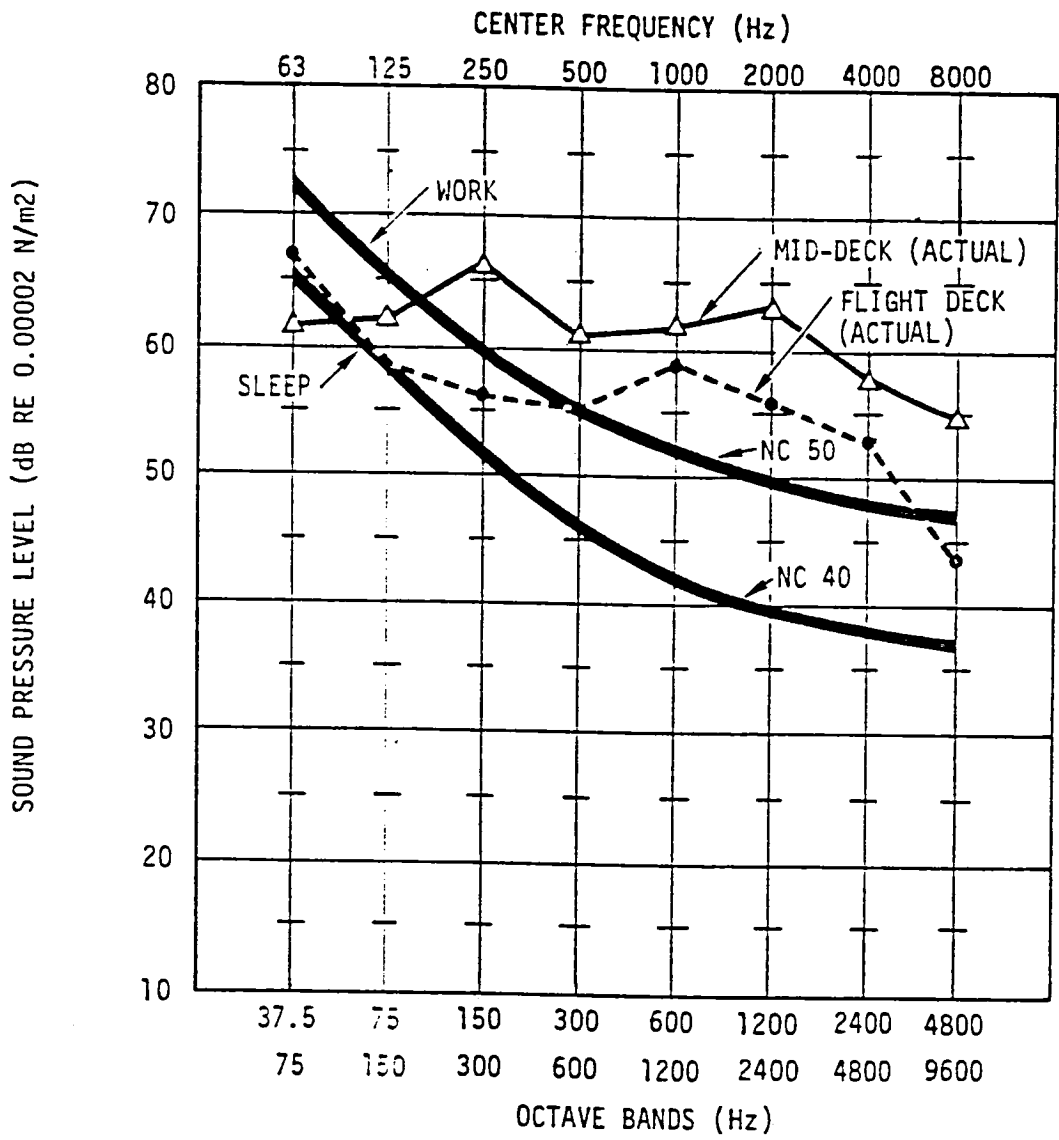


Figure 5-2 Shuttle Acoustics

TABLE 5-1 RELATIONSHIP OF NC-SERIES CURVES TO SOUND APPLICATIONS (376)

OFFICES	
NC (OR NCA) CURVE	COMMUNICATION ENVIRONMENT
NC-20 TO NC-30	VERY QUIET OFFICE; SUITABLE FOR LARGE CONFERENCES. TELEPHONE USE SATISFACTORY
NC-30 TO NC-35	"QUIET" OFFICE; SATISFACTORY FOR CONFERENCES AT A 15-FT TABLES; NORMAL VOICE, 10 TO 30 FT. TELEPHONE USE SATISFACTORY
NC-35 TO NC-40	SATISFACTORY FOR CONFERENCES AT A 6- TO 8-FT TABLE; NORMAL VOICE, 6 TO 12 FT. TELEPHONE USE SATISFACTORY
NC-40 TO NC-50	SATISFACTORY FOR CONFERENCES AT A 4- TO 5-FT TABLE; NORMAL VOICE, 3 TO 6 FT; RAISED VOICE 6 TO 12 FT. TELEPHONE USE OCCASIONALLY SLIGHTLY DIFFICULT
NC-50 TO NC-55	UNSATISFACTORY FOR CONFERENCES OF MORE THAN TWO OR THREE PEOPLE; NORMAL VOICE, 1 TO 2 FT; RAISED VOICE 3 TO 6 FT. TELEPHONE USE SLIGHTLY DIFFICULT
ABOVE NC-55	"VERY NOISY," OFFICE ENVIRONMENT UNSATISFACTORY. TELEPHONE USE DIFFICULT
WORKSPACES, SHOP AREAS, ETC.	
NC-60 TO NC-70	PERSON-TO-PERSON COMMUNICATION WITH RAISED VOICE SATISFACTORY, 1 TO 2 FT; SLIGHTLY DIFFICULT, 3 TO 6 FT. TELEPHONE USE DIFFICULT
NC-70 TO NC-80	PERSON-TO-PERSON COMMUNICATION SLIGHTLY DIFFICULT WITH RAISED VOICE, 1 TO 2 FT; SLIGHTLY DIFFICULT WITH SHOUTING, 3 TO 6 FT. TELEPHONE USE VERY DIFFICULT
ABOVE NC-80	PERSON-TO-PERSON COMMUNICATION EXTREMELY DIFFICULT. TELEPHONE USE UNSATISFACTORY

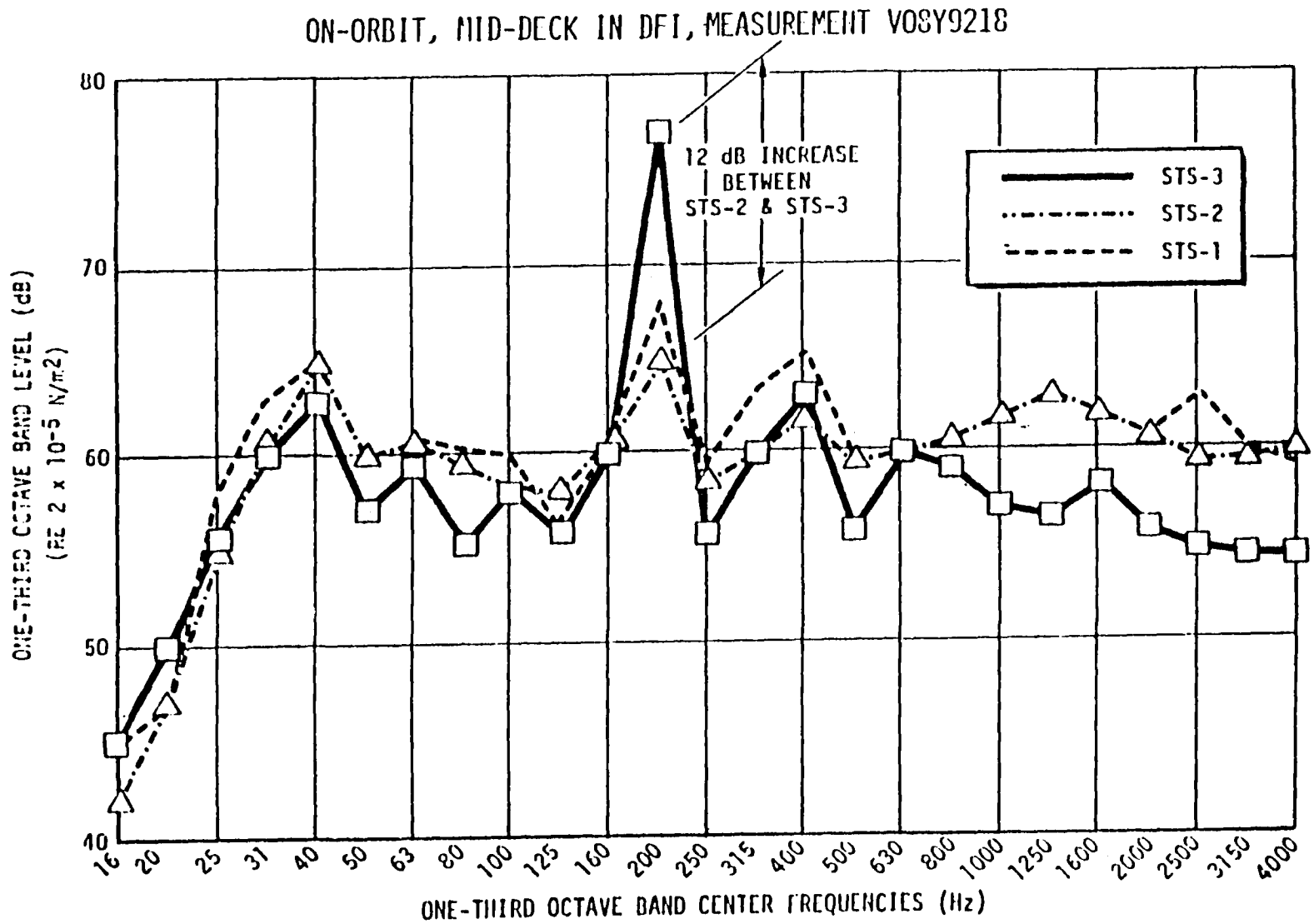


Figure 5-3 Shuttle Flight STS-3 Acoustical Trace

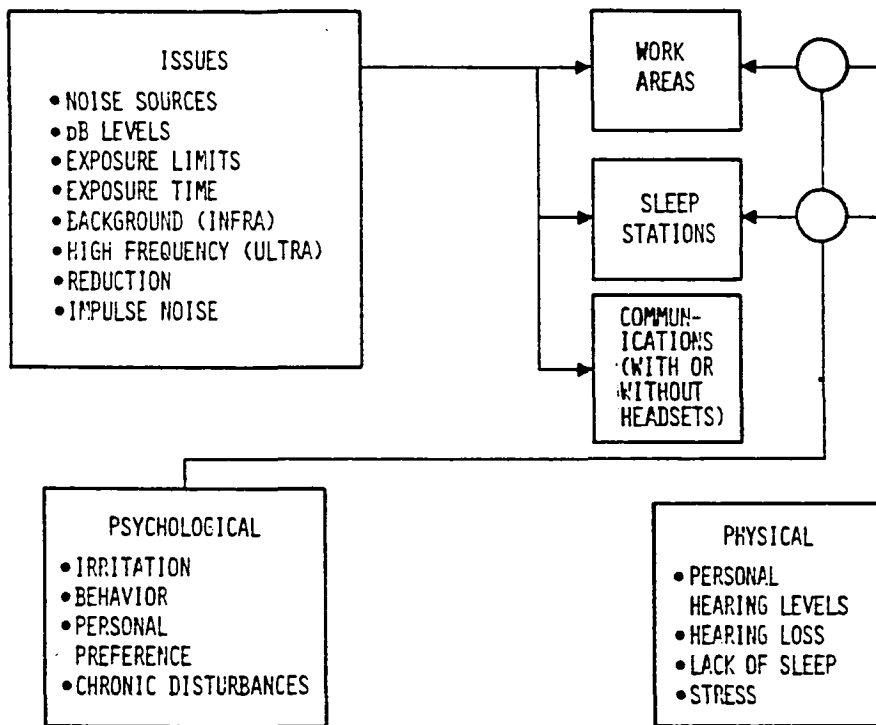


Figure 5-4 Acoustical Impacts

STRATEGIES

1. In order to maintain a reasonably quiet space station, necessary design requirements and specification must be imposed during the initial phase of the program, and maintained throughout the design, engineering, and manufacturing process. Investigation of latest technology in sound attenuation should be utilized for equipment design and materials.

2. It is suggested that measurements and assessments be apportioned for all noise sources that will include DB levels and frequencies, for individual compartments and accumulated noise. Sleep stations would require special analyses to determine an average sound level, as these areas should not be completely silent. Work and laboratory areas will need levels that will cause ease of communication and a system of hand-signals should be developed as an emergency back-up procedure. All crew members require a screening for establishment of baseline noise levels and sensitivity.

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Develop standard decision-making techniques to be used for insulation vs. isolation of noise
2. Specify the need for a maximum allowable NC-acoustic requirement per module (work area vs. habitable area) and require acoustic subsystem input apportionment within each module. Include a qualification test to apportioned acoustical requirements
3. Provide for standard hand signals for emergency communication in untenable noise environment.

6. TERRITORIAL ISSUES

BACKGROUND

The spatial organization of small groups in the cabins of spacecraft that are limited in size is characterized by the presence of common working and living quarters, unchanging and specific decor, and the virtual impossibility of evading "the territorial waters" of another. All this has a significant effect on the nervous system and alters the nature of socialization and interpersonal processes.

ISSUES

Crowding and Privacy in the Space Habitat

With the exception of Skylab, American and Russian spacecrafts have had very limited living space. In the earlier programs, Gemini and Apollo, former astronauts have commented on the extreme crowding in the capsules. But the adjustment to these conditions was good, presumably due to the nature of the astronauts and the prestige of the program. The difference between these programs, including Shuttle and Space Station, must be established clearly to prevent unsupportable generalizations. This generalization could lead to misleading information which could find its way into the design of Space Station.

As the personal rewards from spaceflight diminish, participants may be much more susceptible to the stresses of negative environmental conditions such as territorial issues. Sommer, Hall and others have defined personal space as an "invisible bubble", immediately surrounding the body. (119) Intrusions into this space could lead to anxiety and discomfort - the perception of crowding.

Personal space thus is perceived as an extension of the self. The size of this personal space in any one social contact is a function of the type of interaction and relationship between the people who are interacting. Stress arises when a person perceives that the space has been violated.

Personal Property

On the Shuttle program, the astronauts are allowed to carry on their own personal "ditty-bag". That is, each astronaut has certain items that are unique to his/her person. As the stay in space increases these personal items become attached with the instinct of home (Earth). To violate these articles could cause psychological problems along with a disruption of the team concept. The potential conflict arises in the need to inspect the contents of these bags for hazardous substances.

Task/Work Space

It has been noted on the Shuttle/Spacelab flights that work space within a module is at a premium. The allocation of work tasks should be incorporated into the time line to ensure that people will not be working on top of each other. On one of the Russian flights, a personnel problem occurred when one of the cosmonauts proceeded to do the other's work.

Intrusion of Personal Space

On the prior space programs, intrusion has not been addressed. But as the program moves into long duration stays, it must be considered. Both American and Soviet crews have commented on the lack of privacy. On the Soviet mission of 175 days, the Progress resupply vehicle brought up a privacy curtain on its last trip, even though the crew was to return to Earth in a short time. (155) Skylab crews also commented on the need for a place to be alone.

Lack of privacy also implies the intrusion of one's personal space. This intrusion can cause such symptoms as anxiety and stress. In spaces as confined as the Salyut-6 station, the Spacelab module, or the Orbiter crew cabin, there is little opportunity to prevent this intrusion.

STRATEGIES

1. Determine reasonable "invisible bubble" dimensions and screen out non-compatible peoples
2. Define/provide personal storage space
3. Provide logistic support to personal preference
4. Allow "personalization" of personal space
5. Train for mutually understood definition of "territory"

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Define/provide personal storage space.
2. Orient crew toward "non-violation" of personal territory.
3. Include personal consumables (toilet articles, etc.) in a master logistics planning list.
4. Determine method of measuring reasonable personal "space bubble" - flat vs. the sphere within which an individual feels threatened. Then, screen for crew who can function within this volume.

7. BEHAVIORIAL PROTOCOLS

BACKGROUND

Both the Russian and the United States space programs have experienced incidents wherein the crew by its own choice, either did not respond to or ignored ground control direction. On Skylab 3, many new experiments were added to the flight plan that the crew had not trained for. As a result, there were many unanticipated difficulties, such as errors and lost data. The ground pressed the crew in order to take advantage of precious time. The crew finally turned off ground communication for one day and spent their time in leisure activity, mostly looking out the window. The commander finally asked Mission Control to rework the schedule to give the crew more discretion in scheduling experiments. Once this new system began, the crew's performance improved considerably. (379) Some Soviet crews have demonstrated hostility with ground control staff by holding back on confidential messages and purposely hiding information and reactions. Apparently, on the 185 day mission, cosmonauts Ryumin and Popov turned off all radio communication with the ground for 2 days. (177)

In inter-cultural flights, the Russian cosmonauts were concerned about crew integrity during emergency situations. There is concern about translating from one language to another during these times. Multi-national crews are sent up to visit long duration crews to break the boredom. However, they can also bring a certain degree of misunderstanding and confusion based on language and value differences. Russian crews have complained that foreign accents deform Russian expressions leading to misunderstandings. (177) There are also the more subtle issues of customs and cuisine that may create difficulties.

ISSUES

The "Who's in charge?" issue has a very strong safety flavor. Someone has to be responsible for 1) the space station and, 2) the crew actions. The personal prerogatives of the crewmen should be spelled out clearly; what can one do and what can one not do. The degree of discipline is an important safety issue. Some workarounds to a potential risk situation beyond design capability rely on following very explicit instructions. Not to do so could expose the crew and station to pre-assessed risk situations.

The "Who's in charge?" issue extends to include the degree of autonomy from the ground that the station will enjoy. Rather than the naval/merchant capitol ship concept wherein the captain implements a clearly defined mission, the astronauts/cosmonauts appear to be in a situation where the advisors by far outnumber the advisees. This could be a stress generator for the crew particularly if the current system of mission ground control is utilized.

In a multi-cultural space station crew, a long term stay in space could cause problems if the crewmembers are not compatible: an example is if a crewmember must express or insists on expressing social or cultural characteristics or behaviors that conflict with other crewmembers. The implicit safety issues are the unwillingness to cooperate, the failure to communicate or plain misunderstanding.

STRATEGIES

1. Screen crewmembers for open vs. closed acceptance patterns
2. Clearly define "Who's in charge?" in the station and "Who's in charge?" on the ground with a concise delineation of the division of responsibility and authority
3. Educate crewmembers in cross-cultural and intra-cultural tolerances

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Screen crewmembers for prejudices and openness to differing cultural norms.
2. Provide education/orientation for crewmembers regarding cross-cultural issues and problems.
3. Train crewmembers to utilize group dynamics to work out potential behavioral protocol conflicts.
4. As a last resort, develop chemical/physical restraint system for out-of-control crewmembers.

8. SCHEDULING

BACKGROUND

In continuous 24 hrs/day, year round operations, personnel must be scheduled to provide on-going services. Most shift work schedules currently in use by both military and civilian facilities do not take into account even the most basic scientific knowledge about sleep-wake cycle physiology and the limits of human circadian entrainment. Further work needs to be done on both the basic theory of scheduling and its practical application.

Some fundamental information is already available on the range of entrainment of human sleep-wake cycles and this can be used to design duty-rest schedules which least disrupt the sleep-wake cycle and minimize deterioration in alertness and performance. The Soviet Union is paying considerable attention to circadian factors and scheduling.

The Space Station will be functioning 24 hours a day, with efficiency and smooth performance required in many key aspects of the system. There are significant costs incurred by inappropriately designed duty-rest time schedules which reduce the performance and productivity and increase the probability of errors through fatigue on the part of personnel. The joint flight of Russians/French were able to sleep as planned early in the flight but as the burden of work mounted throughout the week they had to skip some sleeptime to keep up with the workload. (198)

The Russians monitor the heart rate of the cosmonauts to maintain a constant rate. When the heart rate decreases or increases the schedule is adjusted to maintain the constant rate. (180)

Performance and physiological functions show deterioration after rapid travel by air across time zones - the syndrome known as jet-lag. The exact mechanisms underlying jet-lag are not fully understood. Efforts should be directed to defining the pathophysiological mechanisms involved and developing methods to better facilitate adaptation.

It has been shown that disturbance of circadian rhythmic internal phase relationship in animals, particularly over long periods, can result in pathological manifestations. In humans, circadian desynchronization in shift workers is often manifested by various psychosomatic complaints, including fatigue, sleep disturbances and gastrointestinal problems. Transmeridian flight, which induces phase shifts between the circadian rhythms of the body and the timing of external environmental synchronizers has been known to result in non-specific fatigue, insomnia and sleep disturbances, gastrointestinal complaints, headaches, disorientation and irritability.

The Apollo astronauts generally scheduled 12 hours of work, 8 hours of sleep, and 4 hours of relaxation each day. However, their days were busy, interesting and new. For more routine, long-term space-mission conditions, shorter work/rest cycles may be preferred. Naturally, these work/rest schedules would have to be modified somewhat to fit into the sleep/awake rhythm for the crew. (096)

Despite the circadian advantages of similar sleep-awake cycles for the crew, a staggered schedule has been proposed. The baseline indicates, at the present, an 8 crewmember society with 4 on and 4 off. Thus, a crew would be awake at all times to handle the station.

The third Skylab crew demonstrated the problems associated with overscheduling. With boredom a constant threat of potential stress, it is often seen as wise to make days extremely busy, leaving little time for reflection or inactivity. (089)

The stresses with scheduling experienced to date in the space programs have been mainly related to prearranged schedules. The Russians allow some options in the day to day organization of work and leisure time. This was initiated due to the identification of the psychological need to have some options of control; some freedom of choice in how they spent the day. (155) The results of overscheduling are now beginning to show during the Shuttle flights.

ISSUES

Disturbances of Circadian Rhythm

The circadian timing system is one of the most poorly understood physiological systems. This is because the neural pace makers which time circadian rhythms have only begun to be identified in the last decade and the neural and endocrine mechanisms of communications of circadian timing information and the consequences of disruption are just now being investigated.

On the first Shuttle/Spacelab flight, the first time a split-shift was utilized, the crew reported having trouble telling what time/day it was. This issue may affect the role of sleep, response to extreme environments, and mood and effective state.

Fatigue

Considering the importance of optimal crewmember performance during missions, it is desirable to monitor fatigue status thru crew reports. In this way, realistic expectations can be derived with respect to physical performance capability. With the onset of fatigue, appropriate action remedial can be taken to best achieve the desired outcome of the mission.

The efficiency and well-being of the crew, on any length of a space mission, is affected adversely when the crewmembers' sleep patterns are consistently disturbed by the environment within the spacecraft. Spaceflight experience to date has indicated that many crewmembers experience difficulties in falling asleep, and have needed to take medication.

No clear evidence exists that all astronauts are affected or that crew members who are affected suffer the same disturbances. Some complain that sleep was inadequate or that there was a considerable shift in sleep periods from expected home sleep time. On the Skylab flights, it was found that a pre-sleep period of at least 1 hour of mentally nondemanding activity was required. This allowed the crew to relax to the point where they could fall asleep. (134)

Several astronauts were affected more for the first two or three days. Others (on Apollo flights), had difficulty sleeping on the lunar surface. Skylab astronauts, on the other hand, experienced little difficulty as a group, and it has been stated that any difficulties they had did not affect performance. Skylab crewmembers slept satisfactorily in sleep restraint systems in erect, against-the-wall orientation, and the only relocation of sleep facilities was attributed to environmental, not psychological factors. (134) Both temperature and airflow triggered sleep restraint reorientation or relocation. Sleep compartment ventilation should flow in a head-to-foot pattern and flexibility in "blanket" arrangements should also be provided to accommodate varying thermal conditions.

During the first 5 years of an Antarctic study, the major effort of a research program was an analysis of the electroencephalogram (EEG) sleep data collected at six points in time during the subjects' participation in the study. S. Hurly and Pierce selected sleep as the primary dependent variable because it provided an objective, quantifiable measure of all the forces acting upon the individual: psychological, social, and environmental. (086)

Work/Rest Cycles

The long term consequences of rotating rest and duty time schedules are poorly understood but there is now sufficient information to give credence to concerns about effects on morbidity and mortality. Research done to date on such personnel as air traffic controllers and others on rotating schedules can aid in establishing criteria for crew performance without deterioration. (204)

Crew Changeover

This issue has not been addressed to date. The changeover period is one that will have to be studied in great detail. The impacts include: consumables, impact to timeline, escape/rescue considerations, logistics, etc. (See Figures 8-1 and 8-2).

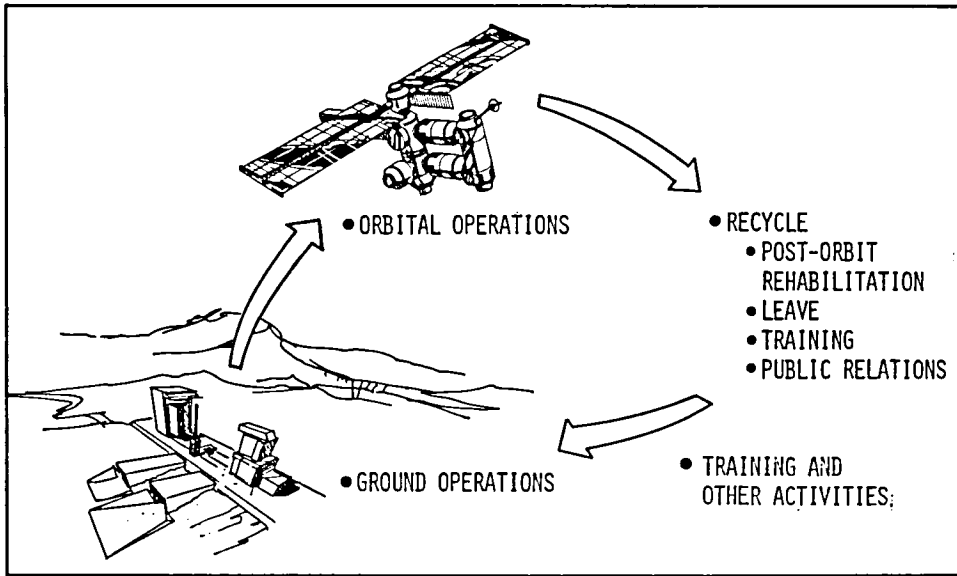
Interruption of Diurnal Periodicity

During prolonged submerged missions of 60 days or more, typical nuclear submarine duty, the submariner is removed from day-night cues. The literature reviewed supports the findings that such biological processes as heart rate, blood pressure, body temperature and quite possibly quality of performance are synchronized to such circadian cues as sunrise and sunset. (95)

Studies are indicating that the desynchronization of these cycles by the imposition of 4 hours on 8 hours off work/rest cycles may contribute to fatigue-like symptoms observed during long periods of submergence.

The crew debriefing of STS-6 revealed that due to the timeline scheduling on the Shuttle flights, the crew were beginning to experience difficulty in being able to distinguish what day it was and what time it was. Because of this, a mission time clock has now been added, along with a map that allows them the knowledge of their location in relation to Earth.

• AGGREGATE TEAM CONCEPT



• ONE FOURTH OF TIME SPENT IN EACH MISSION SEGMENT

Figure 8-1 Scope of the Teaming Concept

SPACE HABITAT SCHEDULING - PERSONNEL

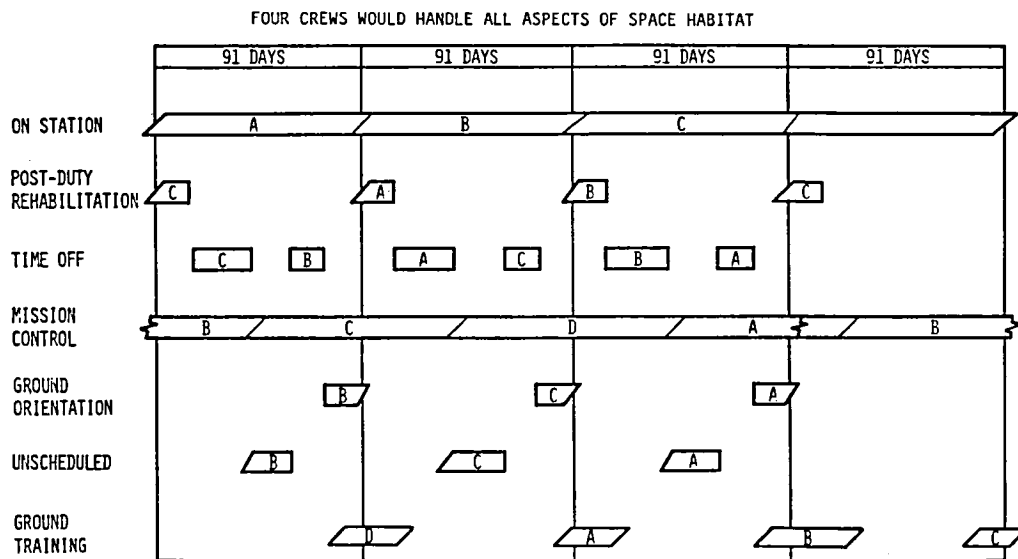


Figure 8-2 Scheduling Consideration

STRATEGIES

1. Set up integrated air-ground training to prevent the them/us syndrome and also to help facilitate the crew-changeover period
2. Scheduling must take into account:
 - a. Maximum allowable time in orbit recommended per year (radiation, physical debilitation, psychological aberration)
3. For crew changeover;
 - a. Begin changeover on the ground
 - b. Maintain orbiter at station during changeover
 - c. Prepare detail plan for station contingency operations during the changeover
4. Continuous monitoring of "health maintenance" to ensure constant status of astronaut (fatigue, heart rate, etc.)
5. Allow flexibility in schedule so that astronauts have the option of choice
6. Provide separate enclosed sleep stations to prevent interference of sleep time allotment due to noise, lighting, vibration, etc.
7. Allow rest periods during work schedule to prevent fatigue, etc. (i.e., 1-g criteria)
8. Scheduling must take into account those areas of work, maintenance, recreation and exercise

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Dedicated module tasks for crew vs. common task, all-module assignment.
2. Generalist vs. specialist for crew training guidelines.
3. Less than 90 day recycles vs. on-station expendable costs and crew personal equipment needed to support extended stay.

9. CLEANING/DISINFECTING

BACKGROUND

Cleaning and disinfecting during flight, in the prior space programs, was not an issue due to the short duration and non-reusable capsules. The Skylab program developed a microbial contamination control intercenter working group whose membership represented both scientific (medicine, micro-biology, chemistry) and engineering (systems and materials) disciplines as well as the program offices and astronaut office. Their primary purpose was to identify all sources of microbial contaminants, determine specific microbial contaminants (both bacterial and fungal) that would occur in the habitat, determine acceptable levels and establish control methods and techniques.

Microbial control was accomplished through the use of biocide wipes and wet wipes. The biocide wipes were used for general surface disinfecting in the wardroom, waste management utility and the trash airlock, as well as major organic (urine) spills. The wet wipes were used for food utensils and food tray cleanup. (377)

With the on-set of the Shuttle program, the strategy for this issue had to change. The scenario changed to longer duration and for the first time, a reusable vehicle. Also, the concept of the variable facility came into being. Experiments, equipment and people are being changed out each flight. With these changes in mind, the issues of hygiene, cleaning, disinfecting, prevention of pathogenic build-up, trash management, etc., had to be addressed. The program is still learning in many of these areas.

The Space Station scenario will change these issues over again. The main forcing functions will be: a non-returnable vehicle; equipment, experiments, people interchanging every 90 days, the introduction of material processing, animals, etc. All of these will have to be assessed for impact upon the station and people.

ISSUES

Crew Tasks

In the past, for areas requiring little or no technical background, people could be hired to do the mundane work. On the Space Station this luxury will not exist. Specialists will have to be cross-trained to do general tasks, even the lowly tasks of cleaning the area.

Schedule of Activities

Accurate data regarding amount of time spent in maintenance on the Salyut stations and on Skylab are not available. The Skylab figures are biased by the work arounds caused by shroud failure on launch and subsequent inability to deploy one of the panels. Salyut data are subjective and not discrete. The objective of the space station program appears to be that no more than 20% of the station - station chargeable hours be devoted to maintenance, upkeep or repair. The allocation for these activities should be included in the space station planned timeline.

Methods and Materials Used

Cleaning and disinfecting could be accomplished with an emphasis on aqueous materials. Organic solvent usage should be held to a minimum. A practical clean environment can be achieved through the judicious use of steam and dilute solutions of Hydrogen Peroxide (H_2O_2). Neither approach would achieve sterilization, but would drastically reduce physical and microbiological contamination.

Steam cleaning will remove surface contamination by means of solvation and/or increasing the vapor pressure of semi-volatile contaminants. A complimentary vacuum system would rapidly remove the contaminated moisture. This could then be treated to remove contaminants and yield pure water.

Hydrogen Peroxide would be stored as concentrated aqueous solutions (80-90% by weight) in a suitable aluminum container. The concentrated H_2O_2 would be diluted with water to form solutions containing 3 to 6% H_2O_2 . The means of dispensing the concentrated H_2O_2 in zero-g would be similar to the X-15 APU system. The aluminum reservoir would contain a collapsible bladder, a perforated stand-pipe, and means of pressurizing the exterior of the bladder.

The bladder material would be made from class 1 or 2 elastomers. (Note: Vicone 31-2 was used on the X-15. More compatible vicones were developed after completion of the X-15 program.)

The diluted H_2O_2 solutions would be used for washing or scrubbing contaminated surfaces. Hydrogen Peroxide has the advantage of being effective against anaerobic microorganisms and produces nonpolluting decomposition products (re: H_2O and O_2). Liquid gaseous effluent detoxification systems based upon H_2O_2 have been developed. Thus H_2O_2 could be used for cleaning and disinfection, and in these detoxification systems.

Additional disinfecting can be achieved by: 1) use of ultraviolet (UV) radiation, 2) exposure to hard vacuum by venting to outer space. The use of the above-mentioned methods should achieve a satisfactorily clean working environment with a minimum of residual pollution. (374, 375)

Consumable Logistics

The consumables must be logged on a data management system so that amounts, location, where used, when used, can be assessed. In case of loss of module, etc., dual storage capability must exist.

Pathogenic Development

Modules, equipment, etc., must be tested on a periodic schedule to ensure that pathogenic build-up is not occurring. Trash management will be most important in the prevention of this build-up.

Breakdown of Crew Immunology System

Due to the isolated environment and zero-g impact upon the body, an on-going health maintenance program must be maintained. For example: rigid exercise program, constant diet, etc.

STRATEGIES

1. Identify areas for primary and secondary cleaning
2. Develop methods to clean special areas
3. Rotate crewmember through "grunt" work tasks
4. Establish maintenance items and regularly scheduled activities
5. Consumables/logistics consideration
6. Determine cleanliness/disinfectant levels
7. Identify materials to be used and screen for compatibility
8. Biological/bacteriological on-orbit testing should be incorporated to prevent build-up
9. Storage area for trash should strategically be located to prevent propagation of pathogens
10. Next scheduled crew should be isolated for TBD period of time prior to inhabiting the Space Station to preclude infection of on-board crew

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Consider adequate capability for storage inventorying, handling and disposition of servicing, maintenance, plain garbage, and consumables for cleaning and repair.
2. Identify family of cleaning/disinfecting chemicals compatible with selected ECLSS approach.
3. Train crewmembers in all phases of station tasks, housekeeping.
4. Define minimum crew cleanliness requirements (this may be an intra-cultural issue).
5. Define requirements (total volume and flow rates) for potable and non-potable water.

10. HYGIENE

BACKGROUND

Hygiene consists of washing up, showering, shaving, combing one's hair, washing clothes, etc. Before the Skylab program, the hygiene did not include showers because of the lack of space. The Orbiter in its early flights did not even include a hygiene station. This now has been added and tested by the crew.

For crew morale and health purposes, the need for a simple shower and hand-wash sink becomes desirable for long duration missions. On Skylab, crewmembers reported taking a shower was a "pain in the neck", but well worth the inconvenience. (136) The crewmembers did feel "clean" after a shower.

There are other areas of socially acceptable hygiene practices that should be initiated to provide for personal choices and crew compatible personalities. Keeping each allocated personal space in order and clean should be addressed as housekeeping practices, coupled with frequency of clothing cleaning changes. Each individual should have a choice of environmentally acceptable soaps, deodorant, toothpaste, etc.

A more efficient method of body waste disposal and collection should be investigated. The Waste Management System should be reliable, safe, comfortable, easy to use, uni-sexual and hygienically controlled. Also involved with this system are the factors of privacy, restraints and anthropometrics.

In addition to full body shower, hand washers should be in convenient locations with housekeeping added for design considerations. Figure 10-1 is an approach for a micro-g shower. This shower concept fulfills the need for an efficient, fast method of personal hygiene. Water is applied under pressure, recirculated through a filtration system and reused through a non-potable reservoir. The combination of water and partial vacuum will be utilized to remove airborne water and soap globules. This type of evacuation will partially dry the crewmember and then a minimum amount of towel drying will be required.

ISSUES

Space Clothing Standards

Establish safe, comfortable, utilitarian clothing guidelines for space applications. These guidelines will serve as a base for any necessary NASA standards. Previous space studies have shown that reusable clothing is more cost effective than disposable items. Durability, linting, and electrostatic standards need to be established for long duration missions. Areas to be addressed encompass how to clean and store, personal considerations (i.e., color, coverage, feel, allergenics), and compatibility with projected atmospheric compositions need to be assessed. (Figure 10-2). Investigate past experiences and establish fundamental primary criteria for the following main categories: Comfort, Design, Utility, Health & Safety.

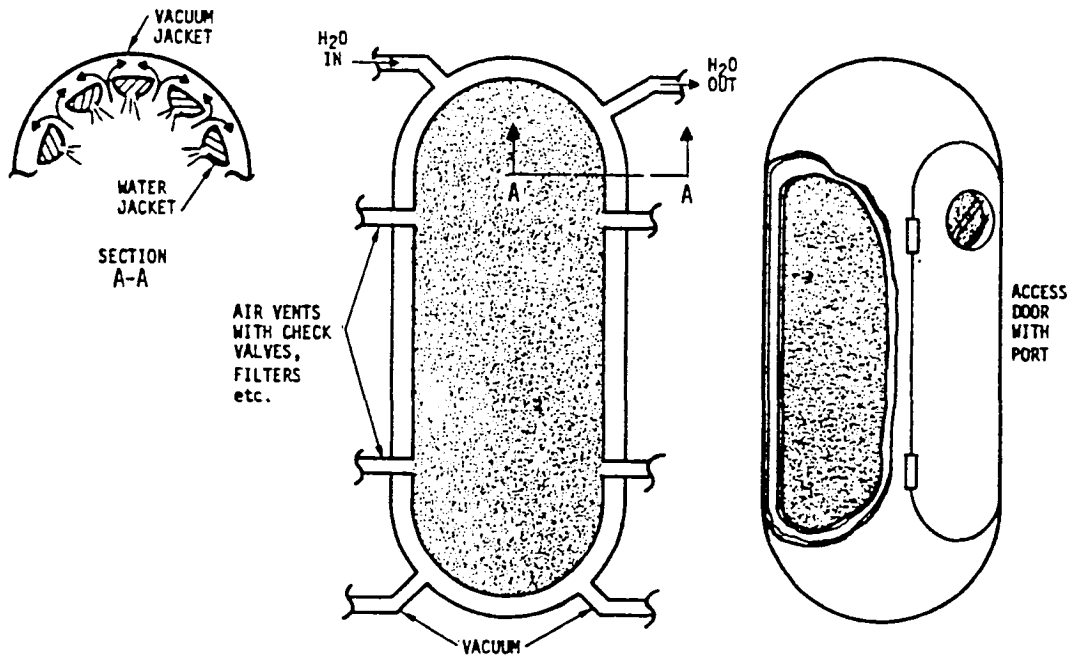
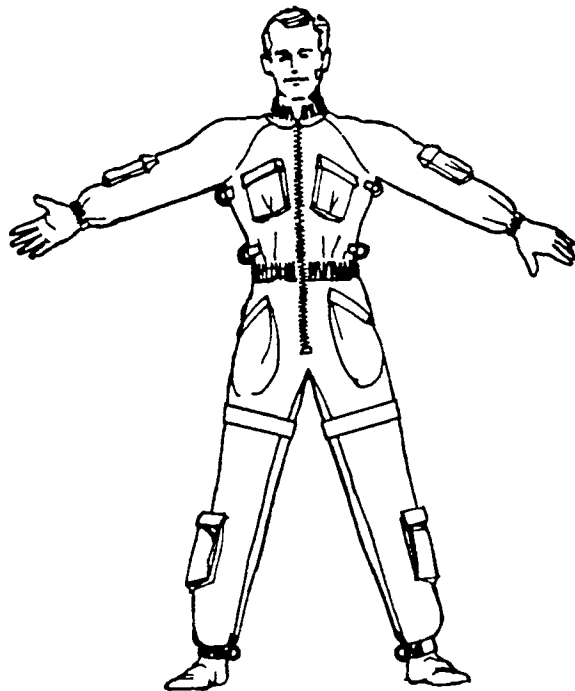


Figure 10-1 Micro-g Shower Approach (Rockwell International)



MULTIFACETED REQUIREMENTS:

- FUNCTION
- HEALTH
- MODESTY
- STYLE
- SURVIVAL
- PERSONAL HYGIENE
- SAFETY
 - RESTRAINT RINGS
 - NONFLAMMABLE
 - ANTI-STATIC

Figure 10-2 Space Station Crewmember Apparel Considerations
(Rockwell International)

Comfort - The material selection shall include the physical properties of: color, wearability, feel and permeability. It should also be tested for the chemical properties of out-gassing, allergenics, chemical compatibility and static electricity.

Design - Clothing should have the ease of donning and doffing with adequate pocket accessibility and securement. The uniformity of design should be considered, with possible consideration as to distinction between male, female, rank and task related duties. The garment fit should be loose and/or stretch for optimum movements and flexibility.

Utility - Clothing should be compatible with task performance with adequate padding protection for bumps and abrasion. Material will be best utilized when tear and abrasion resistant qualities are included, coupled with the use of gloves for finger dexterity, tactile quality and non-slip surface.

Health/Hygiene - Space Station garments shall be reusable and methods provided for wash and wear (or alternate form of cleaning). Clothing must be hypoallergenic and have thermal protection for heat and cold. Garments should include the necessary health monitoring equipment potentials for dosimeters and other bio-med instrumentation connections. Fasteners/connections for clean room accommodations may be considered.

Safety - The basic overall garment should include a reasonable number of D-rings (or equivalent) for body restraint and stability. Consideration should be given to the bungee/tethers and/or standard reels for restraint at various work stations. These connections require electrical conductivity to enable electrostatic grounds for each crewman.

Skylab Experience (132)

The clothing worn during these missions became soiled from the crewmember's body and not the spacecraft environment. Shoes were noted to wear-out rapidly, as the toes would not hold up to the scuffing from motion of pushing about and wear from the grid-type floor.

STRATEGIES

1. Hygiene equipment scheduling must be incorporated into time-line (i.e., shower use)
2. Consumables/logistics must be taken into consideration
3. Waste handling-methods established
4. Personal equipment screening for flammability, off-gassing, crew compatibility
5. Minimum defined crew cleanliness requirements
6. Potential/past crew participation in design and selection of clothing and hygiene equipment

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Consulting with astronauts, develop a standard for clothing options and hygiene consumables options.
2. Consider scheduling hygiene (common) equipment.

11. RECREATION

BACKGROUND

With the increasing of flight duration, the satisfaction of leisure needs will become more critical. Most U.S. missions to date have been relatively short and all have had extremely high work loads. The astronauts of Skylab, particularly the third crew, had such a heavy work load that virtually no spare time was left over. Available to the crew were books, tape decks and games, but few were used (132). It is note worthy that not even one Skylab astronaut finished more than one book during the entire 84-day mission. (132)

Matching the preferences of the crewmembers could become an issue. On Apollo 9, Astronaut Rusty Schweickart took two pieces of classical music. Apparently one of the other astronauts did not care for that type of music and it mysteriously disappeared until the 9th day of the flight. (173)

Problems with recreation has occurred on oceanographic research vessel. During a 2-year voyage of the British Antarctic vessel RV Brensfield, the crew tossed over-board a large part of the specimens collected because of a dispute about the use of the freezer. The freezer, on the beginning of the trip, was used to store cold beer for use within the recreational periods. As the specimens became more numerous, more storing space was needed. Alas, the beer freezer was taken over. Differences also showed up in tension over the different types of music and the available leisure activities. (088) In 1978, one of the cosmonauts began to miss his music and guitar. To prevent a psychological issue, his guitar was delivered on the next progress supply ship. (155)

Future crews, with more division of tasks, especially the mundane type tasks, are likely to live according to schedules similar to those on ocean rigs, ships, etc. This would assume an 8 to 10 hour working day. The 8 to 10 hour day would be work only (does not include meals, personal hygiene or leisure).

The scope of leisure activities possible on board the space station may be limited and probably will exclude sports and any outdoor activities. Some type of substitutes will have to be found which will be considered satisfactory. During the Skylab missions, the large areas available allowed the Skylab crew to bounce off the walls, perform somersaults, etc. (119) This was reported as a major source of enjoyment during the mission. Also, the wardroom window provided one of the more important means of relaxation. Most of the time, the Earth was in view and crewmen never seemed to tire of it. (132). Although exercise is a mandatory part of life for space duration, it also provides a source of relaxation. On Skylab, a bicycle (ergometer) was available. (132)

Hobbies and leisure activities of Antarctic participants have been an increasing interest as an area of psychological research. During the winter months, when work activities are reduced for most station members, free time is available for avocational and recreational activities. The use made of this time and the satisfaction or boredom experienced by the individual may significantly affect his psychological adjustment.

An investigation was made of hobby interest likes and dislikes and leisure activities preferred by wintering-over personnel at small stations. Analyses were conducted separately for Navy construction, Navy technical-administrative and civilian personnel. Drastic differences were noted in the study.

Crews mixed on the basis of sex, nationality, and vocation will have different leisure interests. As space will be at a premium, accommodation must be made to include leisure activities in the time line, and provisions should be made in the facilities.

ISSUES

Personal Preference - Each person has their own unique definition of what recreation means to them. Their personal preference may not be compatible with the micro-g environment or the restrictions of the space station.

Types - An evaluation of the different types of recreational activities, equipment, etc. must be made prior to introduction into the space station. Also screening for compatibility among the crew must take place to prevent intra-crew stressors.

Location - The question of where recreation will take place has not really been addressed. The astronaut may want to retreat to his sleep area or maybe sit in the eating area with a headset on. The Russian cosmonauts engage in chess games with various people on the ground. The where and when will have to be scheduled into the time line.

Alone vs. Group Recreation - Recreational devices fall into two categories. The first are those that require one person interaction. For example: listening to a personal tape from the family or ground communication with a loved one or reading a book. The second type involves crew interaction: playing of cards, other games or just sitting and talking. Again, intra-crew incompatibilities may result if some concurrence is not reached.

Strategies

1. Require minimum crew "Active Leisure Time"
 - a. Must be incorporated into Timeline Schedule
 - b. Should be adjustable per the needs of the astronaut
2. Screen for crew segment compatible leisure activities
 - a. Screen for crew likes/dislikes
 - b. Screen for compatibility with Space Station criteria/guidelines
3. Define allowable recreational equipment and facilities
 - a. Incorporate into definition logistical needs

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Define a private electronic center for each cabin to include at least an entertainment center (visual/aural), a private television link to Earth, background mood generator (white noise).
2. When teaming, screen crewmembers for compatible recreation interests.
3. Prepare specification for recreation equipment/kit pertaining to safety - with options for person.

12. VIOLATION OF SAFETY

BACKGROUND

In 1979, the cosmonaut Romanenko was so excited that he could not wait to poke his head out of the station for EVA. In his eagerness he did not follow the checklist. He forgot to secure the safety tether. Had not the other cosmonaut grabbed Romanenko's foot, he would have become a bit of free orbit debris. (173)

In the evolution of tasks planned on the space station (fabrication, maintenance, repair, EVA/IVA, rigging, etc.), each activity will have been assessed for risks. Unlike industrial tasks on the ground, safety controls and inhibiting devices will have been included in the product/function development. Because of this, there will tend to be fewer "safety and/or emergency procedures" needed. But where needed, these safety and/or emergency procedures will require enforcement. In the spectacular nature of the initial Skylab and Shuttle flights, crew constraints were either implied, assumed or presented few occasions for explicit enforcement. With the advent of an operational space facility with more total in-space hours being realized, discipline governing safety procedures will have to be observed.

ISSUES

Non-standard procedures are, and will be devised as workarounds in unexpected situations. The program should be flexible enough to accommodate these workarounds. Other issues are derived from undefined contingency actions. For instance, the inability of the Solar Max trunnion pin docking device to latch caused a contingency operational mode to be implemented. Some actions taken could have endangered the EVA crewman or damaged the Solar Max satellite. In other cases on some Shuttle flights, some personal equipment has not been screened for flammability or toxicity, such as cotton "T" shirts, magic markers, and the like.

STRATEGIES

1. Clearly identify safety critical segments of procedures requiring mandatory compliance
2. Prepare logic or task flow charts that identified as many contingency operations
3. Screen all carry-on personal equipment
4. Training for all crew to understand importance and consequences of safety procedures.

AREAS FOR FURTHER STUDY

The following listing extracts areas identified in the initial study that should be given more attention. Some of these items may be underway or have been completed. These items in no way comment on completeness or status of the related items. Rather, the list indicates that within the data reviewed there seemed to be areas of data deficiency.

1. Develop realistic allowable radiation dose rate tables for part of body for EVA, flight, quarter, year and whole life.
2. Develop color coding system for all tubing, piping, emergency passageway, damage control equipment and tasks including "warnings", "cautions", and "notes".
3. Clearly identify safety critical segments of tasks to insure mandatory compliance (hardware, procedural software).
4. Prepare task flow charts that identify as many contingency operations as possible to determine response need.
5. Screen all carry-on personal equipment.

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16. Abstract The scope of this study considered the first 15 years of accumulated space station concepts for Initial Operational Capability (IOC) during the early 1990's. Twenty-five threats to the space station are identified and selected threats addressed as impacting safety criteria, escape and rescue, and human factors safety concerns. Of the 25 threats identified, eight are discussed including strategy options for threat control: fire, biological or toxic contamination, injury/illness, explosion, loss of pressurization, radiation, meteoroid penetration and debris. This report consists of five volumes as noted: Vol. I - Final Summary Report (NASA CR-3854) Vol. II - Threat Development (NASA CR-3855) Vol. III - Safety Impact of Human Factors (NASA CR-3856) Vol. IV - Appendices (NASA CR-3857) Vol. V - Space Station Safety Plan (NASA CR-3858)					
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