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SAFETY STUDY

CREW SAFETY

GUIDELINES

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VOLUME I

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PREFACE

This document constitutes one volume of the final report prepared under Contract NAS9-9046, Space Station Safety Study, which was conducted by the Aerospace Systems Division, Aerospace Group, The Boeing Company, under the direction of the Advanced Projects Office, Advanced Missions Program Office, Manned Spacecraft Center, NASA. The objective of the study was to develop a management tool for evaluating conceptual designs of future manned space systems from a safety viewpoint. This objective was achieved through the application of methodical techniques, which are described where necessary in appropriate volumes of this final report, for analyzing space station safety problems. This work resulted in the development of Crew Safety Guidelines which can be used in evaluating future space station concepts.

In Phase I of the study, the work was directed toward a broad class of space stations, using several specific configurations as examples, and considering both crew safety and mission accomplishment as safety goals. In May 1969, the study was redirected by NASA into Phase II to provide more direct support to the NASA Phase B Future Space Station Study, considering only crew safety as the safety goal. To the extent possible, the work done in Phase I was revised and adapted to Phase II and all documents of this final report, except as otherwise noted, include the results from both phases. In both phases the study scope included only on-orbit operations and not launch, boost, de-orbit, and recovery operations, or any operations of the logistics support system, except for close-in rendezvous and docking operations.

The approach taken in the study was to examine the space station from the viewpoint of safety only, with the intent of identifying as complete a list as possible of those measures which should be taken to maximize crew safety. Also, and especially in Phase II, the study dealt primarily with station concepts, rather than specific designs or hardware items. It was not possible, and no attempt was made, to examine the impact of safety measures on other important aspects of space station development, such as cost, design difficulty, or operational suitability. As station development proceeds, trade studies between safety measures and other factors will be required and management decisions must be made as to the extent to which other desirable features will be permitted to override safety measures.

The documents constituting the final study report are:

- D2-113070-4, Condensed Summary Report
- D2-113070-5, Crew Safety Guidelines, Volumes I and II

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- D2-113070-6, Supporting Analyses
 - Analysis of Operations
 - Experiment Program
 - Traffic Patterns Analysis
 - Human Requirements
 - Meteoroid Penetration
- D2-113070-9, Logic Diagram
- D2-113070-10, Fault Tree Analysis
- D2-113070-11, Subsystems Analysis

Other documents produced during the study but not part of the final report are:

- D2-113070-1, Detail Study Plan (Phase I only)
- D2-113070-2, Midterm Oral Report
- D2-113070-3, Final Oral Report
- D2-113070-7, Baseline Mission Description (Phase I only)
- D2-113070-8, Baseline System Description (Phase I only)

This document, D2-113070-5, "Crew Safety Guidelines", is published in two volumes. Volume I, consisting of pages 1 through 186, contains the Introduction, the Crew Safety Guidelines Description, and Crew Safety Guidelines covering Hazard Groups 1.0 through 8.0. Volume II, consisting of pages 187 through 396, contains Crew Safety Guidelines covering Hazard Groups 9.0 through 12.0, the Cross Indexes, and the References. See the Table of Contents, page vii, for a further breakdown of Hazard Groups and specific page numbers.

ABSTRACT

This document contains the space station Crew Safety Guidelines developed under Contract NAS9-9046. The basic arrangement of the guidelines is by hazard groups, with each guideline appearing only once. Cross-indexes are provided which relate each guideline to other hazard groups if appropriate, to subsystems affected by the hazard, to key words, and to damage containment and control procedures.

KEY WORDS

crew hazard
crew safety
safety analysis
safety guideline
space base
spacecraft
space station
space system

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1.0 INTRODUCTION

The Crew Safety Guidelines developed during the Space Station Safety Study are presented in this document. Each guideline describes a safety measure which is suggested as a means of alleviating a particular hazard or group of hazards and which, if followed, would tend to increase space station crew safety.

The majority of the effort in the Safety Study was directed essentially toward two goals. The first was to identify those actions which should be taken to make a space station as safe as possible. The second was to provide a means by which management could insure either that the actions had been taken or that they had been considered and rejected for good and sufficient reasons. The Crew Safety guidelines presented herein are at the same time a listing of actions to be taken in the interest of safety and a checklist by which management can review and assess the extent to which consideration was given to specific safety improvement. A condition precedent to any use of the guidelines, however, is the establishment of a strong safety organization.

The Safety Study was oriented solely and strongly to crew safety and this safety orientation is reflected in the guidelines in several ways. They are directed generally towards measures to prevent the existence of a hazard, to preclude the occurrence of an undesired event, or to protect the crew if something does go wrong, with after the fact remedial actions getting much less emphasis. They show measures directed against all hazards which were identified, including already accepted safety measures taken against well-recognized hazards, and measures proposed against hazards which may carry a very low risk. Furthermore, in certain instances, they are somewhat contradictory, because a measure which is desirable in the light of one hazard may not be compatible with a measure desirable in light of another hazard.

The Safety Study, particularly in Phase II, dealt primarily with future space station/base concepts, rather than with hardware. In consequence the guidelines generally are statements of "what" things should be done and not of "how" they should be done, although suggestions of how to do something are sometimes made.

The guidelines, then, should be considered as safety suggestions, not commands. They are statements that point the way toward courses of action which will enhance crew safety. Their application must be judicious, taking into account the various trade-offs which are implicit, and sometimes stated, in each one.

Each guideline appears in this document only once, listed under a hazard group which was considered, sometimes arbitrarily, as being most appropriate. In addition, the guidelines are cross-referenced in several ways which include: by hazard groups for those guidelines which relate to more than one hazard group; by the subsystem(s) or functions affected by the guideline; by key words; and by guidelines pertinent to damage containment and control.

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2.0 CREW SAFETY GUIDELINES DESCRIPTION

2.1 FORMAT AND CONTENT

Figure 1 shows the format used in reporting all guidelines. An explanation of the content of each part of the format follows.

2.1.1 NUMBER

A unique identifying number consisting of an integer and a decimal is assigned to each guideline. The integer is the number assigned to some particular hazard group and the decimal is the serial number of the guideline within the hazard group.

2.1.2 Hazard Groups

The 12 hazard groups used in the study, and listed in the following paragraphs, were identified early in the development of the Logic Diagram (Document D2-113070-9) as representative of hazard groupings or categorizations stated or implied in various literature sources.¹ Subsequent checks against additional sources or hazard lists show that the list used herein is in general agreement with others. A difficulty common to all lists, including this one, is that there is considerable overlap between hazard groups, and the assignment of a hazard to a particular group must often be done arbitrarily. At a later date, if it proves necessary or desirable, the hazard groups may be broken down into subgroups or other major groups.

2.1.2.1 Contamination

This group includes hazards which are related to or caused by contamination of the spacecraft, including the air, food, and water. The sources of contamination vary and include contaminants produced as by-products of human metabolism, those produced by the spacecraft through outgassing or otherwise, and those produced by interreactions among various combinations of chemicals and/or hardware. In addition, a potential and varying source of contaminants are the materials brought on-board the spacecraft for operational, scientific, or experimental purposes. In many cases, contaminants will be present in trace amounts only, but in some cases a potential contaminant will be on-board the spacecraft in relatively large quantities, with the possibility of massive contamination.

2.1.2.2 Debris and Meteoroid Impact

This group includes collisions with or impact by items external to and not under any form of control by the spacecraft, such as meteoroids or other

¹For example, the Rand Corporation report on Contingency Planning for Space Flight Emergencies and the Aerospace Corporation report, Manned Space Flight Emergency Concepts.

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HAZARD GROUP:		NO.
TITLE:		
APPLICABLE SUBSYSTEMS/FUNCTIONS:		
SAFETY GUIDELINE:		
REFERENCES:		
REMARKS:		

Figure 1
Guideline Format

natural bodies, other satellites, spent stages, debris left in space by other space programs, and the like. The items in this group are generally those having relatively high energy levels. Not included is impact with items which form a part of the related equipment of the spacecraft, as noted in Section 2.1.2.5.

2.1.2.3 Decompression

This group includes partial or total loss of atmosphere, either in the entire station or in any one or more separately pressurizable compartments.

2.1.2.4 Electrical

This group includes injury or fatality to crew members caused by an electrical current passing through the body, or any portion thereof. It also includes the effects of electrical arcing, over-currents, or power failures, and hazards due to static electricity.

2.1.2.5 Equipment Impact

This group includes crew member impacts with internal station equipment, supplies, cargo, and the like, whether the impact is caused by motion of the equipment, by motion of the crew member, or both. It also includes impacts by station-related equipment external to the station, such as the logistics support system, free-flying or attached experiment modules or subsatellites, and vehicles used as space ferries or tugs.

2.1.2.6 Explosion

This group includes violent disruption of the station, compartments of the station, or components within or attached to the station. The disruption may result from over-pressure, chemical or physical reactions, or other means.

2.1.2.7 Illness and Injury

This group includes all mental and physical disabilities of the crew from any cause. In the case of physical disability, the causes may be physical injury of any sort or illness of any sort, including illnesses caused by contamination. It includes illness of laboratory and experimental plants and animals when such illness may affect the crew. Also included are the effects, if any, of the weightless or low-gravity environment.

2.1.2.8 Loss of Vital Supplies

This group includes partial or total loss of oxygen, food, or water, whether caused by failure to resupply, loss of the item, or contamination.

2.1.2.9 Radiation

Hazards in this group are defined specifically as those which are associated with any or all of the following: alpha particles, beta particles, gamma rays, X-rays, cosmic rays, neutrons, high-speed electrons, high-speed protons, other atomic particles, bremsstrahlung, and any non-ionizing radiation with established biological safety limits.

2.1.2.10 Temperature Extremes

This group includes those hazards associated with the departure of temperatures from normal, including temperature increases, decreases, or fluctuations. It also includes extreme heat, such as that generated by fire, and extreme cold, such as that associated with cryogenics and the space environment itself.

2.1.2.11 Spacecraft Accelerations

This group includes hazards associated with all planned or unplanned motions of the spacecraft, without regard to the cause of or reason for the motion.

2.1.2.12 General

Certain hazards either are not clearly associated with any particular group or appear to be associated with many or all groups and are listed, therefore, in this general group. Any application of the guidelines which considers one of the other hazard groups should also consider this general group.

2.1.3 GUIDELINE TITLE

The title is a short statement consisting usually of descriptive words which most accurately represent the subject matter of the guideline.

2.1.4 APPLICABLE SUBSYSTEM OR FUNCTION

The subsystem or function affected by the guideline is listed. The subsystems and functions provide for both normal station operations and experiment operations. The classifications used in this study are:

- Communications and Data Management (CDM)
- Crew System (CS)
- Electrical Power System (EPS)
- Environmental Control/Life Support System (EC/LSS)
- Stability and Control System (SCS)
- Structures/Mechanical Systems (S/MS)
- Operations (OPS)
- Experiments (EX)

The basic structure provides the structural shell and support racks for the subsystems. The subsystems, therefore, consist only of the hardware needed to perform the subsystems functions. The subsystems shown above are those required for only the in-orbit phase of an earth-orbit mission and do not include subsystems specifically required for launch, boost, de-orbit, and recovery operations. For planetary missions, propulsion systems and guidance and navigation systems would also have to be considered. Following is a brief description of each of the subsystems listed above.

2.1.4.1 Communications and Data Management

This system provides the data processing and communications capability for the crew, experiments, and the space station. The communications functions include transmission of processed engineering and experiment data, voice, and television to the ground network; receiving command data, voice, and ranging data from the ground; intercommunication within the space station and between the space station and EVA personnel, logistics vehicles, and independent modules; rendezvous and docking communications and ranging data. For the purposes of this study, it also includes navigation and guidance functions to the extent that they require inputs from sources external to the station. Data management is provided by telemetry units, computer and data adapter, and recorders; to acquire, process, store, and present the engineering and experiment data for transmission.

2.1.4.2 Crew System

The crew systems support the crew by providing their requirements for food, clothing, physical conditioning, personal hygiene, medical examination and treatment, portable environmental protection and locomotion (including that required for extravehicular activity), living facilities and provisions, recreation, and storage and packing facilities.

2.1.4.3 Electrical Power System

This system provides the electrical energy required to operate the space station systems and experiments. These power sources may be one or a combination of solar panels, batteries, radioisotopes, nuclear, etc. The system includes power regulation and conversion equipment, a bus system with appropriate distribution network, and switching and protection devices.

2.1.4.4 Environmental Control/Life Support System

This system includes both the life support and environmental control provisions required to sustain the crew and the station equipment for the duration of the mission. The system basically encompasses the following functions: atmosphere supply and control, humidity control, CO₂ control, atmosphere purification (contaminant control), cabin temperature control, suit loop operations, airlock environmental control, equipment temperature control, heat rejection to space, water management, and waste management.

2.1.4.5 Stability and Control System

This system controls the attitude of the space station during the in-orbit phase of the mission. The system must maintain spacecraft attitudes or control orientation as necessitated by aerodynamic forces, gravity gradient, solar pressure, rendezvous and docking operations, experiment requirements, solar panel orientation, thermal control, and internal disturbances. The categories of equipment needed to accomplish these functions include sensors, computers, controls, displays, and actuators. For the purposes of this study this system also includes propulsion, navigation, and guidance functions internal to the station.

2.1.4.6 Structures/Mechanical Systems

This system classification includes the structural shell, pressure bulkheads, internal structure, docking ports and mechanisms, hatches and mechanisms, airlock structure and mechanisms, logistics or resupply support equipment, windows, artificial gravity equipment, living quarters furniture, cabinets, and, in general, other equipment of this classification that cannot specifically be included under one of the other subsystems.

2.1.4.7 Operations

This classification is a function and is used to include safety guidelines pertaining to procedures and activities that are not necessarily hardware-oriented. At a later date, consideration of the total mission spectrum may result in considerable expansion and further breakdown of this classification.

2.1.4.8 Experiments

The experiments classification has elements of both subsystem and function. It includes the hardware and operations required to make the observations and tests other than those required for normal station "housekeeping" operations. It also may require considerable expansion at a later date.

2.1.5 SAFETY GUIDELINE

A safety guideline itself consists of a minimum number, preferably one, of complete sentences which briefly describe a suggested means by which a hazard may be alleviated or eliminated. They are phrased in conditional terms, since they are intended to be guides and not requirements.

2.1.6 REFERENCES

The references associated with a guideline usually refer to a specific, identifiable segment of one or more of the analyses conducted during the study and described in other volumes of this report. Additionally, where appropriate, reference is made to other documentation, which is not a part

of this report, with the provision that such documentation be authoritative, readily identifiable, and generally available.

2.1.7 REMARKS

The remarks section includes a brief description of the rationale behind the guideline. Other guidelines and hazard classifications which are related to the guideline are cited. Alternate approaches to the problem are mentioned and the need for trade studies identified.

2.2 GUIDELINES DERIVATION

The Crew Safety Guidelines were derived through a methodical process involving the following steps. Existing information, especially that pertaining to safety in manned spacecraft, was reviewed. On the assumption that future manned space programs would be to some degree analogous to those of the past, several analytical techniques were employed to project this information to future concepts. The techniques, which are described in such detail as is appropriate in other volumes of this report, included the logic diagram, fault tree analyses, subsystems analysis, and a set of minor tasks in support of or supplementing the three major techniques. The hazards associated with future concepts were identified, including those analogous to past programs and those believed peculiar to future programs. A means of safeguarding against each identified hazard was developed and a guideline derived expressing the safeguard. In some cases safeguard development and guideline derivation were a single step. Over 500 guidelines were derived initially, this number being reduced to 282 in the final reviews. The final steps, conducted simultaneously, were a review and consolidation of guidelines to combine several like or similar guidelines into one and a feasibility evaluation to ascertain if and how a guideline could be practically employed. During these final steps, also, some of the original guidelines were discarded because they did not, in fact, provide safeguards against the hazard identified.

2.3 GUIDELINES APPLICATION

In considering how best to apply the guidelines, two extremes suggest themselves. One way would be to use the guidelines as a checklist against a final design. The other way would be to use them to derive certain station or base concepts which would be optimized with respect to crew safety. There are, of course, applications which lie somewhere between these two extremes. In any case, the guidelines do provide a basis for a strong and viable safety program. Establishment of such a program, however, will require the existence of a strong safety organization, responsible to top management for planning, directing and controlling the space station/base safety program.

2.3.1 REVIEW OF FINAL DESIGN

Application of the guidelines as a checklist for review and evaluation of the safety aspects of a final design will serve a useful purpose. It will reveal, on an item-by-item basis, the extent to which the guidelines have

actually been applied. Cases of non-application will raise questions of whether the guideline had been, in fact, considered but rejected for good reasons or whether design changes should be made to apply the guideline. If the latter is the case, however, it may prove difficult in some cases to incorporate desired design changes. The guidelines have aspects of indicating design details, of establishing procedures, or of driving the configuration, and most guidelines have all three aspects. Design details and procedural matters often may be incorporated at a relatively late date, but configuration drivers are best incorporated at the earliest possible time.

2.3.2 CONCEPT DERIVATION

A very useful application of the guidelines is to derive station or base concepts in which safety is the primary consideration. These concepts can then be used as a safety baseline against which other necessary and desirable factors can be weighed. The following discussion will demonstrate how this can be done. It will also serve to illustrate certain limitations to the guidelines, including compromises which must be made between opposing safety guidelines.

2.3.2.1 Definition and Ground Rule

No existing definition of the term "guideline" was found which was appropriate to the intent of the study, so the following definition was developed:

A guideline is a statement which points the way toward a course of action.

In the case of the guidelines presented herein, it follows that the course of action, if pursued, will add some increment of safety to the space station or base.

In the early stages of the study, the attempt was made to draw inferences and make statements about the zero-gravity space station and later on transfer them to the artificial-gravity space base. As the study progressed it began to appear that this approach, while producing some results, was not as effective as the reverse, namely, to consider first the space base and transfer to the station. The ground rule was established and should be kept in mind in the following, that statements made are equally applicable to the space station and the space base unless specifically indicated otherwise.

2.3.2.2 Traffic/Work Flow Guidelines

The arrangements for traffic flow, for work flow, and work stations are important configuration drivers. Furthermore, they represent problems of the future space base which are a major change from present programs. For these reasons they were selected for the starting point in concept development, although some other set of guidelines might also be used.

Typical guidelines dealing with these subjects are:

7.7 Design of rotating spacecraft should be such that the direction of major traffic flow is parallel to the vehicle spin axis.

7.19 Design of rotating spacecraft should be such that radial traffic is kept to a minimum.

7.23 Crew living and working stations should be oriented such that, during normal activity, the lateral axis through the crew member's ears is parallel to the axis of spin. In conjunction with this guideline, the work console instruments and controls should be designed so that left-right head rotations and up-down arm motions are minimized.

Considering only these guidelines, a concept such as presented in Figure 2 is developed. Making the base long and slender forces major traffic flow in the direction of the axis of rotation. A single deck minimizes radial traffic flow. The work stations are located with the crew member facing the direction of rotation (or away from the direction of rotation), with the work station arrangements as shown in the detail. The base rotates in the -Y direction about a central non-rotating hub, not shown, in the Z' axis and with appropriate counter-weights, e.g., the nuclear-fueled electrical power supply in the +X direction.

Without further elaboration on the point, such a configuration probably would be impractical in the light of factors other than safety. It should be recognized, therefore, that a series of trade studies, at least on an informal basis, will ultimately be required in which other factors are weighed against the safety increment of each guideline. In addition, however, this configuration does not incorporate certain other desirable safety features, as will be further discussed, and leads to the need for a second set of trade studies in which compromises between desirable safety features must be made.

2.3.2.3 Compartmentation

A number of guidelines deal with the compartmentation of the base, and matters related to compartmentation, two of which are:

12.13 The space station/base areas inhabited by the crew should consist of two or more independently pressurizable compartments with more than one exit from each compartment.

12.30 Each compartment should have a minimum of two escape routes, which should not terminate in a common compartment.

Together, these guidelines dictate that the space station/base should have a minimum of three compartments with access between each pair, as illustrated in the schematic diagram of Figure 3. The long, slender station

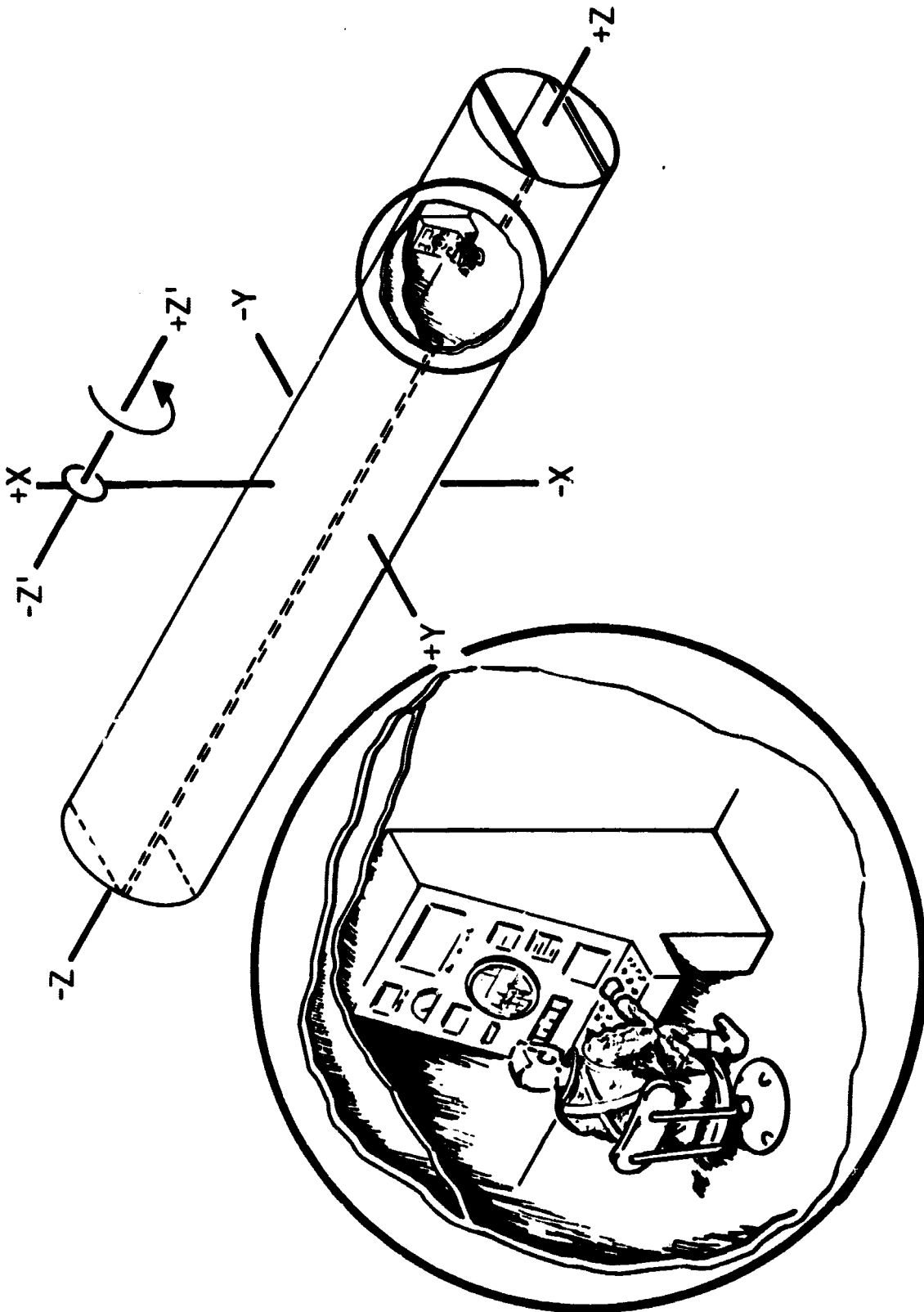


Figure 2: TRAFFIC/WORK CONFIGURATION

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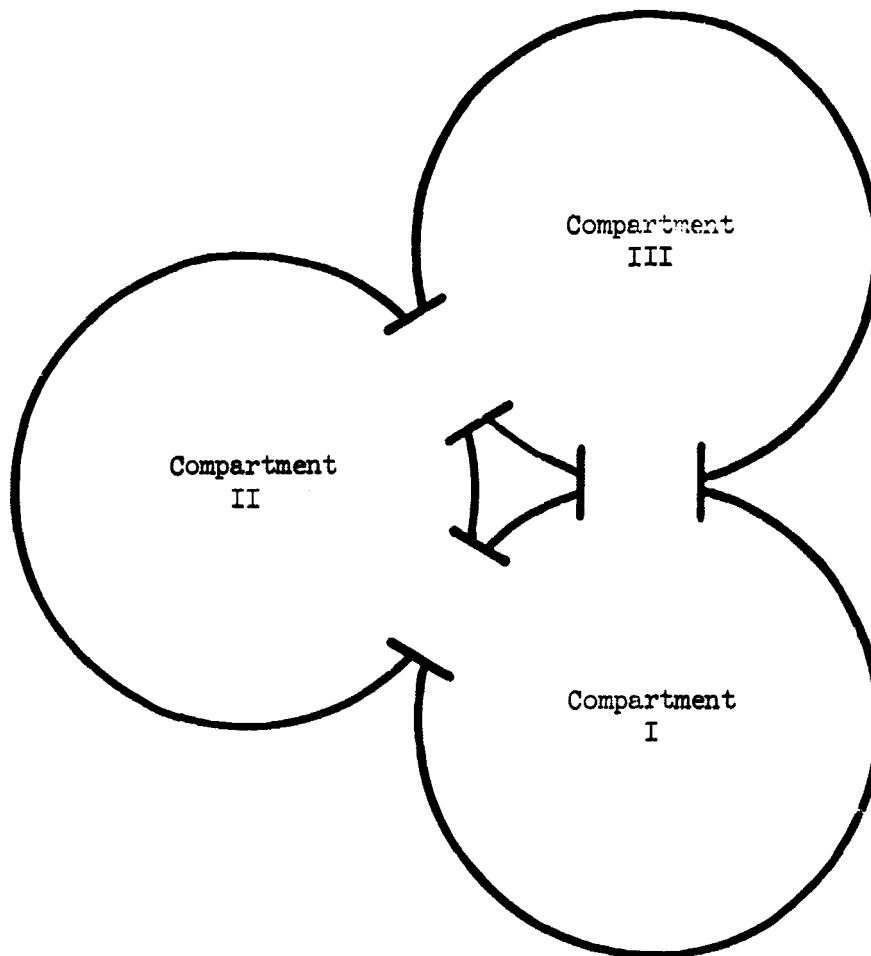


Figure 3: COMPARTMENTS, MINIMUM

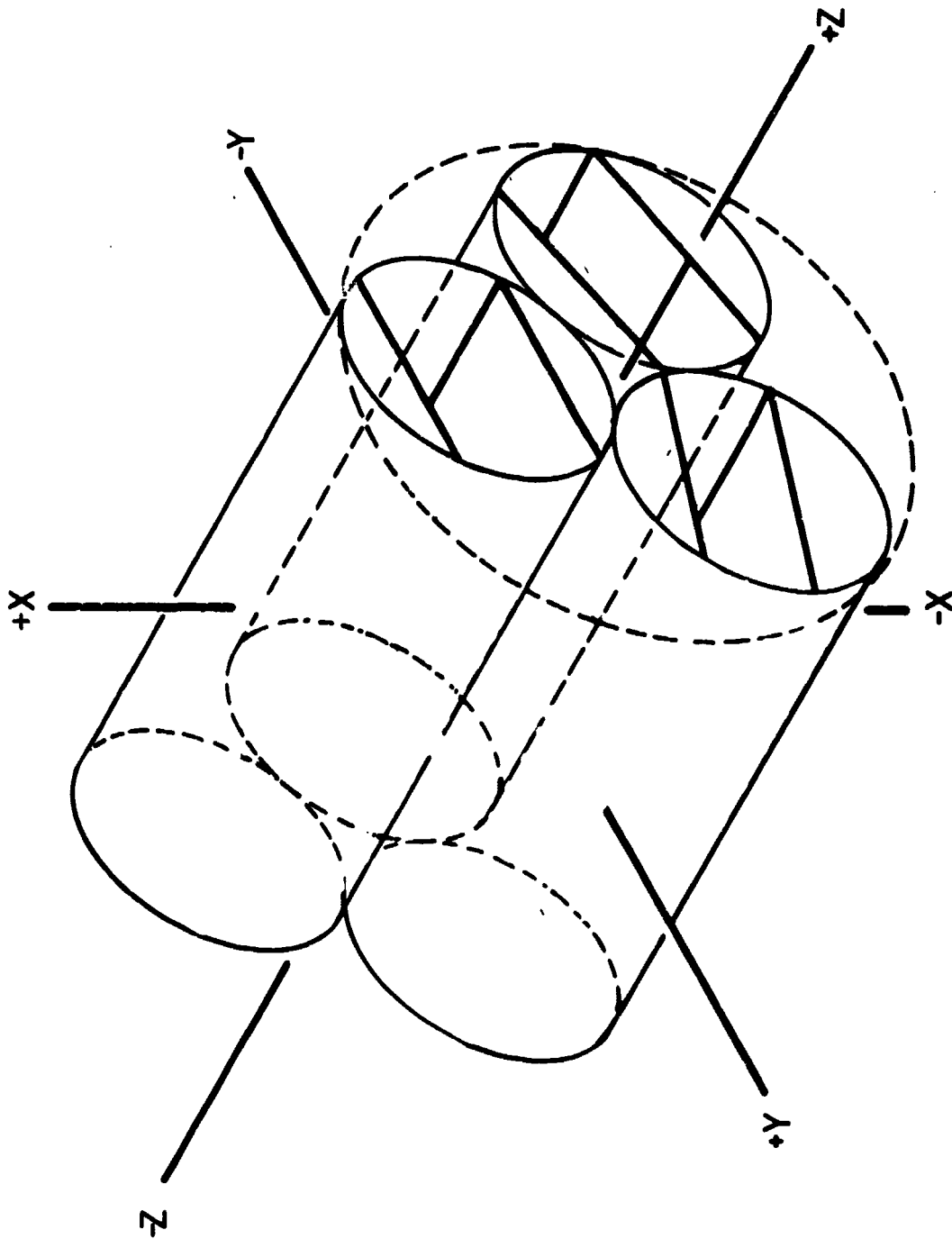


Figure 4: COMPARTMENTATION

shown in Figure 2, while it might be established with three compartments, is not readily adaptable to the idea of escape routes which do not terminate in a common compartment. The need for some compromise between traffic flow requirements and compartmentation is shown in Figure 4. Here a triple-tier arrangement is used, having three single-deck compartments. As before, it rotates in the -Y direction, the X-axis being the radius with non-rotating hub and counterweights not shown. (While no attempt has been made to establish sizes or dimensions of these concepts, it is interesting to note that the concept shown in Figure 4 could accommodate three compartments approximately 14 feet in diameter within an envelope 33 feet in diameter, shown by the dotted circle.) Note that a compromise in traffic flow is required in which axial traffic would be reduced to some extent while radial and tangential traffic is increased. Furthermore, as before, there may be some elements of impracticality in this concept and certain desirable safety features are still not included.

2.3.2.4 Crew Distribution

In the interest of exposing the least possible number of crew members to hazards, a guideline states:

12.18 The number of crew members in any compartment at one time should be held to the minimum necessary to perform the required function.

Compliance with this guideline may be difficult, however; or, at least, the "minimum number" may prove to be rather large. The Traffic Pattern Analysis presented in D2-113070-6 showed that crew members spend about two-thirds of their time, and, hence, tend to congregate, in those areas of the station/base which are devoted to crew health and well-being. Figure 5 illustrates this for the 12-man space station, but the finding is equally valid for all other configurations examined. Note that there is extensive use of those areas intended for sleeping, eating, and personal hygiene. By contrast, Decks 1, 2 and 3 of the 12-man station had no areas with more than 10 man-hours per day utilization.

This situation led to the following guideline:

12.20 The areas in which crew members spend the majority of their time, e.g., staterooms, dining facilities, personal hygiene, exercise, and recreation areas, should be located and designed to be the safest parts of the station.

A crew area location concept which would implement this guideline is shown in Figure 6, in which the crew area is shown by the shaded area located centrally in the station. The area would be separately pressurizable from the rest of the station.

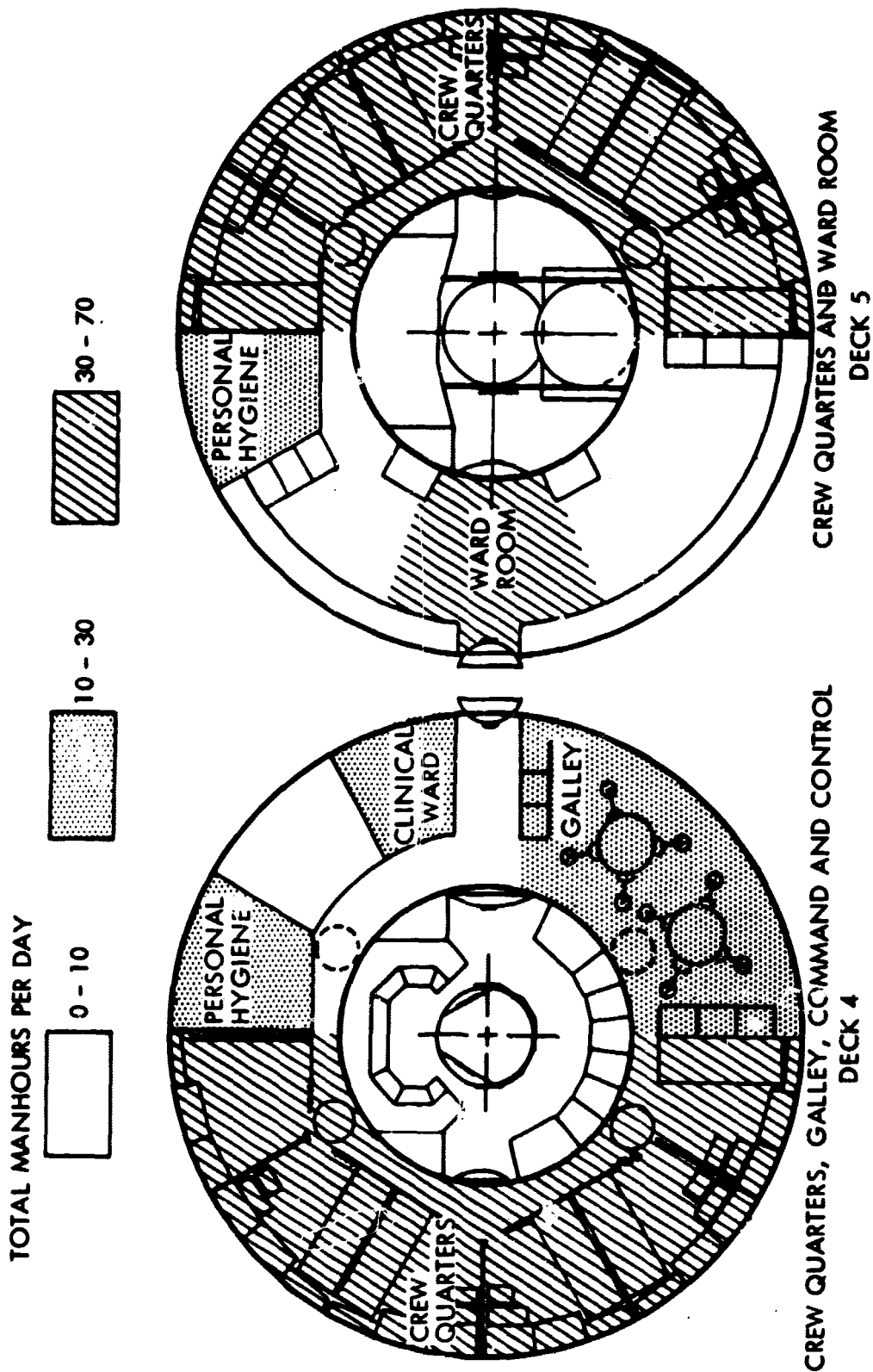


Figure 5: CREW DISTRIBUTION, 12-MAN SPACE STATION

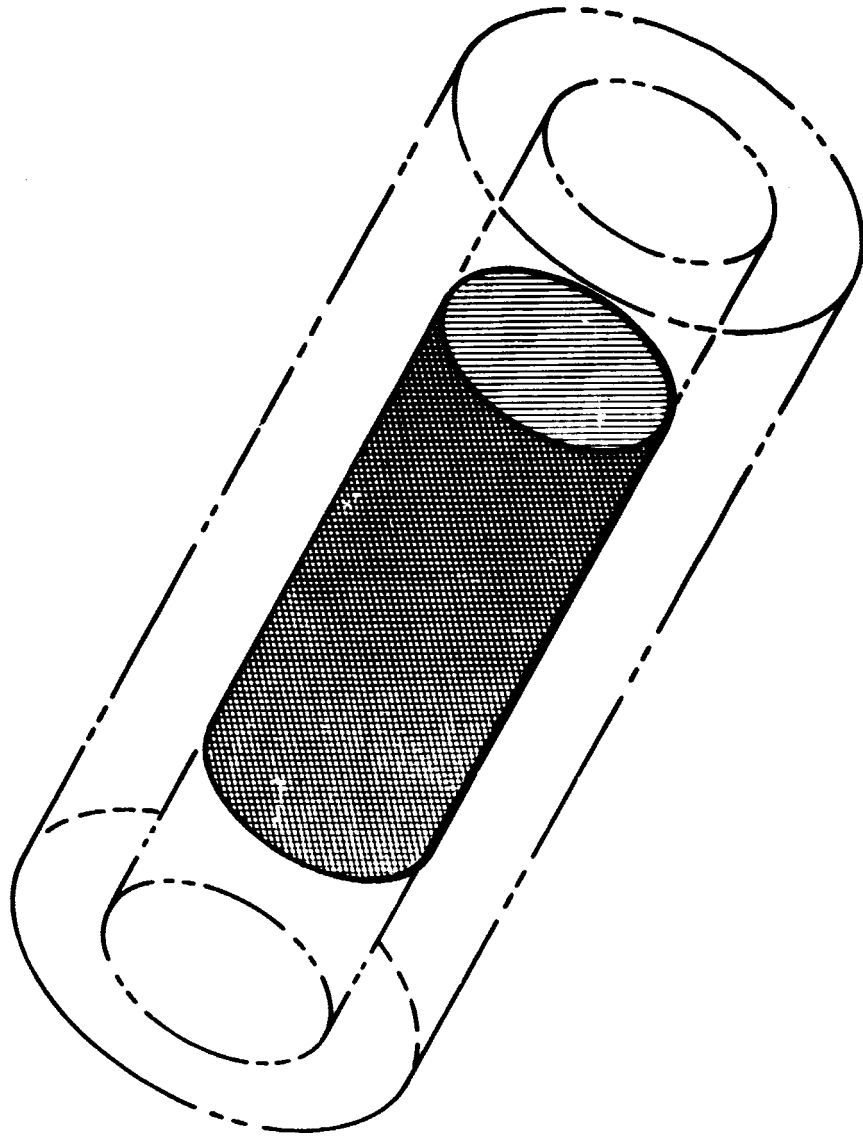


Figure 6: CREW AREA LOCATION

2.3.2.5 Redundancy Concepts

Not surprisingly, a great many guidelines require some sort of redundancy. Typical of these is the following:

- 8.9 A space station should include at least two independent EC/LSS's located in separate compartments. These systems should be capable of supplying the atmospheric requirements even with one system inoperative.

Similar guidelines require redundancy in food, air, and water supplies; in electrical power and distribution equipment; in hatches and docking mechanisms, and so on. Usually, the guideline also specifies that either one of the redundant systems should be capable of meeting the total station/base requirements. The net result of the redundancy requirements is that the station concept begins to approach that of two interconnected and mutually supporting stations.

2.3.2.6 Station/Base Concepts

The station/base concept shown in Figure 7 embodies the safety features which have been discussed in the foregoing. It is essentially a Siamese twin, consisting of two identical, or nearly identical, halves connected together by the central pressure bulkhead in which hatches provide access between halves. As a rotating base, two elevator shafts would connect it to and provide access to the central non-rotating hub and the nuclear electrical power supplies on the opposite side of the hub. All systems, supplies, etc., essential to crew safety would be duplicated in each half as far as function is concerned, but the operating principles of the two members in each pair should be different whenever possible. In any case, either one of each pair would be capable of meeting crew safety needs of the entire station. The crew area is double-decked and centrally located. It is surrounded by a pressure wall with the end bulkheads, as well as the central bulkhead, being pressure bulkheads. The exterior walls and bulkheads of the entire station are pressure structures, thereby dividing the station into six compartments. Major traffic flow is in the axial direction with tangential and radial traffic minimized and with an elevator as the normal means of radial movement.

The process of applying the guidelines to this concept can be continued and would undoubtedly indicate further compromises. For example, the following guideline states:

- 3.9 Provision should be made for an airlock in the hatch or hatchway between separately pressurizable compartments.

Since the intent of this guideline is to permit access to a depressurized compartment without having to depressurize the entire station, it becomes most important when the number of compartments is small. As the number of compartments increases it may be that an acceptable compromise, at least in emergencies, would be to use an entire compartment adjacent to the depressurized one as the airlock.

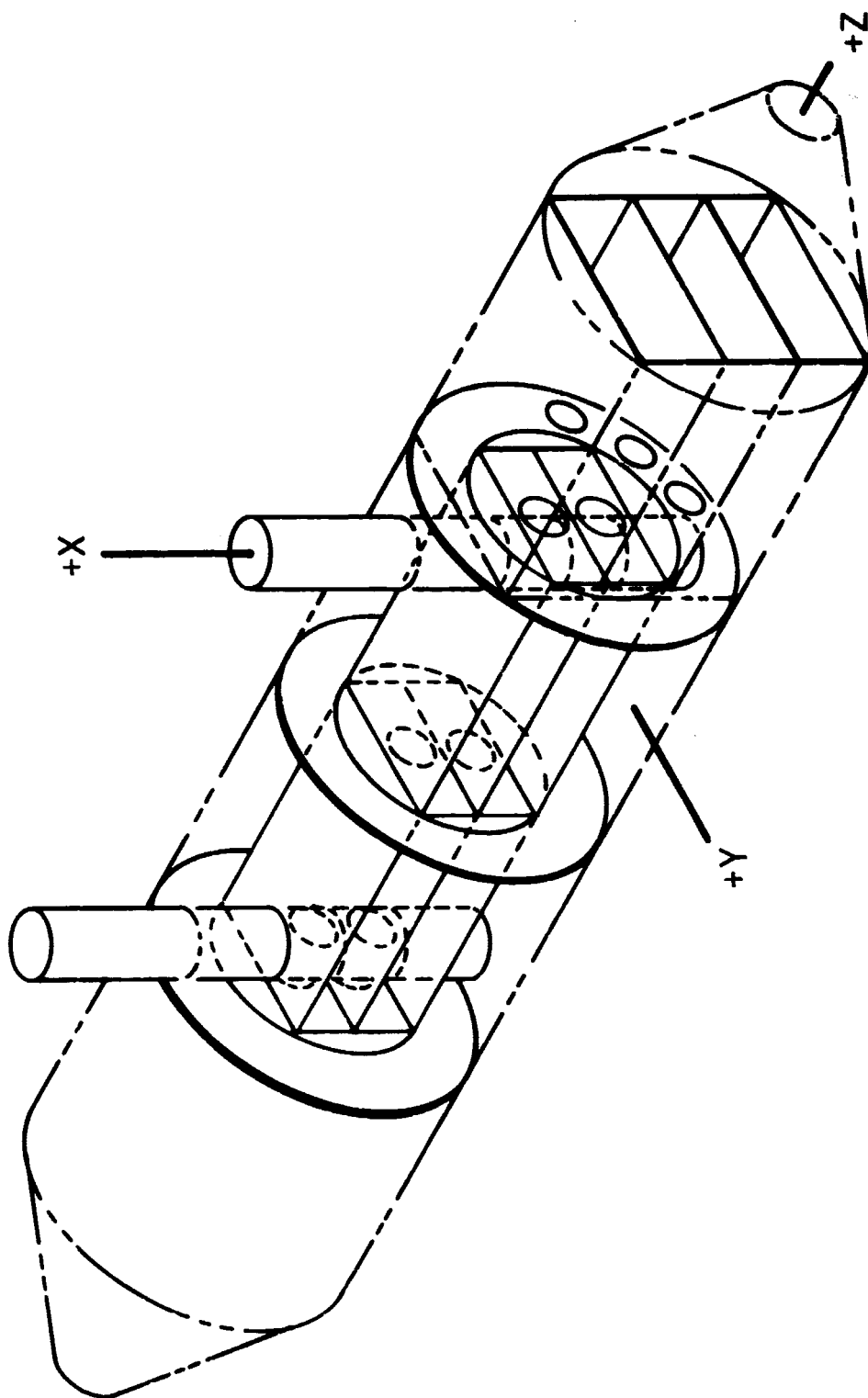


Figure 7: STATION/BASE CONCEPT

2.3.2.7 Cargo Restraint Concepts

One further example of guideline application will be given involving the problems of restraining and moving cargo. Two typical guidelines state:

5.1 All bulk cargo should be properly tethered or otherwise controlled during zero-gravity or reduced-gravity operations.

5.10 Adequate restraints, tethers, or aids to assist the crew in personal movements and handling large-mass equipment should be available throughout the interior and exterior of the space station.

With respect to cargo, these guidelines imply that a means should be provided to prevent undesired motion, either in translation or rotation, with respect to all three axes. Figure 8 presents a concept which does this and shows cargo being transferred by elevator between the non-rotating hub and the artificial-gravity portions of the base. The cargo is tied-down to a pallet or dolly. The dolly is mounted on sets of dual wheels which operate in slotted tracks in the station decks. A suitable braking system is provided on the dual wheels, for example, by extending the wheels against the sides of the slots. The elevator operates through a rack and pinion arrangement. This concept provides the required restraint against undesired motion in all parts of the base, including zero gravity and artificial gravity. However, the question arises as to how to transition across the interface between the rotating and non-rotating portions of the station.

A concept for performing this transition is illustrated in Figure 9, which shows the interface between the non-rotating sections, at right and left, and the rotating section with portions of the elevator shafts in the center. A transfer cage is positioned across the interfaces and held in position laterally by travelers in slots in the bulkheads, but free to rotate. A transfer platform with slotted tracks is mounted in the cage. A set of clutches permits the cage to be locked to and aligned with either the rotating or non-rotating sections. Assume that cargo is to be transferred from the non-rotating to the rotating section. Clutch set A is engaged and the transfer platform aligned with the station deck. The cargo, tied down to the dolly, is rolled from the deck to the transfer platform. Clutch set A is released and clutch set B engaged, causing the cage to rotate, with the operation done so as to align the transfer platform with the elevator platform. The dolly, with cargo, is rolled onto the elevator platform and transported by elevator to its destination. For simplicity, necessary safety features such as interlocks and guards are not shown.

2.3.2.8 Comments

The foregoing brief discussion has illustrated the following:

- a. A method of applying the guidelines to develop station/base concepts in which crew safety is the primary consideration.

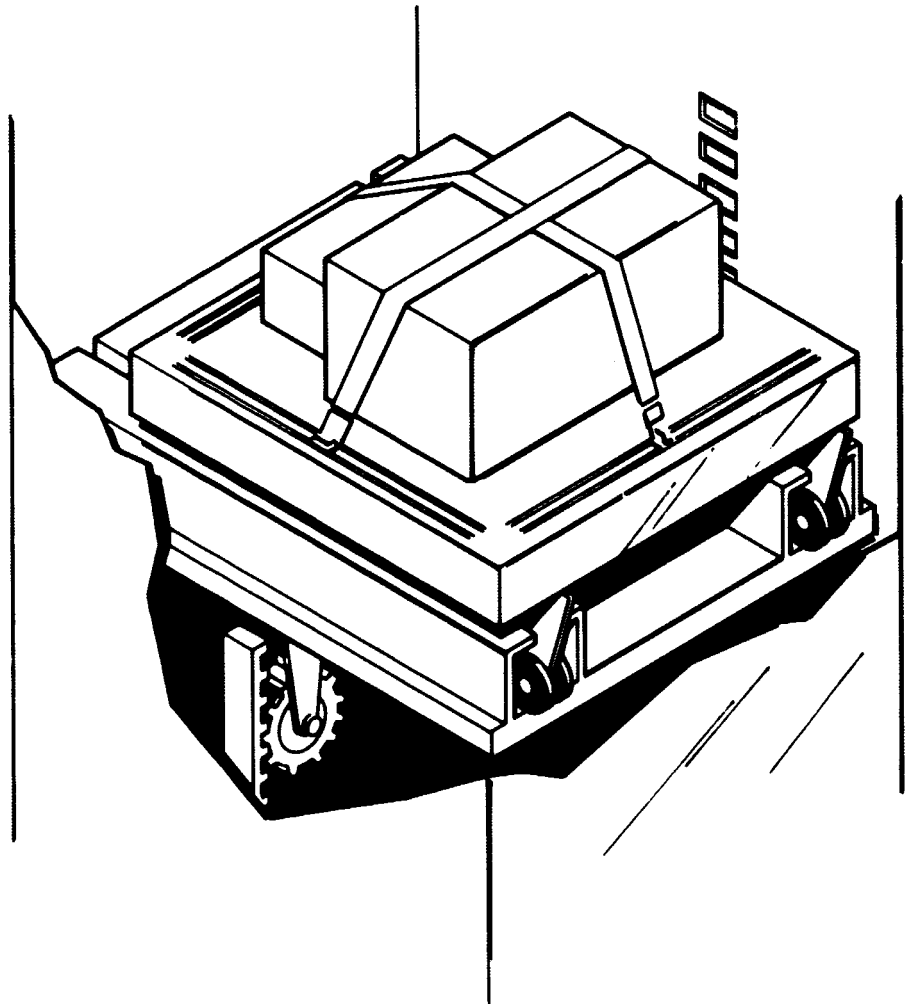


Figure 8: RESTRAINTS CONCEPTS

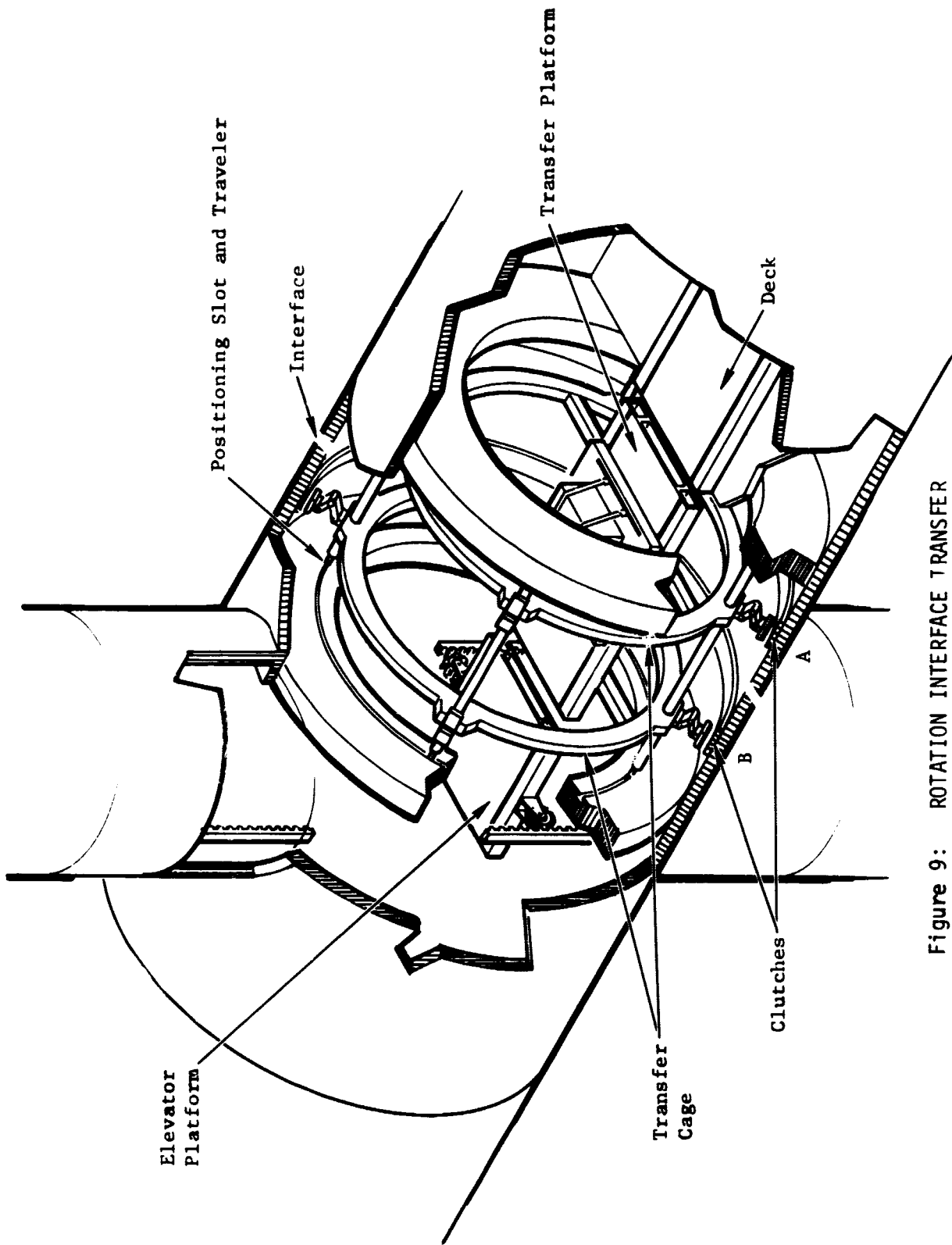


Figure 9: ROTATION INTERFACE TRANSFER

- b. The need for compromise (and by implication for a second set of trade studies) between guidelines which specify safety features which are not compatible with each other.
- c. A requirement for trade studies in which the safety features incorporated in a guideline or set of related guidelines are compared with and evaluated against other factors.
- d. That application of the guidelines is feasible, at least in the sense that a concept can be developed which incorporates the safety features required by the guidelines.

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D2-113070-5

3.0 CREW SAFETY GUIDELINES

This section contains the complete set of guidelines, arranged alphabetically by hazard groups. The guidelines are filed as follows:

In Volume I

3.1	Contamination	-- Nos. 1.1 through 1.32
3.2	Debris and Meteoroid Impact	-- Nos. 2.1 through 2.4
3.3	Decompression/Overpressure	-- Nos. 3.1 through 3.25
3.4	Electrical	-- Nos. 4.1 through 4.14
3.5	Equipment Impact	-- Nos. 5.1 through 5.12
3.6	Explosion	-- Nos. 6.1 through 6.13
3.7	Illness and Injury	-- Nos. 7.1 through 7.23
3.8	Loss of Vital Supplies	-- Nos. 8.1 through 8.33

In Volume II

3.9	Radiation	-- Nos. 9.1 through 9.21
3.10	Temperature Extremes	-- Nos. 10.1 through 10.30
3.11	Spacecraft Accelerations	-- Nos. 11.1 through 11.12
3.12	General	-- Nos. 12.1 through 12.63

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D2-113070-5

HAZARD GROUP: Contamination		NO. 1.1
TITLE: Airflow Cutoff to Enclosed Contamination Sources		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)		
SAFETY GUIDELINE: Enclosed air duct systems that include potential sources of atmosphere contamination should provide sensors immediately downstream of the contamination source, which, if activated, would shut off the airflow through this equipment and provide a visual and audible alarm at the command and control center(s).		
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of atmosphere contamination. 2. D2-113070-10, FT-2 (Temperature Extremes), 10-D, "The fire warning system is inadequate at the time required." 3. D2-113070-9, Logic Diagram, Propositions 8H, 18D, 44B, 45B and 76J.		
REMARKS: Space station systems air ducts may include equipment that contains material or particulate matter which is used for filtering or absorbing substances contained in the air. If failure of this equipment could release quantities of these materials that could seriously affect the operation of other equipment, or contaminate the compartment atmosphere, then the system should be designed for this contingency. Also applies to the following hazard group: 8. Loss of Vital Supplies		

HAZARD GROUP: Contamination	NO. 1.2
TITLE: Battery Venting	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power (EP)	
SAFETY GUIDELINE: Adequate venting of batteries should be provided to prevent contamination, over-pressure, or explosion.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EP), for potential hazard of fire, smoke, toxicity. 2. D2-113070-9, Logic Diagram, Propositions 8F and 61D.	
REMARKS: Batteries that are not properly vented can become over-pressurized, e.g., when inadequate cooling or cooling failure results in increased operating temperatures, and give off toxic gases that could cause crew illness, or electrolyte leakage that could cause structural corrosion. Extreme cases could result in battery explosion and possible serious damage to crew members and/or equipment vital to crew safety. Also applies to the following hazard groups: 3. Decompression/Overpressure 6. Explosion	

HAZARD GROUP: Contamination	NO. 1.3
TITLE: Contaminant and Waste Products Collection	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: All filters, screens, or other devices used to collect contaminants or waste products should be designed so they can be easily serviced or replaced without releasing contaminants into the atmosphere.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of atmosphere contamination. 2. D2-113070-9, Logic Diagram, Propositions 10G, 32B, 60E and 61E.	
REMARKS: Equipment used to collect contaminants or waste products during long-duration missions will require servicing and/or replacement of the collection device when its capacity has been exhausted. Equipment design and associated maintenance procedures must be such as to prevent release of the collected contaminants or waste products into the atmosphere when the collection device is replaced. Consideration must also be given to the problem of long-term storage of removed filters, etc., as entrapped bacteria may grow and present a potential health hazard.	

HAZARD GROUP: Contamination	NO. 1.4
TITLE: Contaminant Control Equipment Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Active redundancy should be provided for equipment which is essential to the control and detection of atmosphere contaminants.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of atmosphere contamination. 2. D2-113070-9, Logic Diagram, Proposition 10F.	
REMARKS: Controlling atmosphere contaminants within specified limits is required for crew safety. To ensure continuous control of contaminants and a continuous capability for detecting excessive contamination, active redundancy should be provided for equipment that is essential to these functions.	

HAZARD GROUP: Contamination	NO. 1.5
TITLE: Control Procedures for Excessive Contamination	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Structures/Mechanical (S/M)	
SAFETY GUIDELINE: Procedures should be established and means provided the crew for controlling and/or eliminating contamination that is in excess of the EC/LSS capability to control on a timely basis.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, Appendix 6B, List of Possible Contaminants. 2. D2-113070-11, Subsystem Analysis (EC/LSS), Potential hazard of atmosphere contamination. 3. D2-113070-10, FT-2 (Temperature Extremes), 17-C, "Fire results in overtaxing (EC/LSS) equipment operation." 4. D2-113070-9, Logic Diagram, Propositions 8H, 42H and 45B.	
REMARKS: Excessive contamination may occur in several ways, such as accidental spillage of hazardous materials, by failure of the EC/LSS, or as by-products of fire. If this situation does occur, the crew should be able to take the necessary corrective action as expeditiously as possible. Therefore, emergency procedures should be developed to provide for controlling and/or eliminating the contamination. For example, the contamination level might be regulated through a controlled leakage of air that is compensated by the addition of O₂ to the atmosphere. If the contamination level cannot be regulated in some manner it may be necessary to purge the affected compartment by complete evacuation of the atmosphere. Also applies to the following hazard groups: 3. Decompression/Overpressure 8. Loss of Vital Supplies 10. Temperature Extremes	

HAZARD GROUP: Contamination	NO. 1.6
TITLE: CO ₂ Partial Pressure Monitor	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: An audible and visual alarm should be provided to warn the crew of cabin CO₂ partial pressure which is not within prescribed limits for crew safety. This alarm should be provided both in the affected space station compartment and at the command and control center(s).	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of excessive CO₂. 2. D2-113070-9, Logic Diagram, Propositions 45B, 48H, 48I and 76J.	
REMARKS: The space station crew should be made aware of out-of-tolerance CO₂ partial pressures in any pressurized compartment which, if allowed to continue, could affect crew safety. Procedures should be developed for controlling the space station atmosphere after this warning has been received.	

HAZARD GROUP: Contamination	NO. 1.7
TITLE: CO ₂ Removal Equipment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Redundant CO₂ removal equipment with capability of manual override of automatic operation should be provided to ensure a continuous capability to keep the cabin CO₂ partial pressure within allowable limits.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of excessive CO₂. 2. D2-113070-9, Logic Diagram, Propositions 8H, 10F and 45B.	
REMARKS: The CO₂ partial pressure must not exceed certain limits in any inhabited compartment or the safety of the crew will be endangered. To ensure continuous operation of the CO₂ removal function, even if there is an equipment failure, redundant CO₂ removal equipment should be provided. In addition, situations may arise where automatic control of the CO₂ removal function is inoperative and it would be advantageous to have the capability to manually control the CO₂ removal equipment until automatic control can be re-established.	

HAZARD GROUP: Contamination	NO. 1.8
TITLE: Equipment Contamination by Propellants	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Stability and Control System (SCS), Electrical Power System	
SAFETY GUIDELINE: Equipment, including electrical wiring, that could become contaminated or damaged by leaking propellants should be located to preclude coming in contact with possible leakage or should be provided suitable protection.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (SCS), for potential hazard of propellant leakage. 2. D2-113070-9, Logic Diagram, Propositions 9C and 32B.	
REMARKS: Propellant systems are susceptible to leakage from the equipment and the numerous plumbing connections throughout the system. Depending on the type used, propellant leakage may have a detrimental effect on wiring or other equipment. This possibility should be considered when determining the location of those items. If a satisfactory location away from possible propellant leakage cannot be found, then the wiring or equipment should be shielded to ensure protection against leakage.	

HAZARD GROUP: Contamination	NO. 1.9
TITLE: Fluid/Debris Collection and/or Containment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Crew System, Stability and Control System	
SAFETY GUIDELINE: Means should be provided for collecting and/or containing any loose fluids or debris that might result during the replacement of system components.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Propositions 32B, 60D, 61D and 65D.	
REMARKS: Other guidelines suggest use of minimum loss fluid connectors and designing contaminant or waste collection devices so they can be replaced without releasing contaminants into the cabin atmosphere. Despite these precautions there still will be the possibility of fluids or debris being inadvertently released during maintenance or by faulty equipment operation. Therefore, some means should be provided for containing these materials during maintenance and/or collecting materials lost during maintenance or equipment operations.	

HAZARD GROUP: Contamination	NO. 1.10
TITLE: Fluid Leak Isolation	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control	
SAFETY GUIDELINE: Fluid systems should have provisions for shutting off the flow of fluid to sections of the system or equipment which are susceptible to damage or leakage.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Propositions 6B and 61D.	
REMARKS: Fluid leakage can be a hazard to crew safety through contamination of the breathable atmosphere, it can be detrimental to the operation of system equipment, and it can create the possibility of fire or explosion. To minimize any leakage which might occur, provisions should be included in the system for shutting off the fluid supply to possible leakage points. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Contamination		NO. 1.11
TITLE: Fluid Lines Contamination		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System (SCS)		
SAFETY GUIDELINE: All orifices, close tolerance valves and contamination-sensitive equipment in fluid systems, should be adequately protected from contamination. Furthermore, if the system is either designed for periodic flow reversal, or a possibility exists that flow reversal could occur, both sides of these items should be protected.		
REFERENCES: 1. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard Nos. 17, 161 and 171. 2. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of fluid leakage.		
REMARKS: Filter design should take into account the increased demand imposed by orbital operation to remove debris which, under 1-g operation, would naturally separate out and be retained in sumps. Crew procedures should direct that extreme caution be exercised if the fluid line is opened between a device and its protecting filter, to ensure that additional contamination is not introduced.		

HAZARD GROUP: Contamination	NO. 1.12
TITLE: Food Storage Containers Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Food supplies should be stored in more than one storage container or device.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of food contamination. 2. D2-113070-9, Logic Diagram, Propositions 31G and 59B.	
REMARKS: Edible food is vital to the life support and, therefore, to the safety of the crew. To preclude the loss of all food supplies because a failure results in contamination of the food, the food supplies should be stored in more than one container. The containers should also be located so they are not in the proximity of known sources of contamination. They should be further protected from contamination from outside sources by providing adequate sealing of the containers. Also applies to the following hazard groups: 7. Illness and Injury 8. Loss of Vital Supplies	

HAZARD GROUP: Contamination	NO. 1.13
TITLE: Food Storage Sterilization	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/ Life Support System (EC/LSS)	
SAFETY GUIDELINE: A means for sterilizing containers where food is stored should be provided.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (CS), for potential hazard of food contamination. 2. D2-113070-9, Logic Diagram, Propositions 31G and 59B.	
REMARKS: Preservation of food supplies is vital to the safety of the crew. It will be a particular problem on space missions where food must be stored for long durations. Therefore, it is essential that adequate provisions be provided for ensuring that food spoilage does not occur. This could be done through proper food storage sterilization methods. Also applies to the following hazard groups: 7. Illness and Injury 8. Loss of Vital Supplies	

HAZARD GROUP: Contamination	NO. 1.14
TITLE: Food Supplies Refrigeration System Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Food supplies which require cooling or refrigeration should be protected by a redundant capability for accomplishing the cooling function.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of food contamination. 2. D2-113070-9, Logic Diagram, Propositions 10F and 31G.	
REMARKS: Preservation of the food supplies is vital to the safety of the crew. Some of the food requires cooling or refrigeration to prevent spoilage or contamination. Since the cooling is a continuous requirement and the food supplies usually cannot withstand a prolonged loss of the cooling, redundancy should be provided. Also applies to the following hazard groups: 7. Illness and Injury 8. Loss of Vital Supplies	

HAZARD GROUP: Contamination**NO.** 1.15**TITLE:** Hazardous Materials--Quantities**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Experiments, Crew System (CS)**SAFETY GUIDELINE:**

The amount of toxic or potentially toxic materials (such as materials or chemicals utilized in experiments) on-board the spacecraft should be limited such that accidental release of the total quantity of the materials will not produce contamination above the capability of the environmental control system to remove on a timely basis.

REFERENCES:

1. D2-113070-10, FT-2 (Temperature Extremes), 15-J, "Fire results in failure of EC/LSS," and 17-C, "Fire results in overtaxing (EC/LSS) equipment operation."
2. D2-113070-6, Supporting Analyses, Section 6, Appendices 6A, B, C.

REMARKS:

If mission requirements dictate the presence of large amounts of such materials, consideration should be given to storage in unpressurized or unmanned locations, bringing into the manned portions of the spacecraft only the minimum amounts for immediate requirements.

HAZARD GROUP: Contamination	NO. 1.16
TITLE: Human Tolerance to Atmosphere Contaminants, Long-Term	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Threshold Limit Values (TLV's) of contaminants for long-term human exposure should be established, for spacecraft environments.	
REFERENCES: 1. Nuclear Powered Submarine Atmosphere Control (U), NAVSHIPS 0938-011-4010, Confidential, Dept. of the Navy. Washington, D.C., December, 1967. 2. AFSC Design Handbook, System Safety, AFSCDH 1-6, Headquarters, AF Systems Command in cooperation with the NASA, 20 January, 1969. 3. NASA SP-86, Medical Aspects of an Orbiting Research Laboratory, pages 30, 34-35. 4. NASA CR-1205(III), Compendium of Human Responses to the Aerospace Environment, Vol. III, Section 13, 1968. 5. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements."	
REMARKS: The data on human tolerances to chemicals are usually related to the normal work week and are published periodically by the American Conference on Governmental Industrial Hygienists (ACGIH) as Threshold Limit Values (TLV). These values represent time-weighted average concentrations below which most individuals may be exposed for 8 hours per day, day after day, without adverse effects. The long-term space missions contemplated create a requirement for tolerance criteria for both short-term, high-concentration and long-term, low-concentration exposures. Unfortunately, few data are currently available for long-term exposures and, when available, they demonstrate that TLV's should not be extrapolated.	

HAZARD GROUP: Contamination	NO. 1.17
TITLE: Insect Control	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Operations, Experiments	
SAFETY GUIDELINE: A means of controlling insects in the spacecraft should be provided. The control method should be harmless to men and equipment.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements." 2. Candidate Experiment Program for Manned Space Stations, NASA Headquarters, May 1969.	
REMARKS: The likelihood of insect contamination of a spacecraft appears low but it could occur through escape of insects on-board for experimental purposes or through resupply and crew rotation operations. Normal control means, such as fumigation or poisoning, would probably not be acceptable on a spacecraft.	

HAZARD GROUP: Contamination	NO. 1.18
TITLE: Materials--Configuration Control	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Strict configuration control procedures should be established over all materials incorporated in or brought on-board the spacecraft.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, Appendices 6A, B, C. 2. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of atmosphere contamination. 3. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard No. 13.	
REMARKS: Spacecraft operations and the experiment program will unavoidably require that considerable quantities of hazardous material be on-board the spacecraft. If the materials are known, equipment and procedures can be established to safeguard against hazards but materials not identified could pose unexpected hazards. Control should extend to materials used in spacecraft manufacture, such as solvents and cleaning compounds, and to personal possessions of the crew, such as toilet articles.	

HAZARD GROUP: Contamination	NO. 1.19
TITLE: Mercury Metal	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: The use of mercury metal on-board space stations should be prohibited.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of atmosphere contamination. 2. D2-113070-9, Logic Diagram, Propositions 59B, 59F, 61B and 61D.	
REMARKS: Mercury is commonly used in temperature indicating devices, for testing and calibrating instruments, as part of different experiments, and in some power system concepts. Mercury is very toxic and spillage of small quantities could rapidly endanger crew safety. Mercury will also cause extremely rapid deterioration and structural failure of aluminum materials. Therefore, mercury should not be permitted on-board the space station.	

HAZARD GROUP: Contamination	NO. 1.20
TITLE: Ozone	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power, Experiments, Crew System	
SAFETY GUIDELINE: Provision should be made for the removal of ozone generated by X-ray equipment or electrical arcs.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, Appendix A.	
REMARKS: The Threshold Limit Values for ozone are very low. Therefore, equipment which might generate ozone should be isolated or ventilated in such a manner that ozone does not escape into the general spacecraft atmosphere. There is also a possibility that ozone could be formed through photochemical reaction.	

HAZARD GROUP: Contamination	NO. 1.21
TITLE: Plumbing Connectors--Minimum Loss	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System	
SAFETY GUIDELINE: Connectors used to connect plumbing or components in fluid systems should be designed for minimum loss of fluid when disconnected.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Propositions 10G and 61D.	
REMARKS: It is expected that there will be numerous times during a long-duration mission when it will be necessary to disconnect plumbing in fluid systems during maintenance and repair activities. To avoid contamination of the crew's atmosphere this should be done with minimum loss of fluid, particularly if the fluid is toxic or flammable. Provisions should also be made for collecting or containing any fluid which might be lost. Even if non-toxic and non-flammable fluids are used there still is a possibility of leaking fluids causing damage to equipment which is essential to crew safety. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Contamination	NO. 1.22
TITLE: Plumbing Connectors--Minimum Quantity	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System, Electrical Power, Crew System	
SAFETY GUIDELINE: The number of connectors used in plumbing and connections of fluid systems should be kept to a minimum.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Proposition 10G.	
REMARKS: Experience has shown that one of the most troublesome aspects of system designs has been leakage of fluid connectors. In a space station, leakage presents a problem of atmosphere contamination that could jeopardize crew safety and/or damage equipment which is essential to crew safety. Therefore, the number of fluid connectors should be kept to a minimum. One approach to minimize fluid connectors is to use a manifold concept for small valves. The valves would have permanent housings interconnected by welded or brazed tubes. The movable part of the valve would be a cartridge type that could be replaced without disturbing the housing or tubing. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Contamination	NO. 1.23
TITLE: Toxic or Flammable Fluids	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System, Electrical Power	
SAFETY GUIDELINE: Fluids required for the operation of subsystems located in pressurized compartments inhabited by the crew should be non-toxic, non-flammable, and non-corrosive.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Propositions 16D and 16H.	
REMARKS: Space station subsystems that use fluids may sustain failures which will result in leakage. If a leak occurs within a pressurized compartment, the leak may contaminate the atmosphere, cause damage to essential equipment or cause a fire which could endanger crew safety. To minimize this hazard it is suggested that only non-toxic and non-flammable fluids be used within pressurized compartments. If toxic fluids are required, either for use in experiments or operations, special precautions should be spelled out in handling procedures which require the approval of a Safety Director. Also applies to the following hazard groups: 5. Equipment Impact 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Contamination	NO. 1.24
TITLE: Warning System--Contaminants Detection and Alarm	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System, Crew System	
SAFETY GUIDELINE: A visual and audible alarm should be provided to warn the crew of atmosphere contamination which exceeds the limits established for crew safety. This alarm should be provided at a minimum in the affected space station compartment(s) and at the central command and control station(s).	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS) for potential hazard of atmosphere contamination. 2. Atmospheric Contaminants in Spacecraft, Space Science Board, NAS-NRC, October 1968. 3. D2-113070-6, Supporting Analyses, Section 6, Appendices 6A, B, C. List of potential contaminants. 4. D2-113070-10, FT-2 (Temperature Extremes), 3-N, "Fire occurs within an unmanned area." 5. D2-113070-9, Logic Diagram, Propositions 8H, 18D, 44B, 48H and 48I.	
REMARKS: Numerous contaminants (e.g., liquids, gases and particulate matter) are expected to be present in any atmosphere used in a space station. As long as these contaminants are controlled and kept within limits, crew safety will be ensured. However, if the contaminant level exceeds these limits the crew must be provided sufficient warning to allow them to take appropriate corrective action. Also applies to the following hazard groups: 6. Explosion 8. Loss of Vital Supplies	

HAZARD GROUP: Contamination	NO. 1.25
TITLE: Warning System--Fluid Systems Contamination	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System, Crew System	
SAFETY GUIDELINE: Where the possibility exists that a fluid in a system could become contaminated, means should be provided to detect any contamination and provide an alarm at the command and control center(s).	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Proposition 6B.	
REMARKS: There can be many places in fluid systems where there is a possibility that the fluid could be contaminated by another fluid; e.g., pressurized fluid tanks and heat exchangers. If contamination of the fluid can seriously affect the operation of systems or equipment which are essential to crew safety, there should be some means available for detecting this and alerting the crew that fluid contamination exists. Provisions should also be made for isolating the contaminated systems, and procedures established for purging and recharging the system after corrective maintenance has been accomplished. This guideline is directed toward fluid systems other than the spacecraft atmosphere system, and drinking water supply.	

HAZARD GROUP: Contamination	NO. 1.26
TITLE: Warning System--Hazardous Materials	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System	
SAFETY GUIDELINE: A system should be provided to monitor the environmental status of all potentially hazardous (explosive, flammable, toxic, etc.) materials stored on-board the space station and space base, and display a warning signal in the command and control center(s) when established limits are exceeded.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Paragraph 3.2.5, "Space Base Activation."	
REMARKS: This system would alert the crew of an "out-of-tolerance" condition and possible impending emergencies. Remedial procedures should be developed to counter each hazardous situation for which detection capability is provided. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Contamination	NO. 1.27
TITLE: Warning System--Relative Humidity	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Operations	
SAFETY GUIDELINE: A warning and alarm system should be provided to alert the crew of atmosphere relative humidity levels which are not within prescribed limits, with the warning displayed at the command and control center(s).	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazards of excessive CO₂ and atmosphere contamination. 2. D2-113070-9, Logic Diagram, Propositions 18D and 48H.	
REMARKS: The space station equipment located in compartments inhabited by the crew is designed to operate within a humidity range specified for crew comfort. Excess humidity could have a detrimental effect on the operation of equipment because of water condensation and could also result in decreased performance of the crew. Therefore, the humidity should be monitored in all humidity-controlled compartments. Also applies to the following hazard group: 7. Illness and Injury	

HAZARD GROUP: Contamination	NO. 1.28
TITLE: Waste Byproducts Control	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Crew System	
SAFETY GUIDELINE: Provisions should be made for containing, venting or eliminating odors and bacteria generated by waste products and other sources, e.g., plants and animals.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of atmosphere contamination. 2. NASA CR-1205. 3. D2-113070-9, Logic Diagram, Propositions 21B and 45B.	
REMARKS: Equipment on-board a space station will provide for general atmosphere contamination control. It appears desirable to have separate provisions for containing, venting, or otherwise eliminating contamination from known sources such as byproducts of wastes. Also applies to the following hazard group: 7. Illness and Injury	

HAZARD GROUP: Contamination	NO. 1.29
TITLE: Water Contamination	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Crew System	
SAFETY GUIDELINE: The composition of the water should be checked at regular intervals to ensure that contamination does not exceed prescribed limits.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazards of water and/or food contamination. 2. D2-113070-9, Logic Diagram, Propositions 31G, 48H, 59B and 76K.	
REMARKS: A potable water supply is necessary for the health and safety of the crew. Therefore, the water supply should be monitored very closely for the presence of contaminants. By one approach, the water composition would be monitored continuously and automatically, and an alarm be provided the crew when contamination becomes excessive. Alternately, the crew would be able to perform a simple test on water samples at sufficiently regular intervals to detect water contamination before it endangers the crew. This in particular should apply to the water dispenser used for drinking water and food preservation. Also applies to the following hazard groups: 7. Illness and Injury 8. Loss of Vital Supplies	

HAZARD GROUP: Contamination	NO. 1.30
TITLE: Water Sterilization	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Crew System	
SAFETY GUIDELINE: A capability should be provided for maintaining the sterility of on-board water supplies	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazards of water contamination. 2. D2-113070-9, Logic Diagram, Propositions 21D and 30D.	
REMARKS: Once water is sterilized it will remain so as long as no leakage of contaminants occurs and no substrate is available for organism growth. However, it is assumed that occasional failures may result in contamination of the water supply. Therefore, it is suggested that provisions be made to re-sterilize stored water or to permit temporary sterilization at the point of use. It would also be desirable to have the capability to sterilize the complete water reclamation system in case of severe contamination problems. Also applies to the following hazard groups: 7. Illness and Injury 8. Loss of Vital Supplies	

HAZARD GROUP: Contamination	NO. 1.31
TITLE: Water Storage Isolation	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Crew System	
SAFETY GUIDELINE: Water storage systems should have provisions for isolating parts of the system which may have become contaminated.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of water contamination. 2. D2-113070-9, Logic Diagram, Propositions 9C, 21B and 76C.	
REMARKS: If contamination is present it will be necessary to isolate the part of the system that is contaminated so the necessary corrective action can be taken. Also applies to the following hazard groups: 7. Illness and Injury 8. Loss of Vital Supplies	

HAZARD GROUP: Contamination	NO. 1.32
TITLE: Water Supply Location	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Crew System	
SAFETY GUIDELINE: Water supplies should be stored in areas which will minimize the possibility of contamination from other spacecraft systems.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of water contamination. 2. D2-113070-9, Logic Analysis, Propositions 21B and 76B.	
REMARKS: To decrease the chance of any of the water storage tanks becoming contaminated from external sources, the tanks should <u>not</u> be located in proximity to other systems or equipment that could possibly contaminate the water supply. Also applies to the following hazard groups: 7. Illness and Injury 8. Loss of Vital Supplies	

HAZARD GROUP: Debris and Meteoroid Impact	NO. 2.1
TITLE: Component Design for Meteoroid Impact Protection	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: System components should be designed to withstand the over-pressure and heat pulse attendant to meteoroid penetration.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-J, "Conductor element fails due to secondary causes." 2. D2-113070-6, Supporting Analyses, Section 7, "Meteoroid Penetration."	
REMARKS: The probability of meteoroid penetration appears to be low, but it is a hazard. If a penetration does occur, the effects will probably be quite drastic, including heat, shock, shrapnel, and decompression. Subsystem components, at least those critical to crew safety, should be designed to withstand these effects.	

HAZARD GROUP: Debris and Meteoroid Impact	NO. 2.2
TITLE: Flight Path Orbit Selection	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Stability and Control System, Operations	
SAFETY GUIDELINE: The original orbital flight path selection and changes required by station-keeping during the mission should be such that the probability of collision with man-made debris or other spacecraft is sufficiently low to provide adequate confidence in orbit selection and program decision to proceed.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 3-F, "Failure results from impact with man-made objects."	
REMARKS: In-orbit collision presents a hazard to the spacecraft which should be minimized through selection of a satisfactory orbit.	

HAZARD GROUP: Debris and Meteoroid Impact	NO. 2.3
TITLE: Insulating Material	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical	
SAFETY GUIDELINE: Materials used for insulation or filler in spacecraft walls should be non-combustible.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 7, "Meteoroid Penetration."	
REMARKS: Tests conducted by The Boeing Company have demonstrated that combustible insulation or filler material in spacecraft walls will be ignited by a meteoroid penetration. Burning material is scattered throughout the affected compartment and some of the material in the wall is consumed by fire. Also applies to the following hazard group: 10. Temperature Extremes	

HAZARD GROUP: Debris and Meteoroid Impact**NO.** 2.4**TITLE:** Window Replacement**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M)**SAFETY GUIDELINE:**

Windows should be designed to permit replacement without degrading the pressure or structural integrity of the space station.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of structural damage.
2. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard Nos. 41 and 242.
3. D2-113070-9, Logic Diagram, Propositions 9G, 16C and 48F.

REMARKS:

During a long-duration space mission there is a possibility that the optical quality of the windows may become impaired by engine exhaust, erosion from natural space debris, outgassing of window sealant, etc. The windows should be able to withstand this damage and should be replaceable without a loss of cabin pressure. Use of covers when windows are not in use should be considered.

Also applies to the following hazard group: 5. Equipment Impact

HAZARD GROUP: Decompression/Overpressure	NO. 3.1
TITLE: Compartment Integrity	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems	
SAFETY GUIDELINE: The individual pressurizable compartments should be structurally designed to withstand a rapid decompression of any adjacent compartment.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 3-M, "Substructure failure results from internal pressure bulkhead failure."	
REMARKS: The overall structural integrity of the spacecraft should be maintained to prevent cumulative catastrophic structural failure. The pressure compartment bulkheads should also be capable of withstanding particle impacts or pressures resulting from explosions in adjacent compartments.	

HAZARD GROUP: Decompression/Overpressure**NO.** 3.2**TITLE:** Crack Propagation in Primary Structure**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical Systems**SAFETY GUIDELINE:**

The spacecraft structure should be designed as a structural matrix with the capability of arresting crack or tear growth.

REFERENCES:

1. D2-113070-10, FT-1 (Decompression), 1-J, "Failure of pressure retention results from failure of structural matrix."

REMARKS:

The structural design should be such that no single structural failure will create additional or cumulative failure. The skin panel installation should be designed to halt the potentially catastrophic growth of cracks or tears.

HAZARD GROUP: Decompression/Overpressure	NO. 3.3
TITLE: Equipment Design for Rapid Decompression	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Equipment located in pressurized compartments should be designed to withstand the changing environment associated with rapid decompression of the space station/base.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 5-E, "Emergency equipment inoperative due to damage from effects of decompression." 3. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard No. 29. 4. D2-113070-9, Logic Diagram, Proposition 9B.	
REMARKS: Equipment located in pressurized compartments may be subjected to the effects of rapid decompression at some time during a long-duration space mission. Some of this equipment may be essential to the long-term safety of the crew. To avoid further degradation of crew safety and assure continued operation during a critical period, all such equipment should be designed to withstand rapid decompression without failure. Equipment should also be designed and/or procedures developed to preclude equipment damage that might result from operating in the depressurized environment.	

HAZARD GROUP: Decompression/Overpressure	NO. 3.4
TITLE: Hatch Automatic Closure	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems	
SAFETY GUIDELINE: Automatic closure of hatches between pressurized compartments of the space station, when cabin pressure decreases below a specified limit, should be considered as a design feature.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 1-E, "Decompression results from failure of spacecraft pressure retention." 3. D2-113070-9, Logic Diagram, Propositions 8C and 12E.	
REMARKS: Implementation of this guideline would minimize loss of cabin atmosphere and possible damage to equipment when the cause of the pressure loss is located in only one of the compartments. The automatic closing hatches should have the capability of being manually overridden.	

HAZARD GROUP: Decompression/Overpressure	NO. 3.5
TITLE: Hatch Closure	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Structures/Mechanical (S/M)	
SAFETY GUIDELINE: Hatches between compartments should be closed except when required for crew transit.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 1-H, "All crew members are exposed to decompression," 6-E, "Decompression rate exceeds procedure response time," and 9-K, "Hatch or other access to area undergoing decompression is open." 2. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."	
REMARKS: This guideline is of special significance in that the effectiveness of containing and isolating hazards in a given compartment will depend on the extent to which this instruction is implemented with respect to other on-board procedures. Due to the limitations imposed by this guideline, a trade study may be required to consider possible alternatives, such as the following: a. Partial isolation wherein two or more compartments would comprise a volume entity by leaving the hatches between them normally open. b. No isolation in order to: (1) Facilitate normal traffic flow. (2) Facilitate quick egress of crew members from the affected compartment to a more remote location. (3) Utilize the maximum available net volume while evaluating the emergency condition and determining the course of action to be taken, should an undesired event occur. Also applies to the following hazard groups: 2. Debris and Meteoroid Impact 5. Equipment Impact 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Decompression/Overpressure	NO. 3.6
TITLE: Hatch Positive Closure	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems (S/M)	
SAFETY GUIDELINE: A means should be provided for visual inspection of the hatch as well as a warning system, as a safety check to assure that hatches or other accesses to an area at a different pressure level have been secured properly. Warning system displays should be at the hatch and at the command and control center(s).	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 3-0, "Pressure hatch fails due to improper latching or securing."	
REMARKS: The intent of this guideline is to provide a means of assuring proper hatch closure. Positive hatch closure is required to maintain the total pressure integrity of the isolated volume involved.	

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HAZARD GROUP: Decompression/Overpressure		NO. 3.7
TITLE: Hatch Pressure Loading		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems (S/M)		
SAFETY GUIDELINE: Pressure hatches providing access to an area of differential pressure should be of a type that becomes more positively engaged under pressure loading.		
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 3-N, "Failure of pressure hatch results from excessive pressure loading."		
REMARKS: This feature basically would pertain to exterior hatches, but could also apply to hatches between two pressurized compartments, in which one compartment is at a higher pressure than the other; e.g., biological studies, airlock operation, etc.		

HAZARD GROUP: Decompression/Overpressure	NO. 3.8
TITLE: Hatch Seal Leakage Rate	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems	
SAFETY GUIDELINE: Hatch design should be such that loss of a hatch seal element will not result in a pressure leakage rate which exceeds the emergency recompression system rate.	
REFERENCES: 1. D2-113070-10, FT-1 (decompression), 3-P, "Pressure hatch fails due to failure of seal element."	
REMARKS: A single failure of the hatch assembly should not create additional or cumulative failures leading to the catastrophic failure of the pressure shell.	

HAZARD GROUP: Decompression/Overpressure	NO. 3.9
TITLE: Hatchway Airlocks	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical, Operations	
SAFETY GUIDELINE: Provision should be made for an airlock in the hatch or hatchway between separately pressurizable compartments.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 3, "Analysis of Operations," and Section 5, "Traffic Pattern Analysis."	
REMARKS: In the event of an emergency in any compartment a desirable procedure is to contain the emergency to its original site by closing all entrances to the compartment. If the compartment is manned, however, evacuation of crew members may also be desired. If an airlock were provided it would allow for both containing the emergency and evacuating personnel. Also, if a compartment is depressurized, an airlock would facilitate access to the compartment for repair or rescue purposes. An alternate possibility would be a portable airlock which could be brought to the emergency site as necessary. This guideline becomes particularly significant for a space station comprising only a small number of compartments. Also applies to the following hazard groups: 1. Contamination 6. Explosion 7. Illness and Injury 10. Temperature Extremes	

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HAZARD GROUP: Decompression/Overpressure

NO. 3.10

TITLE: Leakage Repair System

APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Structures/Mechanical (S/M)

SAFETY GUIDELINE:

A leakage repair system employing techniques and equipment appropriate to the vacuum and gravity environment of the space station/base should be provided on-board the spacecraft.

REFERENCES:

1. D2-113070-10, FT-1 (Decompression), 1-L, "Crew exposed and protective action not initiated through use of emergency equipment;" and 1-M, "Crew exposed and protective action not initiated through emergency procedures."
2. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of no airlock capability.
3. D2-113070-9, Logic Diagram, Proposition 10G.

REMARKS:

The procedures and equipment required to perform repairs should be compatible with the movement and handling limitations imposed by the wearing of a pressure suit. IT is desirable that repairs be performed by IVA rather than EVA.

HAZARD GROUP: Decompression/Overpressure	NO. 3.11
TITLE: Medical Equipment for Emergencies	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems, Crew System	
SAFETY GUIDELINE: Consideration should be given to providing the equipment and supplies necessary for general cardiopulmonary resuscitation and other equipment and supplies that might be required for the individualized treatment of residual effects of decompression.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 5-C, "Decompression emergency equipment is nonexistent at the time required." 2. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements."	
REMARKS: Of the equipment and supplies to be considered, decompression and/or hyperbaric chambers do not appear warranted. Due to the bulk, weight, and functional characteristics, such features might be combined with other spacecraft facilities (e.g., airlock) to satisfy multiple operational requirements. As a "configuration driver," this should be evaluated early in the conceptual phase. Also applies to the following hazard group: 7. Illness and Injury	

HAZARD GROUP: Decompression/Overpressure	NO. 3.12
TITLE: Pressure Regulator Failure	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Environmental Control/Life Support System (EC/LSS), Stability and Control System (SCS)	
SAFETY GUIDELINE: All pressure relief valves should be designed to protect against a regulator failed or stuck in the full open position.	
REFERENCES: 1. Space Flight Hazard Catalog, MSC 00134, September, 1969, Hazard No. 68. 2. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of fluid leakage.	
REMARKS: Inability of a relief valve to adequately relieve resultant pressure from a full open regulator could damage downstream equipment, impair its operation, or rupture the pressure vessel (line).	

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HAZARD GROUP: Decompression/Overpressure

NO. 3.13

TITLE: Pressure Relief for Trapped Fluids

APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System (SCS)

SAFETY GUIDELINE:

Plumbing systems which carry cryogens or hydrogen peroxide should be designed such that adequate pressure relief capability exists in those areas most likely to trap the fluids. Furthermore, to guard against the possibility that a relief valve in these systems becomes frozen shut or otherwise rendered inoperative, a backup pressure relief device, such as burst disks, should be incorporated in parallel with the valves.

REFERENCES:

1. Space Flight Hazard Catalog, MSC 00134, September, 1969, Hazard No. 76.
2. D2-113070-11, Subsystems Analyses (EC/LSS), for potential hazard of fluid leakage.

REMARKS:

Though high pressure fluid systems should be designed to avoid entrapment of the fluids, design constraints may still permit this to occur. Special consideration should be given to design features which would compensate for this entrapment by ensuring adequate excess pressure relief.

HAZARD GROUP: Decompression/Overpressure	NO. 3.14
TITLE: Pressure System Depressurization	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: All pressure systems should be designed to enable a planned depressurization; accurate sensors should be incorporated to ensure that the pressure is totally relieved prior to opening the system should that requirement arise for maintenance or other reasons.	
REFERENCES: 1. Space Flight Hazard Catalog, MSC 00134, September, 1969, Hazard No. 129. 2. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure.	
REMARKS: Opening a pressure system prior to total depressurization could create a hazard to personnel or equipment in the immediate vicinity, as well as subject equipment on that system to possible damage from explosive decompression.	

HAZARD GROUP: Decompression/Overpressure**NO.** 3.15**TITLE:** Pressurizable Volume Relief Protection**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Environmental Control/Life Support System
(EC/LSS), Stability and Control System (SCS)**SAFETY GUIDELINE:**

Any pressurizable volume that can be confined or isolated by any means, such as by valves, should include some means for automatic protection from overpressure.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (EC/LSS) for potential hazard of fluid leakage.
2. D2-113070-10, FT-1 (Decompression), 4-G, "Loss of subsystem function results in overpressurization of structure."
3. D2-113070-9, Logic Diagram, Propositions 13D, 60D and 61D.

REMARKS:

All systems which use pressurized fluids should be examined to identify those portions which are confined or could be confined by closing valves or by other means. This condition could result in overpressures and subsequent rupture or explosion, or leakage and contamination, that may affect crew safety. Therefore, it is necessary to provide some means of protecting these volumes with an overpressure device such as an automatic relief valve.

Also applies to the following hazard groups: 6. Explosion
10. Temperature Extremes

HAZARD GROUP: Decompression/Overpressure	NO. 3.16
TITLE: Pressurized Gas Flow Restriction	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control (SCS)	
SAFETY GUIDELINE: Pressurized gas supplies should include restrictions that will limit gas flow in the event of a pressurized gas plumbing failure, to that which can be handled by the relief valves or venting system.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Propositions 15C and 16F.	
REMARKS: In some installations it may be possible for a pressurized gas line to fail so that the total gas supply would be dumped directly into a compartment. If this flow is greater than the relief or venting capability of the compartment, over-pressurization could result. Therefore, flow restrictions should be incorporated at the pressure source to restrict the gas flow to that which can be handled by the relief or venting system.	

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HAZARD GROUP: Decompression/Overpressure	NO. 3.17
TITLE: Primary Structure Inspection and Repair	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems (S/M), Operations, Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Design of spacecraft structure and equipment, including their interfaces, should be such that all portions of the pressure shell, bulkheads and seals will be accessible for damage inspection and repair. This should apply to exterior as well as to interior spacecraft surfaces.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 1-J, "Failure of pressure retention results from failure of structural matrix." 2. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 3. D2-113070-9, Logic Diagram, Propositions 48B and 48F.	
REMARKS: There is a distinct possibility that the pressure wall and/or pressure seals of a manned spacecraft will sustain appreciable damage before it completes a long-duration mission. When this occurs, it will be necessary to repair the damage to prevent excessive loss of cabin air, thereby enhancing the possibility of continuing crew safety throughout the mission. To the extent possible, it is suggested that access to the pressure shell and bulkheads be gained via the interior of the spacecraft. Also applies to the following hazard groups: 2. Debris and Meteoroid Impact 5. Equipment Impact 6. Explosion	

HAZARD GROUP: Decompression/Overpressure	NO. 3.18
TITLE: Rapid Decompression Effects	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems, Crew System	
SAFETY GUIDELINE: The potentially harmful effects on crew members of rapid decompression should be minimized through engineering considerations in selection of the spacecraft atmospheric composition, pressure, and compartment net volume.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 1-A, "Crew members will be in immediate danger of directly fatal exposure to decompression." 2. NASA SP-117, Space Cabin Atmospheres, Part III, Physiological Factors of Inert Gases. 3. NASA SP-118, Space Cabin Atmospheres, Part IV, Engineering Tradeoffs of One-Versus Two-Gas Systems.	
REMARKS: The possible detrimental effects of rapid decompression are dependent upon the rate of change of total pressure. Thus, trade studies involving the above engineering considerations should reflect their influence upon the time available for crew response and the corrective action required during an emergency leak situation.	

HAZARD GROUP: Decompression/Overpressure	NO. 3.19
TITLE: Spacecraft Structural Strength	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems (S/M)	
SAFETY GUIDELINE: The spacecraft should be of sufficient structural strength to safely maintain the required internal pressure within the expected launch and mission environment for the period of orbital stay.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 1-J, "Failure of pressure retention results from failure of structural matrix." 2. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of structural damage. 3. D2-113070-9, Logic Diagram, Propositions 16C and 52B.	
REMARKS: The above references provide the context for this guideline. This represents the basic structural requirement to be met by a manned spacecraft.	

HAZARD GROUP: Decompression/Overpressure	NO. 3.20
TITLE: Vented Component Replacement	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Components which are vented to space (vacuum) should be replaceable without requiring cabin depressurization.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 4-F, "Loss of subsystem function results in spacecraft pressure dump." 3. D2-113070-9, Logic Diagram, Proposition 43F.	
REMARKS: Certain components of the EC/LSS are vented to space (vacuum) or unpressurized areas of the space station. These components should be designed and installed so they can be replaced without loss of cabin pressure and without requiring EVA.	

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HAZARD GROUP: Decompression/Overpressure		NO. 3.21
TITLE: Venting of Cabin Pressure		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Electrical Power, Stability and Control, Experiments		
SAFETY GUIDELINE: Cabin pressure should not be vented to space through compartments or outlets that are used to vent other fluids.		
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-9, Logic Diagram, Propositions 15K and 16C.		
REMARKS: Compartments or outlets to which fluids other than the spacecraft atmosphere are vented would be subject to freezing of the fluids. This could prevent the venting of cabin atmosphere and result in overpressurization of the cabin.		

HAZARD GROUP: Decompression/Overpressure	NO. 3.22
TITLE: Venting of Pressure Relief Devices	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Stability and Control System	
SAFETY GUIDELINE: Pressure relief devices for all pressurized volumes should be vented to areas that will not endanger the crew or equipment.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of fluid leakage. 2. D2-113070-9, Logic Diagram, Propositions 60D and 61D.	
REMARKS: Guideline provides for relief protection of confined pressure volumes. If the pressure relief action does occur, it is necessary to ensure that the vented fluid will not contaminate the crew's atmosphere, will not endanger the crew by direct exposure or will not damage or contaminate system equipment. Therefore, pressure relief devices should be vented to areas that will avoid these problems. Also applies to the following hazard group: 1. Contamination	

HAZARD GROUP: Decompression/Overpressure	NO. 3.23
TITLE: Venting Provisions	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System, Structures/Mechanical Systems	
SAFETY GUIDELINE: All cabin atmosphere overboard relief or "dump" valves (any valve venting into space) should be fail-safe in the closed position and should be self-indicating when failed. Manual override or redundant manual valving should be provided as backup.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 4-F, "Loss of subsystem function results in spacecraft pressure dump."	
REMARKS: There should be positive measures to prevent or limit any single failure from progressing into the complete loss of pressure in a compartment.	

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HAZARD GROUP: Decompression/Overpressure	NO. 3.24
TITLE: Warning Systems, Cabin Pressure	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Total cabin pressure sensors should be provided to detect out-of-tolerance values of the total cabin pressure. Detection of pressure change at an excessive rate, or outside the desired operating range, should activate an alarm system to warn the crew to initiate appropriate remedial action. The alarm should be activated both in the affected space station compartment and at the command and control center(s).	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-9, Logic Diagram, Propositions 8C, 24I, 48H, and 48I.	
REMARKS: The space station crew should be warned of abnormal cabin pressure situations in time to take the necessary corrective action to ensure crew safety.	

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HAZARD GROUP: Decompression/Overpressure	NO. 3.25
TITLE: Warning Systems, Fail-Safe	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System	
SAFETY GUIDELINE: All pressure warning systems should include provisions for self-test and should be self-indicating when in the failed state.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 5-B, "Emergency equipment is inoperative at time required."	
REMARKS: Safety devices and warning systems should inherently provide for verification and assurance that they will operate properly when and if required. Also applies to the following hazard groups: 1. Contamination 9. Radiation 10. Temperature Extremes	

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HAZARD GROUP: Electrical	NO. 4.1
TITLE: Cable Insulation Damage	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Wire bundles should be so routed and protected as to preclude damage to the insulation through flexing or bumping.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-E, "Insulation fails due to physical damage."	
REMARKS: Insulation failure and the resultant possibility of arcing, fire, or equipment failure may be caused by physical abuse of the cable. Also applies to the following hazard group: 10. Temperature Extremes	

HAZARD GROUP: Electrical	NO. 4.2
TITLE: Connector Mismatching	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Comm & Data Mgmt., Electrical Power, Environ. Control/Life Support, Experimenters, Stability & Control	
SAFETY GUIDELINE: Suitable positive means, such as keying, should be provided to preclude accidental mismatching of electrical connectors. This would be especially significant for connectors which are to be connected and disconnected during flight operations (e.g., experiments).	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-P, "Conductor element is severed due to secondary events," and 12-Q, "Conductor element fails due to erroneous mating of connectors, or other procedural error."	
REMARKS: Electrical arcing leading to fire, or dangerous stray currents, could be caused by attempts to erroneously mate connectors. Failure reports of current systems show this to be an area which is critical to system safety. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Electrical		NO. 4.3
TITLE: Electrical Arcing		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Comm. & Data Mgmt., Electrical Power, Environ. Control/Life Support, Experiments, Stability & Control		
SAFETY GUIDELINE: Consideration should be given to design of electrical subsystem components (e.g., wall switches, light bulbs, or hot plates) to protect them from wear-out or inadvertent breakage, which could result in generating shorts or arcing.		
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-C, "Potential is available due to failure of electrical component."		
REMARKS: The undesired events described above could not only be an ignition source for fire/explosion but could lead to other hazards such as electrical shock to crew members or undesired stray currents to other equipment. Components which are liable to arc when worn should be designed so there is a very low probability of wear-out occurring during the mission. Alternatively, replacement times should be specified and closely observed to ensure that such units are operationally safe. Also applies to the following hazard groups: 6. Explosion 7. Illness and Injury 10. Temperature Extremes		

HAZARD GROUP: Electrical	NO. 4.4
TITLE: Electrical Connections	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power System, Experiments, Operations	
SAFETY GUIDELINE: All temporary electrical connections (outlets, connectors, etc.) should be so designed and/or operated as to eliminate the possibility of arcing.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 11-E, "An electrical power source produced an electrical arc for ignition." 2. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard No. 43.	
REMARKS: Normal electrical outlets, connectors, etc., are capable of arcing when being mated, unmated, or during use. Design modifications or operational procedures to avoid this problem may be desirable. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Electrical	NO. 4.5
TITLE: Electrical Cable Shorts	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Wire bundles should not be located near potential heat sources, including those areas where a potential for fire exists.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-D, "Insulation fails due to an external heat source."	
REMARKS: Insulation failure and the resultant possibility of arcing, fire, or equipment failure may be caused by a heat source external to the cable. Also applies to the following hazard group: 10. Temperature Extremes	

HAZARD GROUP: Electrical	NO. 4.6
TITLE: Electrical Connector Checks	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Comm. & Data Mgmt., Electrical Power, Environ. Control/Life Support, Experiments, Stability & Control	
SAFETY GUIDELINE: Provision should be made to assure proper pin connection at all critical electrical connectors prior to application of system voltage. Verification should be made to assure that all pin connections exist as designed, no pin-to-pin shorts exist, and that no pin-to-shell shorts exist.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-N, "Conductor element fails shorted due to bent pin or other internal misalignment."	
REMARKS: Electrical arcing leading to fire, or dangerous stray currents, could be caused by bent pin(s) in an electrical connector. Failure reports of current systems show this to be an area which is critical to system safety. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

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HAZARD GROUP: Electrical	NO. 4.7
TITLE: Grounding of Spacecraft and Equipment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: All equipment and substructure should be grounded to the basic spacecraft structure.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 11-F, "A static electrical discharge provides ignition source," and 11-G, "An electrical arc is accidentally provided during system operation."	
REMARKS: Ungrounded equipment permits build-up of an electric potential or static charge which could be discharged to form an arc or spark. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Electrical	NO. 4.8
TITLE: Potential Difference--Docking Spacecraft	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical	
SAFETY GUIDELINE: A means should be provided to equalize electric potential differences between docking spacecraft.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 3, "Analysis of Operations."	
REMARKS: A difference in electrical potential may develop between the space station/base and associated spacecraft, such as the space shuttle, space tug, or free-flying experiment modules. During docking an electrical arc could be caused which could result in damage to the docking mechanism, seals, etc. Discharging the potential differences by a device intended for that purpose would preclude damage to the spacecraft. Also applies to the following hazard groups: 3. Decompression/Overpressure 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Electrical	NO. 4.9
TITLE: Power Distribution Paths Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Multiple power distribution paths to essential electrical equipment should be provided.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of loss of electrical power. 2. D2-113070-9, Logic Diagram, Propositions 10D and 10F.	
REMARKS: The distribution system for power should be designed so that essential equipment can be operated from more than one power bus. This is to preclude the loss of essential electrical equipment when there is a failure in the primary power distribution path to the equipment. At a minimum, essential equipment so protected should include lighting, EC/LSS, communications equipment and computers.	

HAZARD GROUP: Electrical	NO. 4.10
TITLE: Power Source Monitors	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power (EP)	
SAFETY GUIDELINE: Sensors should be provided to detect out-of-tolerance values for critical electrical power source parameters, such as voltage, frequency, current, temperature, etc., or momentary excessive power surges resulting from equipment turn-on or turn-off. The sensors should activate an alarm system at the command and control center(s) of deviations from the desired parameter values.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of loss of electrical power. 2. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard No. 150.	
REMARKS: The electrical power system is essential to the operation of the space station and equipment which is vital to crew safety. A warning should be given, visually and/or audibly, depending on the particular situation, of any abnormal operation of the electrical power equipment in time to take the necessary corrective action. Consideration should also be given to the provision of automatic shut-down or isolation of power sources when specified parameters exceed operating limits which, if allowed to continue, could develop into a hazardous situation before appropriate manual action could be taken.	

HAZARD GROUP: Electrical	NO. 4.11
TITLE: Power Sources Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power (EP)	
SAFETY GUIDELINE: Multiple or redundant primary electrical power sources should be provided such that a single failure will not result in complete loss of primary electrical power, or cause failure of equipment which is unable to survive momentary power interruptions.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of loss of electrical power. 2. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard No. 39. 3. D2-113070-9, Logic Diagram, Proposition 10F.	
REMARKS: A complete loss of primary electrical power would jeopardize the safety of the crew. Therefore, the power system should be designed so more than one source of power is available at all times to supply the main distribution system. The power sources should be located or the distribution system arranged so a single failure can only result in the loss of the affected power source and its associated distribution system. Furthermore, to avoid momentary power interruptions such as might occur during switch-over from primary to stand-by power, all equipment which is sensitive to this anomaly should be powered by active redundant power sources.	

HAZARD GROUP: Electrical	NO. 4.12
TITLE: Protective Covers for Electrical Equipment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power, Comm. & Data Mgmt., Environ. Control/Life Support, Experiments, Stability and Control	
SAFETY GUIDELINE: Protective covers should be provided for all portions of the electrical subsystem to which access is required (switch boards, terminal boards, etc.).	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-P, "Conductor element is severed due to secondary events." 2. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard No. 36.	
REMARKS: Dangerous stray currents, or a source of ignition from accidental generation of an arc, could be produced through a procedural error, facilitated by exposed pins or other exposed conductors. Failure reports from current systems show this to be a condition that can lead to failure. Covers also would provide protection from metallic debris floating in a zero-gravity environment. Also applies to the following hazard groups: 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Electrical	NO. 4.13
TITLE: Redundant Circuits	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power, Crew System, Environmental Control/Life Support, Stability and Control	
SAFETY GUIDELINE: Redundant electrical circuits for items critical to crew safety should not be included in the same wire bundle.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of loss of electrical power.	
REMARKS: Items which are critical to crew safety will usually require redundancy. This requirement would be defeated by including the involved electrical circuits in the same wire bundle since damage to or disconnection of the bundle might render both primary and redundant circuits inoperative.	

HAZARD GROUP: Electrical

NO. 4.14

TITLE: Routing of Power Distribution Lines

APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power (EP)

SAFETY GUIDELINE:

Power distribution wires should be routed in such a manner that any damage resulting from a fire, caused by a fault in the distribution system, will have a minimal effect on other power distribution wires in the vicinity.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (EP), for potential hazards of fire, smoke, toxicity.
2. D2-113070-10, FT-2 (Temperature Extremes), 5-D, "Electrical system component heated through electrical system fault."

REMARKS:

Distribution of power to the various subsystems in the spacecraft could be interrupted, and redundancy provisions negated, unless care is taken to separate power distribution bundles sufficiently to avoid the possibility of secondarily-inflicted damage.

HAZARD GROUP: Equipment Impact	NO. 5.1
TITLE: Bulk Cargo Restraint	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations	
SAFETY GUIDELINE: All bulk cargo should be properly tethered or otherwise controlled during zero-gravity or reduced-gravity operations.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 7-L, "Damage occurs during bulk cargo or personnel transfer." 2. D2-113070-6, Supporting Analyses, Section, "Analysis of Operations."	
REMARKS: The intent of this guideline is to provide protection of the spacecraft structure (and personnel inside cargo compartments) through proper control of cargo mass during handling in the zero-gravity condition.	

HAZARD GROUP: Equipment Impact	NO. 5.2
TITLE: Crew Restrictions During Docking	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Structures/Mechanical Systems (S/M)	
SAFETY GUIDELINE: Activity of crew members not directly involved in docking operations with other vehicles should be restricted to areas structurally and environmentally isolated from the docking interfaces.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Paragraph 3.1.6, Additional Manning or Crew Rotation Missions," and Paragraph 3.3.3, "Docking of Logistic Vehicle." 2. D2-113070-10, FT-1 (Decompression), 3-C, "Structural matrix failure results from damage during space operations." 3. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of docking accident. 4. D2-113070-9, Logic Diagram, Proposition 8C.	
REMARKS: The intent of the guideline is to minimize the number of crew members exposed to a potential hazard during close-in maneuvering and docking operations. Considerations should be given to evacuating crew members from and depressurizing the compartment to which docking is being made. More experience in space ferrying and in use of space "tugs" to dock large vehicles must be acquired before the hazards involved in docking operations can be assessed accurately and normal crew locations during such operations assigned with confidence. Also applies to the following hazard group: 3. Decompression/Overpressure	

HAZARD GROUP: Equipment Impact		NO. 5.3
TITLE: Docking Closure Rate Control		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Stability and Control System (SCS), Structures/Mechanical (S/M)		
SAFETY GUIDELINE: Closure rates during docking maneuvers should be monitored and an automatic attitude control override capability provided to preclude closure rates from exceeding specified limits.		
REFERENCES: 1. D2-113070-11, Subsystems Analysis (SCS and S/M), for potential hazards of loss of attitude control and docking accident. 2. D2-113070-10, FT-1 (Decompression), 7-K, "Damage occurs during logistic vehicle docking operations." 3. D2-113070-9, Logic Diagram, Propositions 12E and 35B.		
REMARKS: Excessive closure rates during docking maneuvers could result in damage to the spacecraft involved and possible tumbling in excess of that considered acceptable for crew safety. Therefore, the closure rates should be automatically monitored, and if the rates exceed specified limits, the attitude control system should automatically take corrective action to prevent impact. Also applies to the following hazard group: 11. Spacecraft Acceleration		

HAZARD GROUP: Equipment Impact**NO.** 5.4**TITLE:** Docking Light Redundancy**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M), Operations**SAFETY GUIDELINE:**

Redundancy should be provided for the docking lights at each port. The redundant lights should be powered from a different source than the primary lights.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of docking accident.
2. D2-113070-10, FT-1 (Decompression), 7-K, "Damage occurs during logistic vehicle docking operations."
3. D2-113070-6, Supporting Analyses, Section 6, "Analysis of Operations."
4. D2-113070-9, Logic Diagram, Propositions 10F and 46B.

REMARKS:

During docking operations it is necessary to provide continuous lighting of the docking area to ensure adequate visibility to avoid accidents. To make sure that continuous lighting of the docking area is available, even though the primary lighting has failed, a separate and independently powered lighting system should be provided. If more than one docking port is provided and it can be assured that another docking port with operating lights will be available, then it may not be necessary to have redundant docking lights at all docking ports.

HAZARD GROUP: Equipment Impact**NO.** 5.5**TITLE:** Docking Port Redundancy**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M), Operations**SAFETY GUIDELINE:**

A space station/base should be provided with more than one docking port.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of docking accident.
2. D2-113070-10, FT-1 (Decompression), 7-K, "Damage occurs during logistic vehicle docking operations."
3. D2-113070-9, Logic Diagram, Proposition 80B.

REMARKS:

Docking accidents or docking port equipment failure could result in the port being temporarily unusable. To ensure continuous availability of a docking port, more than one should be provided. The total number of docking ports will depend upon factors such as the size of the space station, the crew size, and the frequency of docking operations.

HAZARD GROUP: Equipment Impact	NO. 5.6
TITLE: Equipment Operation During EVA	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Operation of equipment that could endanger EVA personnel should be avoided.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (CS), for potential hazard of crew injury or illness. 2. D2-113070-9, Logic Diagram, Propositions 32B, 32C, 32E and 38C.	
REMARKS: In some cases, the operation of externally-mounted equipment can create a hazard that extends beyond the physical dimensions of the equipment, e.g., exhaust plume of thrusters, jettisoning of waste products, RF radiation, movement of solar panels or antennas. When EVA is being performed in the vicinity of this type of equipment, procedures should be available that will preclude the operation of this equipment.	

HAZARD GROUP: Equipment Impact	NO. 5.7
TITLE: Exterior Equipment Design and Location	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: The design and location of equipment on exterior surfaces of the space station (e.g., solar panels, antennas) should minimize their hazards to EVA personnel or to other exterior operations such as rendezvous and docking.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of crew injury or illness. 2. D2-113070-10, FT-1 (Decompression, 2-G, "Damage results from pressure suit tear." 3. D2-113070-9, Logic Diagram, Proposition 52C.	
REMARKS: When determining the external configuration of a space station and the equipment to be located there, consideration should be given to the activities or operations that will be taking place exterior to the space station. Unfortunate location, improper design, or lack of shielding protection for this equipment could impose unnecessary hazards to exterior operations.	

HAZARD GROUP: Equipment Impact	NO. 5.8
TITLE: Injury or Damage from Spacecraft Equipment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Space station equipment, both interior and exterior, should be designed to minimize danger of injury to the crew or damage to pressure suits during all activities.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazards of crew injury or illness and for EVA equipment failure. 2. D2-113070-10, FT-1 (Decompression), 2-C, "Loss of pressure suit pressure retention results from suit damage"; and 2-G, "Damage results from pressure suit tear." 3. D2-113070-9, Logic Diagram, Propositions 27C, 46B, 52C and 78G.	
REMARKS: Because of the volume limitations of space stations, crew members will be performing their normal activities in close proximity to many items of equipment. If not designed properly, this equipment could present a hazard to shirt-sleeved crew members. Therefore, this equipment should be designed to minimize dangers to the crew from sharp projections, hot or cold surfaces, excessive acceleration, vibration, noise, electrical current, etc. Also applies to the following hazard group: 7. Illness and Injury	

HAZARD GROUP: Equipment Impact	NO. 5.9
TITLE: Mechanical Shielding of Electrical Equipment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Comm. & Data Mgmt., Electrical Power, Environ. Control/Life Support, Experiments, Stability and Control	
SAFETY GUIDELINE: Mechanical shielding should be provided to protect electrical equipment, including intra-equipment wire bundles, from possible external physical injury, but allow access when required for repair or replacement.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 12-D, "Insulation fails due to an external heat source," 12-E, "Insulation fails due to physical damage," 12-O, "Conductor element fails shorted due to foreign material," and 12-P, "Conductor element is severed due to secondary events."	
REMARKS: Human error, or shrapnel from an explosion or meteorite, could damage insulation and cause a short, with the possibility of arcing and/or fire. Early design should consider locating wire bundles (cables) in protected areas. Also applies to the following hazard groups: 2. Debris and Meteoroid Impact 4. Electrical 6. Explosion 10. Temperature Extremes 11. Spacecraft Acceleration	

HAZARD GROUP: Equipment Impact

NO. 5.10

TITLE: Mobility Aids, Zero Gravity

APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Structures/Mechanical (S/M), Operations

SAFETY GUIDELINE:

Adequate restraints, tethers or aids to assist the crew in personal movements and handling large-mass equipment should be available throughout the interior and exterior of the space station.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (CS and S/M), for potential hazards of crew injury or illness and structural damage.
2. D2-113070-6, Supporting Analyses, Section 3, "Analysis of Operations."
3. D2-113070-9, Logic Diagram, Propositions 9E, 13C, 13F, 18E, 32C and 48E.

REMARKS:

In the weightless environment, the movement of crew members and equipment can sometimes be hazardous, with a potential of endangering the crew. Large masses, whether equipment or personnel, have a possibility of achieving high momentums which can be dangerous if not held in check. Therefore, adequate restraints, tethers, or other aids should be located throughout the interior and exterior of the space station to assist crew member movements and equipment handling.

Also applies to the following hazard group: 7. Illness and Injury

HAZARD GROUP: Equipment Impact		NO. 5.11
TITLE: Pressure Suit Repair		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/Life Support System		
SAFETY GUIDELINE: Pressure suits should be designed so that minor repairs can be made to the suit.		
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure. 2. D2-113070-10, FT-1 (Decompression), 1-G, "Decompression results from failure of pressure suit pressure retention." 3. D2-113070-9, Logic Diagram, Proposition 33E.		
REMARKS: There is a definite possibility that minor damage (e.g., tears in fabric, seal failure) could be inflicted on the pressure suits during a long-term mission. With the proper repair capability, the crew should be able to restore pressure suits sustaining such damage to serviceable use. This will also reduce the requirements for storing complete spare pressure suits.		

HAZARD GROUP: Equipment Impact	NO. 5.12
TITLE: Rotating Machinery Shielding	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Electrical Power (EP), Environmental Control/Life Support System, Stability & Control	
SAFETY GUIDELINE: Equipment that uses high-speed rotating components should be adequately shielded to prevent a wheel failure from causing damage to other equipment, and should not be located in compartments devoted to crew health and well-being.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity. 2. D2-113070-9, Logic Diagram, Propositions 52C, 52D and 58D.	
REMARKS: High-speed rotating components have an inherent danger associated with the possibility of a wheel rupturing and causing severe damage to other equipment or structural damage to the compartment or space station. Equipment that contains high-speed rotating components, therefore, should be shielded sufficiently to contain any wheel rupture that might occur. Also applies to the following hazard groups: 3. Decompression/Overpressure 10. Temperature Extremes	

HAZARD GROUP: Explosion	NO. 6.1
TITLE: Electrical Ignition	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Comm. & Data Mgmt., Electrical Power, Environmental Control/Life Support, Experiments, Stability and Control	
SAFETY GUIDELINE: All relays, including motor start relays, level sensing devices, switches, cam contacts, commutators, etc., which can produce an electrical arc, should be hermetically sealed. This seal should continue to provide full protection during and after being subjected to deep vacuum.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 11-H, "An electrical arc is provided during normal system operation."	
REMARKS: Arcing relays, switches, commutators, etc., provide a ready source of ignition for an accidentally generated explosive atmosphere. To cause a fire/explosion this event would have to be coupled with a combustible atmosphere or material. Also applies to the following hazard groups: 1. Contamination 4. Electrical 10. Temperature Extremes	

HAZARD GROUP: Explosion	NO. 6.2
TITLE: Explosion-proof Electrical Equipment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Electrical equipment should be sufficiently enclosed to prevent a self-induced explosion from spreading beyond the equipment itself.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity. 2. D2-113070-10, FT-2 (Temperature Extremes), 11-E, "An electrical power source produces an electrical arc for ignition."	
REMARKS: Electrical equipment inherently includes a potential ignition source for fire or explosion which should be controlled by designing to contain any internal explosion that might occur. Any gases escaping as a result of such an explosion should be at a lower temperature than the kindling temperature of the surrounding atmosphere.	

HAZARD GROUP: Explosion	NO. 6.3
TITLE: Flammable/Explosive Material Exterior to Spacecraft	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Design of overboard vent/dump mechanisms should preclude the possibility of accumulation of flammable/explosive or toxic material near the space station.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 3-N, "Fire occurs within an unmanned area."	
REMARKS: Accumulation of such materials could lead to hazardous conditions during operations external to the spacecraft.	

HAZARD GROUP: Explosion		NO. 6.4
TITLE: Hazardous Mixtures		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical, Environmental Control/Life Support, Experiments, Stability & Control, Crew System		
SAFETY GUIDELINE: Drain or vent lines should not be routed in a manner that could generate a hazardous mixture or allow feed-back of hazardous substances to the components being drained or vented.		
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 3-N, "Fire occurs within an unmanned area," and 7-R, "Explosion in remote area is not contained and propagates to vicinity of crew."		
REMARKS: If two or more materials which would form hypergolic or flammable mixtures are vented through a common outlet, an explosion or fire could occur within the vent or external to the spacecraft.		

HAZARD GROUP: Explosion	NO. 6.5
TITLE: Pressure Subsystem Interconnection	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: In subsystems where a possibility exists of misconnecting from one pressure level into a component of a different pressure level, the subsystem should be designed to safely contain the higher pressure.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 12-J, "Failure results from reverse or incorrect installation of system components."	
REMARKS: Pressure system as used herein is defined as consisting of vessels, pumps, tubing, valves, instrumentation, and all hardware that contains liquids or gases under any pressure above 0.1 mm Hg absolute. Also applies to the following hazard groups: 1. Contamination 3. Decompression/Overpressure	

HAZARD GROUP: Explosion	NO. 6.6
TITLE: Pressure System Dynamics	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: The spacecraft pressure system and related components should be capable of withstanding all structural, acceleration, or other loads which are not of hydraulic or pneumatic origin, simultaneously with proof pressure, without permanent set, damage, or leakage at maximum operating temperature.	
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 12-F, "Failure results from inadequate design analysis of the liquid system dynamics."	
REMARKS: A complete structural analysis should be conducted on all pressure systems. For spacecraft systems this should include the "worst case" consideration of vibration stress risers, surge and shock stresses, acceleration loading, and thermal degradation of strength, as applicable.	

HAZARD GROUP: Explosion	NO. 6.8
TITLE: Pressure System Safing	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE:	
The spacecraft subsystem design should provide the capability of returning any pressure system to a safe condition in the event of a failure, or miscarriage of procedural sequence, at any time during operation, test, or maintenance.	
REFERENCES:	
1. D2-113070-10, FT-1 (Decompression), 4-M, "Explosive failure of system normally under pressure results in overpressure and fragmentation."	
REMARKS:	
Provisions such as a bleed system should be included in any subsystem which could be subject to inadvertent overpressure to avert malfunctioning, damage, or possible explosion. Design of such systems also should consider incorporation of redundant critical items, provisions for isolating portions of the subsystem to preclude shutdown of the entire system, and substitution of critical functions when shutdown for corrective action becomes necessary.	

HAZARD GROUP: Explosion**NO.** 6.9**TITLE:** Pressure Tank Relief Protection Redundancy**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS),
Environmental Control/Life Support System**SAFETY GUIDELINE:**

High-pressure tanks should have redundant relief valves with separate vents.

REFERENCES:

1. D2-113070-11, Subsystem Analysis (SCS), for potential hazard of propellant tank rupture.
2. D2-113070-9, Logic Diagram, Propositions 8F, 10F, and 13D.

REMARKS:

Failure of the relief protection for high-pressure tanks could result in tank rupture and injury to the crew or damage to equipment. To ensure continuous relief protection, redundancy should be provided. Each relief device should be vented separately to prevent one failure from affecting the other. Relief vents should not be located in the vicinity of ignition sources.

Also applies to the following hazard group: 1. Contamination

HAZARD GROUP: Explosion	NO. 6.10
TITLE: Propellant Tank Protection	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Stability and Control System (SCS)	
SAFETY GUIDELINE: Propellant tanks should have enough separation, or adequate shielding, to minimize damage to other tanks in the event one tank ruptures.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (SCS), for potential hazard of propellant tank rupture. 2. D2-113070-10, FT-1 (Decompression), 3-G, "Failure results from meteoroid impact"; and 7-K, "Damage occurs during logistic vehicle docking operations." 3. D2-113070-9, Logic Diagram, Propositions 12E, 17E and 35B.	
REMARKS: A propellant tank could be ruptured through overpressure, meteoroid impact, damage during docking operations, or damage during cargo or equipment handling. Therefore, the propellant tanks should be provided some protection, by location or use of shielding, from damage by external forces. The tanks should also have adequate separation to preclude a single failure from damaging more than one tank. Also applies to the following hazard groups: 2. Debris and Meteoroid Impact 5. Equipment Impact	

HAZARD GROUP: Explosion		NO. 6.11
TITLE: Protection of Pressure Vessels		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical System		
SAFETY GUIDELINE: Subsystem pressure vessels and pressure lines should be located as remotely as possible from crew occupied areas, critical equipment, and the primary pressure shell. In addition, protection should be provided from damage by dropped tools, slipping wrenches, drills, and other unrestrained objects.		
REFERENCES: 1. D2-113070-10, FT-1 (Decompression), 4-B, "Failure of pressure retention results from effects of catastrophic subsystem failure." 2. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard No. 138.		
REMARKS: For potentially explosive items not remotely located, consider the use of protective shields or other protective devices to minimize fragmentation damage. Also applies to the following hazard groups: 1. Contamination 3. Decompression/Overpressure		

HAZARD GROUP: Explosi 1	NO. 6.12
TITLE: Shrouding and Shielding of Pressure Lines	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical System	
SAFETY GUIDELINE: Lines carrying pressurized hydrocarbons should be equipped with spray-inhibiting devices such as shrouding or shielding.	
REFERENCES: 1. D2-113070-10, FT-2 (Temperature Extremes), 7-U, "Explosive combination of materials and environment exists."	
REMARKS: Shrouding or shielding would reduce an accidentally generated spray, which would support an explosion, to a liquid state which would not support an explosion.	

HAZARD GROUP: Explosion	NO. 6.13
TITLE: Water Electrolysis Unit: Cell Reversed Polarity	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Protective devices should be provided to prevent reversing polarity on water electrolysis unit cells which could result in an explosive H₂/O₂ mixture.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of O₂. 2. D2-113070-10, FT-2 (Temperature Extremes), 7-U, "Explosive combination of materials and environment exists."	
REMARKS: Water electrolysis units are used in some EC/LS systems for O₂ recovery. Failure of these units would result in the loss of a source of O₂. Also applies to the following hazard group: 8. Loss of Vital Supplies	

D2-113070-5

HAZARD GROUP: Illness and Injury

NO. 7.1

TITLE: Angular Velocity Upper Limit

APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Structures/Mechanical

SAFETY GUIDELINE:

Human factors design envelope parameters should include the establishment of an upper limit on vehicle angular velocity, when considering an artificial-gravity environment.

REFERENCES:

1. Preliminary Technical Data for Earth Orbiting Space Station, Volume II, Standards and Criteria, NASA, MSC-EA-R-66-1, November 1966.

REMARKS:

High values of angular velocity would produce Coriolis forces of sufficient magnitude to exceed the physiological and psychological performance limits. Establishment of tolerable rotation conditions should be in terms of an environment where adequate adaptation can take place to achieve proper performance of duties.

HAZARD GROUP: Illness and Injury	NO. 7.2
TITLE: Artificial Gravity Limits	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Structures/Mechanical	
SAFETY GUIDELINE: Human factors design envelope parameters should include the establishment of an upper and lower limit on the level of artificial gravity to be permitted, when considering an artificial-gravity environment.	
REFERENCES: 1. Preliminary Technical Data for Earth Orbiting Space Station, Volume II, Standards and Criteria, NASA, MSC-EA-R-66-1, November 1966.	
REMARKS: In the cited reference, an upper limit on artificial gravity is recommended as a "one-g" maximum, modified to compensate for Coriolis effects for tangential walking in the direction of spin. The minimum value recommended is the lowest value at which man can walk unaided, also modified to compensate for Coriolis effects.	

HAZARD GROUP: Illness and Injury	NO. 7.3
TITLE: Bacteriological Monitoring of the Crew	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Operations	
SAFETY GUIDELINE: All crew members should be monitored at regular intervals for gross qualitative and quantitative bacteriological changes.	
REFERENCES: 1. Boeing Document D2-90254, Summary Report--Project CREST (Closed Respiratory Environmental System Test), September 1962. 2. Manned Environmental System Assessment, NASA Contract NASw 658, May 1964.	
REMARKS: Distinct bacteriological qualitative and quantitative changes that could affect the health of the crew have been observed in studies such as the two referenced above. These changes appear to be caused by: 1. Relatively small and confined living quarters. 2. Bacteriological cross fertilization between inhabitants of a confined space. 3. High and efficient filtering capacity provided by the ECS and other filtering devices. 4. Use of bacteria-killing devices such as the possible use of ultraviolet sterilization means for air and potable water.	

HAZARD GROUP: Illness and Injury

NO. 7.4

TITLE: Bodily Injuries: Cuts, Contusions, Fractures, Sprains, Etc.

APPLICABLE SUBSYSTEMS/FUNCTIONS: All

SAFETY GUIDELINE:

Complete human engineering analysis and all possible safeguards should be applied in design, construction, and maintenance to minimize, if not eliminate, any possibility of injury to personnel during normal operations, repair and maintenance activities, and in emergency conditions.

REFERENCES:

1. NASA CR-1205 (II), Compendium of Human Responses to the Aerospace Environment, Volume II, (1968), pages 7-212 to 221.
2. NASA SP-86, Medical Aspects of an Orbiting Research Laboratory, pages 15, 31-2.

REMARKS:

A design objective should be to make the space station accident-proof. This means that work and living spaces, tools, and equipment should be designed and thoroughly reviewed during the design, testing, and at all stages of construction and operation, to eliminate hazards to personnel. Provisions should be made for convenience and safety during all maintenance and repair as well as during normal operations. All tasks and procedures, and all training manuals and routines, should be reviewed for hazard potential and revised if necessary.

Also applies to the following hazard group: 5. Equipment Impact

HAZARD GROUP: Illness and Injury	NO. 7.6
TITLE: Communicable Disease Control	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Environmental Control/Life Support, Operations, Structures/Mechanical	
SAFETY GUIDELINE: Provision should be made for isolation of suspected or actual communicable disease cases from the rest of the crew for observation, treatment, and possible evacuation.	
REFERENCES: 1. NASA SP-86, Medical Aspects of an Orbiting Research Laboratory, pages 33-39, (1966). 2. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements."	
REMARKS: Communicable disease in space is unlikely with the medical screening and quarantine that crews undergo. It is, however, not impossible. With relatively minor modification, a multi-compartment space station can be designed so one or more compartments can be isolated (as in hospital) and attendants can use hospital-type procedures (wash-up, linen disposal, etc.) to avoid spreading infection to other compartments. The facilities could be similar (though requirements are not as stringent) to those for returning interplanetary explorers and might even serve for that purpose if mission times coincide.	

HAZARD GROUP: Illness and Injury	NO. 7.7
TITLE: Compartment Orientation within Artificial-Gravity Environment	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Structures/Mechanical	
SAFETY GUIDELINE: Design of rotating spacecraft should be such that the direction of major traffic flow is parallel to the vehicle spin axis.	
REFERENCES: 1. Preliminary Technical Data for Earth Orbiting Space Station, Volume II, Standards and Criteria, MSC-EA-R-66-1, November 1966.	
REMARKS: The Coriolis force in a rotating station will tend to hamper crew movement and may adversely affect the crew's physical and mental health. Routing all possible traffic movement in a direction parallel to the axis of rotation will result in minimizing the effects of the Coriolis force.	

HAZARD GROUP: Illness and Injury	NO. 7.8
TITLE: Crew Restrictions During Internal Hazardous Operations	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Experiments, Operations	
SAFETY GUIDELINE: Only those crew members necessary to the conduct of the operation should be permitted access to areas in which hazardous operations are being conducted.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 3, "Analysis of Operations"; Section 5, "Traffic Pattern Analysis"; and Section 6, "Human Requirements."	
REMARKS: Certain operations or experiments will require use of or exposure to unusually hazardous conditions, e.g., high voltages, high or low temperatures, low pressure, radiation, and the like. To minimize crew exposure to these hazards, only the minimum number of crew necessary to the work should be allowed in the work area. Also applies to the following hazard groups: 1. Contamination 2. Decompression/Overpressure 9. Radiation 10. Temperature Extremes	

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HAZARD GROUP: Illness and Injury	NO. 7.9
TITLE: Death of Crew Members	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Environmental Control/Life Support System, Structures/Mechanical	
SAFETY GUIDELINE: Procedures and equipment should be available for use in the event of death of a crew member.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements."	
REMARKS: The cause of death should be established as quickly as possible and quarantine provisions invoked if infectious disease is diagnosed. A gross autopsy may be performed on-board if qualified personnel are among the crew or, preferably, after evacuation of the body to Earth. To prevent or reduce the threat of contamination, the body should be sealed in plastic and chilled, or treated by other suitable means, to await transport to Earth. In the event that burial in space is permitted and desirable, tissue samples to complete the autopsy may be required for histological examination.	

D2-113070-5

HAZARD GROUP: Illness and Injury	NO. 7.10
TITLE: Death of Experimental Plants and Animals	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Experiments	
SAFETY GUIDELINE: Procedures and equipment should be provided for the preservation or disposal of the remains of deceased experimental plants or animals.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements." 2. Candidate Experiment Program for Manned Space Stations, NASA, May 1969.	
REMARKS: It is expected that normal experiment equipment and procedures would be adequate to accommodate the requirements for disposition imposed by the routine deaths of experimental plants and animals. In the case of unanticipated death, however, provision should be made for prompt determination of the cause of death and, if the cause is one which could adversely affect the crew, for the isolation and/or disposal of the remains in a manner which safeguards the crew. Also applies to the following hazard group: 1. Contamination	

HAZARD GROUP: Illness and Injury	NO. 7.11
TITLE: Emotional Disturbances	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Operations	
SAFETY GUIDELINE: The program of selection, training, mission support, physical conditioning, daily activities, and recreation should insure that crew members remain confident in the mission and their roles in it.	
REFERENCES: 1. NASA SP-86, Medical Aspects of an Orbiting Research Laboratory, pages 33-39, (1966). 2. NASA CR-1205 (I, II and III), Compendium of Human Responses to the Aerospace Environment, Volumes I, II and III, pages 3-51, 81 to 83; 7-5, 48; 16-77 to 96, (1968).	
REMARKS: Emotional disturbances may be caused by anger, fear, anxiety, frustration, etc., and may vary from a mild, transient response of no particular consequence to impaired performance, irrational behavior, and even to psychosis in extreme cases. Even when performance and behavior are not affected, physiological changes may betray stress. Among the milder of these are changes in heart action, circulatory and gastrointestinal disturbances, lowered resistance to infection or allergens, and altered sensitivity to drugs. If prolonged, these conditions can lead to more severe physiological disturbances and impaired performance. Properly selected and well motivated people who have realistic confidence in the mission and in their ability to carry it out should be good risks in this regard.	

HAZARD GROUP: Illness and Injury	NO. 7.12
TITLE: Gastrointestinal and Urinary Tract Disorders	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Environmental Control/Life Support System	
SAFETY GUIDELINE: Adequate nutritional and fluid intakes should be established, and the crew monitored to ensure that they are maintained, to guard against gastrointestinal and urinary tract disturbances.	
REFERENCES: 1. NASA CR-1205 (III), Compendium of Human Responses to the Aerospace Environment, Volume III, Sections 14 and 15, (1968). 2. NASA SP-86, Medical Aspects of an Orbiting Research Laboratory, pages 33-39, (1966).	
REMARKS: Susceptibility to these disturbances varies markedly with emotional state. This includes susceptibility to infections as well as discomforts, functional disorders, indigestion, ulcers, and kidney stones. Adequate diet and fluid intake are primary considerations. Electrolyte balance should be maintained and urine volume should be kept above the physiological minimum to prevent crystal or stone formation in the kidneys. A relaxing environment for eating will also contribute to good health.	

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HAZARD GROUP: Illness and Injury	NO. 7.13
TITLE: Hazardous Materials Accessibility	
APPLICABLE SUBSYSTEMS/FUNCTIONS: All	
SAFETY GUIDELINE: Provisions should be made to prevent unauthorized access to and use of hazardous materials, e.g., drugs, poisons, nuclear materials, and the like.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements."	
REMARKS: The operational and experimental programs of the space station/base will require significant amounts of hazardous materials to be on-board. Use of these materials by unauthorized persons or for unauthorized uses could pose a hazard to the individuals concerned through direct injury and to the crew as a whole through contamination. Also applies to the following hazard group: 1. Contamination	

HAZARD GROUP: Illness and Injury	NO. 7.14
TITLE: Health and Safety Officer(s) Training	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Operations	
SAFETY GUIDELINE: The responsible health and safety crew member(s) should be specifically trained in matters related to the health and safety of the crew.	
REFERENCES: 1. MIL 8-38130, Safety Engineering of Systems and Associated Subsystems and Equipment, General Requirements, March 1967.	
REMARKS: Special training should be given to crew members who will have the responsibility for the health and safety of personnel in the spacecraft. This responsibility includes: 1. Housekeeping aspects of the spacecraft. 2. Safe operating procedures. 3. Utilization of personnel protective equipment and clothing. 4. Identification and preliminary diagnosis of injury and disease. 5. Prognosis of illnesses. 6. Decision-making regarding quarantine requirements. 7. Administration of treatment to injured or ill crew members which includes the use of medicines and drugs.	

HAZARD GROUP: Illness and Injury	NO. 7.15
TITLE: Irrational Crew Member Restraint	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Crew System	
SAFETY GUIDELINE: A means should be provided for restraint and control of irrational crew members.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements."	
REMARKS: In view of the procedures for selection, training, indoctrination, and motivation of space crews, the probability of a crew member becoming irrational does not appear very great. The possibility does exist, however, particularly as space missions become of longer duration and crews become larger. Means of restraint, such as a straight jacket, would not seem to impose much penalty and need be effective only for such time as is necessary to evacuate the crew member to Earth.	

HAZARD GROUP: Illness and Injury**NO.** 7.16**TITLE:** Medical Emergencies**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System, Environmental Control/Life Support System, Operations, Structures/Mechanical Systems**SAFETY GUIDELINE:**

The crew should be prepared, the spacecraft equipped, and the ground complex organized to cope with medical emergencies so there is minimum hazard to crew members and minimum interference with the mission.

REFERENCES:

1. NASA SP-86, Medical Aspects of an Orbiting Research Laboratory, pages 33-39, (1966).
2. D2-113070-11, Subsystems Analysis (CS), for potential hazard of crew injury or illness.
3. D2-113070-9, Logic Diagram, Propositions 22D, 23D, 69J and 70J.

REMARKS:

Although the probability of illness will be low due to the intensive preventive medicine program for crew members, medical emergencies can occur, and might needlessly disrupt station operations if contingency plans have not been made.

Also applies to the following hazard groups:

1. Contamination
3. Decompression/Overpressure
5. Equipment Impact
10. Temperature Extremes

HAZARD GROUP: Illness and Injury	NO. 7.17
TITLE: Protective Clothing	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System	
SAFETY GUIDELINE: Crew members should be provided and wear a coverall type garment made of material which will neither burn nor melt.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 7, "Meteoroid Penetration."	
REMARKS: One of the effects of a meteoroid penetration would be an intense, though short duration, heat pulse having a flux rate as high as 1300 BTU/ft ² -sec. A non-flammable, non-melting garment would provide some protection from flash burns from this source and from other sources as well. Also applies to the following hazard groups: 2. Debris and Meteoroid Impact 6. Explosion 10. Temperature Extremes	

HAZARD GROUP: Illness and Injury	NO. 7.18
TITLE: Quarantine Regulations	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Operations	
SAFETY GUIDELINE: All approved quarantine regulations should be enforced by the Health and Safety Officer with the concurrence and backing of the spacecraft commander.	
REFERENCES: 1. D2-113070-6, Supporting Analyses, Section 6, "Human Requirements."	
REMARKS: Determination of contagious or infectious pathological conditions that in the opinion of the Health and Safety Officer require isolation and quarantine should be executed and enforced for the protection of other members of the crew. The decision to terminate the isolation imposed will be made by the Health and Safety Officer.	

HAZARD GROUP: Illness and Injury

NO. 7.19

TITLE: Radial Traffic in Artificial-Gravity Environment

APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Structures/Mechanical

SAFETY GUIDELINE:

Design of rotating spacecraft should be such that radial traffic is kept to a minimum.

REFERENCES:

1. Preliminary Technical Data for Earth Orbiting Space Stations, Volume II, Standards and Criteria, NASA, MSC-EA-R-66-1, November 1966.

REMARKS:

In a rotating spacecraft the velocity of each point along the radius varies with the radius. This requires that crew members moving radially must adjust their apparent direction of movement to compensate for velocity changes, as well as adjusting the effort required to compensate for the gravity changes. Conflicting sensory impulses from these sources, together with those from eyes and ears, may adversely affect the crew members' health and ability to perform necessary tasks safely.

HAZARD GROUP: Illness and Injury	NO. 7.20
TITLE: Radiation Casualty Evacuation	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Operations	
SAFETY GUIDELINE: In the event of severe exposure of a crew member to ionizing radiation, evacuation to Earth may be desired. If so, it should be scheduled during the latent period, that is, after first symptoms, such as nausea, disappear and before the onset of disability.	
REFERENCES: 1. Bioastronautics Data Book, NASA SP-3006, pages 145-6, (1964). 2. Compendium of Human Responses to the Aerospace Environment, NASA CR-1205 (I), Volume I, pages 3-46 to 67.	
REMARKS: Acute radiation exposure greater than 50r will probably produce gastrointestinal or nonspecific symptoms (nausea, etc.) lasting for a day or so, followed by blood disorders. Even with doses several times this large, an apparently symptom-free period of several days usually comes between the initial reaction and the subsequent longer period of radiation illness. Radiation exposure victims can be evacuated most easily during this time. Also applies to the following hazard group: 9. Radiation	

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HAZARD GROUP: Illness and Injury	NO. 7.21
TITLE: Rotation Radius Lower Limit	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations, Structures/Mechanical	
SAFETY GUIDELINE: Human factors design envelope parameters should include the establishment of a lower limit on the rotation radius, when considering an artificial-gravity environment.	
REFERENCES: 1. Preliminary Technical Data for Earth Orbiting Space Station, Volume II, Standards and Criteria, NASA, MSC-EA-R-66-1, November 1969.	
REMARKS: Artificial gravity produced by a rotating vehicle results in a gradient along the local radius vector. Thus, a man will experience a head-to-foot gravity gradient that may be expressed as a percentage of the centrifugal forces acting at the man's foot. The lower limit of the radius should be based upon a tolerable gravity gradient. (Past evidence on man's tolerance to this gradient has established this percentage at a difference of about 15 percent.)	

HAZARD GROUP: Illness and Injury

NO. 7.22

TITLE: Sanitation Standards

APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System, Environmental Control/Life Support System, Operations, Structures/Mechanical System

SAFETY GUIDELINE:

The living and personal service quarters and all areas where food, potable water, and waste products are handled should be designed for easy cleaning and sanitation so that reasonable sanitary standards can be maintained without excessive expenditure of time, energy, or supplies.

REFERENCES:

1. NASA SP-86, Medical Aspects of an Orbiting Space Station, pages 33-39, (1966).
2. NASA CR-1205 (I and III), Compendium of Human Responses to the Aerospace Environment, Volumes I and III, pages 3-43 to 46, 53, 64, 66, 81; 5-12; 13-10, 92; 15-12, 13; 16-21, (1968).

REMARKS:

Except in the case of infectious diseases or of massive infections, which seem very unlikely, stringent hygienic measures are of questionable desirability. General standards of cleanliness and sanitation similar to those for food handling establishments should prove adequate for the space station. The human body and its environment have large and varied microbial populations to which the body is adapted. Sanitary measures affect some organisms more than others. Stringent sanitation can thus cause shifts in the microbial population to which the body must readjust, sometimes becoming ill in the process.

D2-113070-5

HAZARD GROUP: Illness and Injury

NO. 7.23

TITLE: Work Station Position for Artificial-Gravity Station

APPLICABLE SUBSYSTEMS/FUNCTIONS: Operations

SAFETY GUIDELINE:

Crew living and working stations should be oriented such that, during normal activity, the lateral axis through the crew member's ears is parallel to the axis of spin. In conjunction with this guideline, the work console instruments and controls should be designed so that left-right head rotations and up-down arm motions are minimized.

REFERENCES:

1. Preliminary Technical Data for Earth Orbiting Space Station, Volume II, Standards and Criteria, NASA, MSC-EA-R-66-1, November 66.

REMARKS:

The changing forces to which man's body is subjected while moving within the spacecraft are also applied to the canals of the inner ear. The changing gravity forces and Coriolis forces which result from movement inside the spacecraft or due to movement, rotation, or cocking of the head, act on the inner ear. Such stimulation is conducive to canal sickness (motion sickness), and thus can result in a deterioration of human performance and comfort.

HAZARD GROUP: Loss of Vital Supplies	NO. 8.1
TITLE: Air Circulation	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Air circulation systems should be designed to provide continuous air circulation that will preclude the existence of stagnant air pockets within inhabited areas.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of atmosphere contamination. 2. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard No. 37. 3. D2-113070-9, Logic Diagram, Propositions 10F, 15K, 33E, 43F, 44B, 44C, 45B, and 48H.	
REMARKS: Adequate and continuous circulation of the cabin air is necessary to preclude accumulation of contaminated air pockets, ensure continuous removal of air contaminants, and provide cooling for personnel and equipment. A visual alarm should also be provided to warn the crew if the air circulation decreases below a specified limit. Air flow monitors should be located downstream of filters or other equipment which could restrict or block the airflow if not operating properly. To ensure continuous circulation of cabin air, built-in redundancy should be provided for air circulation equipment. If, as recommended in Guideline 8.9, there are multiple EC/LSS's and the crew can occupy another compartment while the malfunctioning air circulation equipment is being repaired, then this redundancy may not be necessary. All cabin air circulating fans should be protected from jamming by debris floating in zero-gravity conditions.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.2
TITLE: Airlock Oxygen Monitor	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical (S/M)	
SAFETY GUIDELINE: Oxygen usage monitors should be provided to detect abnormal oxygen use during pressurized airlock operations.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of no airlock capability. 2. D2-113070-9, Logic Diagram, Propositions 18D and 42D.	
REMARKS: Excessive loss of oxygen because of airlock or associated equipment failure can probably not be detected unless the airlock is pressurized. Therefore, a means of monitoring oxygen flow or usage in an airlock should be provided. This indication should be closely monitored whenever the airlock is pressurized. Also applies to the following hazard group: 3. Decompression/Overpressure	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.3
TITLE: Airlock Suit Loop Connections	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical (S/M), Crew System, Environmental Control/Life Support System	
SAFETY GUIDELINE: Suit loop connections should be provided in each airlock for the maximum number of crew members planned to occupy the airlock at any one time.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (S/M), for potential hazard of no airlock capability. 2. D2-113070-9, Logic Diagram, Proposition 33I.	
REMARKS: Emergency situations may arise during EVA wherein a PLSS function is degraded or lost and corrective action is required in less time than available for the complete airlock entry cycle. The proper corrective action should be provided by including pressure suit connections that are accessible from inside the airlock. These connections may also be used during normal entry and exit to conserve PLSS capability. Consideration should also be given to the possibility of using these connections and long umbilicals to enable nearby EVA without requiring a PLSS.	

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HAZARD GROUP: Loss of Vital Supplies	NO. 8.4
TITLE: Autonomous Operation of Suit Loop	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: The suit loop should have the capability of operating independently from the rest of the EC/LSS.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of suit loop. 2. D2-113070-9, Logic Diagram, Propositions 33I and 34I.	
REMARKS: Since the suit loop may be used when the EC/LSS is not operating, it is necessary that the suit loop operation not be dependent upon satisfactory operation of the EC/LSS.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.5
TITLE: Continuous Control of Cabin Pressure	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: A capability should be provided for ensuring continuous control of the cabin pressure within specified limits for crew safety.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 4-C, "Failure (of pressure retention) results from loss of subsystem function." 3. D2-113070-9, Logic Diagram, Proposition 42H.	
REMARKS: Controlling the cabin pressure within specified limits is required for crew safety. To ensure continuous control of cabin pressure, even if the primary control malfunctions, active redundancy should be provided for cabin pressure regulators. As an additional backup to parallel redundancy, a capability to operate the necessary valves manually to control cabin pressure could be provided. Also applies to the following hazard group: 3. Decompression/Overpressure	

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HAZARD GROUP: Loss of Vital Supplies

NO. 8.6

TITLE: Crew Shower Failure Protection

APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS)

SAFETY GUIDELINE:

Crew showers, or other means, used for whole-body cleaning in a weightless environment should include protection against suffocation or drowning.

REFERENCES:

1. D2-113070-11, Subsystem Analysis (CS), for potential hazard of crew injury or illness.
2. D2-113070-9, Logic Diagram, Proposition 15E.

REMARKS:

Crew shower designs for weightless environment generally use a recirculating air stream to ensure proper air flow and prevent suffocation by water collecting around the mouth and nostrils. Since the air circulation is essential to the safety of the crew member, active redundancy should be provided for the equipment performing this function or provisions should be made for automatic shut-off of the shower water if loss of air circulation occurs.

HAZARD GROUP: Loss of Vital Supplies	NO. 8.7
TITLE: Emergency Life Support Provisions	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Crew System (CS)	
SAFETY GUIDELINE: Readily available individual emergency life support equipment for the maximum number of crew members planned to occupy a given compartment at one time should be provided in that compartment.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazards of loss of cabin pressure and atmosphere contamination. 2. D2-113070-10, FT-1 (Decompression), 5-C, "Emergency equipment is non-existent at time required." 3. D2-113070-9, Logic Diagram, Propositions 8C, 44B, 44C and 48C.	
REMARKS: The safety of crew members in a compartment could be compromised if the atmosphere becomes uninhabitable due to low pressure or atmosphere contamination. The crew may not be able to leave the compartment in time to avoid the emergency, or it may be necessary to perform some tasks under the unfavorable atmospheric condition. Therefore, emergency life support provisions should be available to each member of the crew that may be in the compartment. This may require more than one type of life support provision; e.g., oxygen masks connected to an oxygen supply for use in contaminated atmospheres, or full pressure suits for use in a compartment where the pressure is too low for crew safety. Also applies to the following hazard groups: 1. Contamination 3. Decompression/Overpressure 10. Temperature Extremes	

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HAZARD GROUP: Loss of Vital Supplies		NO. 8.8
TITLE: Emergency Pressurization Oxygen Supply		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)		
SAFETY GUIDELINE: A separate completely independent oxygen supply should be provided for emergency pressurization.		
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), of potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 5-C, "Emergency equipment is non-existent at time required." 3. D2-113070-9, Logic Diagram, Proposition 33I.		
REMARKS: During long-duration missions, an emergency situation may occur in a depressurized compartment where it is necessary to repressurize rapidly in the interest of crew safety. A separate and independent oxygen supply should be provided for this purpose and it should be capable of rapidly pressurizing a compartment to the oxygen pressure level required for crew survival. Also applies to the following hazard group: 3. Decompression/Overpressure		

HAZARD GROUP: Loss of Vital Supplies	NO. 8.9
TITLE: Environmental Control/Life Support Systems (EC/LSS) Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System	
SAFETY GUIDELINE: A space station should include at least two independent EC/LSS's located in separate compartments. These systems should be capable of supplying the atmospheric requirements even with one system inoperative.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 1-E, "Decompression results from failure of spacecraft pressure retention." 3. D2-113070-9, Logic Diagram, Propositions 8C, 34C and 42H.	
REMARKS: A space station should be able to sustain major damage to a compartment or the equipment located therein without total loss of EC/LSS capability. One means of accomplishing this is to provide at least two completely independent EC/LSS's, which are located in separate compartments to minimize the possibility of damage to more than one system simultaneously.	

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HAZARD GROUP: Loss of Vital Supplies

NO. 8.10

TITLE: Interlocks for Equipment with Critical Operating Ranges

APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System
(EC, SS)

SAFETY GUIDELINE:

Equipment that cannot safely perform its function in a system unless it is operating within a specific operating range, e.g., temperature or pressure limits, should have interlocks incorporated to preclude its use in the system when it is not operating in the proper range.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of atmosphere contamination.
2. D2-113070-9, Logic Diagram, Propositions 6B and 9C.

REMARKS:

Some equipment used in space station systems may require that it operate within specific temperature, pressure, or other parameter limits in order to perform its function safely; e.g., catalytic burners have a minimum temperature operating limit. This equipment should incorporate interlocks in its circuits to prevent their operation in the system when the equipment critical operating parameters are not within specified limits.

Also applies to the following hazard group: 1. Contamination

HAZARD GROUP: Loss of Vital Supplies	NO. 8.11
TITLE: Oxygen Leak Isolation	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Oxygen storage and distribution systems should have provisions to isolate sources of oxygen leakage.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of oxygen. 2. D2-113070-10, FT-1 (Decompression), 1-D, "Decompression eventuates from loss of spacecraft pressure supply." 3. D2-113070-9, Logic Diagram, Proposition 15K.	
REMARKS: Once excessive oxygen usage has been identified it will be necessary to shut off the supply of oxygen to the leakage point until the situation has been corrected. To effectively control as much of the system as possible, an oxygen shut-off device should be located as close to the oxygen supply sources as practicable.	

D2-113070-5

HAZARD GROUP: Loss of Vital Supplies

NO. 8.12

TITLE: Oxygen Quantity and Usage

APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System
(EC/LSS)

SAFETY GUIDELINE:

A visual and audible alarm should be provided to warn of excessive oxygen use rates and low oxygen quantity. This alarm should be provided both in the affected space station compartment and at the command and control center(s).

REFERENCES:

1. D2-113070-11, Subsystems Analysis (EC/LSS) for potential hazard of loss of oxygen.
2. D2-113070-10, FT-1, (Decompression), 1-D, "Decompression eventuates from loss of spacecraft pressure supply."
3. D2-113070-9, Logic Diagram, Propositions 15K and 48H.

REMARKS:

The space station crew should be warned of excessive usage of oxygen supplies which, if allowed to continue, would affect crew safety. Procedures should also be developed for correcting excessive use of oxygen. Some causes of excessive oxygen usage to be considered are leakage from tanks, valves, and plumbing; regulator failures; and vehicle-to-space leakage.

HAZARD GROUP: Loss of Vital Supplies	NO. 8.13
TITLE: Oxygen Regulation Component Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Active redundancy should be provided for components which control and regulate the cabin atmosphere oxygen partial pressure.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of oxygen. 2. D2-113070-10, FT-1, (Decompression), 4-C, "Failure of pressure retention results from loss of subsystem function." 3. D2-113070-9, Logic Diagram, Propositions 10F and 44C.	
REMARKS: The oxygen partial pressure of the atmosphere in all inhabited compartments of the space station is critical to crew safety. To ensure continuous operation of the oxygen partial pressure regulation function, even if the primary regulating device fails, an alternate regulating device should be provided.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.14
TITLE: Oxygen Storage Tanks Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Oxygen supplies should be stored in more than one tank or other storage device.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS) for potential hazard of loss of oxygen. 2. D2-113070-10, FT-1 (Decompression), 1-D, "Decompression eventuates from loss of spacecraft pressure supply. 3. D2-113070-9, Logic Diagram, Proposition 33I.	
REMARKS: Since oxygen is vital to life support of the crew, the oxygen supply system should be designed so that a single failure will not result in a total loss of the oxygen supply. Consideration should be given to locating the oxygen tanks with sufficient separation or adequate shielding so that disintegration of one tank will not affect another. Determination of the number and sizes of the oxygen tanks to be used should involve consideration of the resupply requirements. If oxygen tanks are to be exchanged during resupply, the size of the tanks may dictate additional requirements for the handling and transfer of the oxygen tanks from the resupply vehicle to the space station. Also applies to the following hazard groups: 1. Contamination 6. Explosion	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.15
TITLE: Oxygen Usage Manual Control	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: The oxygen partial pressure in the atmosphere of pressurized compartments should be capable of manual control.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of oxygen. 2. D2-113070-10, FT-1 (Decompression), 1-D, "Decompression eventuates from loss of spacecraft pressure supply." 3. D2-113070-9, Logic Diagram, Proposition 48F.	
REMARKS: In case of failure of the automatic control for the cabin atmosphere oxygen partial pressure, the crew should have the capability to manually control and regulate oxygen partial pressure until automatic control can be restored.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.16
TITLE: PLSS Emergency Backup	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/ Life Support System, Operations	
SAFETY GUIDELINE: An emergency backup capability should be provided for PLSS used with the pressure suits.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure. 2. D2-113070-10, FT-1 (Decompression), 1-F, "Decompression eventuates from loss of pressure suit supply." 3. D2-113070-9, Logic Diagram, Propositions 8C, 18D and 33I.	
REMARKS: There is the possibility of a PLSS failure occurring to a crewman on EVA which could prevent his return to a safe haven, such as an airlock. Therefore, an independent, emergency life support system of sufficient duration to allow return to the space station should be available.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.17
TITLE: Pressure Leak Detectors	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS), Structures/Mechanical System (S/M)	
SAFETY GUIDELINE: Cabin pressure leak detection sensors should be strategically located in the space station to detect any leakage in the structural pressure shell or pressure seals of the space station. The sensor should activate an alarm within the affected compartment and also at the command and control center(s).	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 1-J, "Failure of pressure retention results from failure of structural matrix." 3. D2-113070-9, Logic Diagram, Propositions 8C, 18E and 34C.	
REMARKS: If a total pressure loss alarm is activated or if a pressure leak is not large enough to activate an alarm, it will be necessary to know if leakage is occurring through the pressure shell or pressure seals, and the location of the leakage, so that appropriate corrective action may be taken. Also applies to the following hazard group: 3. Decompression/Overpressure	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.18
TITLE: Pressure Relief Valve Repair Procedures	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: A means should be provided to bypass or inactivate failed cabin pressure relief valves.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of cabin pressure. 2. D2-113070-10, FT-1 (Decompression), 4-C, "Failure (of pressure retention) results from loss of subsystem function." 3. D2-113070-9, Logic Diagram, Proposition 8C.	
REMARKS: A failed-open cabin pressure relief valve could result in the cabin pressure decreasing below the limits normally specified for crew safety, and/or in excessive loss of cabin atmosphere. This indicates a need to inactivate or bypass the operation of the failed valve until the failure can be corrected. Two means which could be considered to accomplish this function are: redundant relief valves in series, or a capability to close an open relief valve manually. Also applies to the following hazard group: 3. Decompression/Overpressure	

HAZARD GROUP: Loss of Vital Supplies

NO. 8.19

TITLE: Pressure Suit/PLSS Atmosphere Composition

APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/
Life Support System (EC/LSS), Operations**SAFETY GUIDELINE:**

Consideration should be given to using a pressure suit/PLSS combination that is designed to operate at pressures and gas compositions which will ensure a safe and rapid transition from the space station atmosphere.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure.
2. D2-113070-9, Logic Diagram, Propositions 44C and 44E.

REMARKS:

Present pressure suit/PLSS designs generally use a much lower suit pressure and a different atmosphere composition than is planned for the space station. This situation will require a period of denitrogenization by breathing 100 percent O₂ at space station pressures before transition to the lower space suit pressure in order to avoid the possibility of "bends." If the two atmospheres were more compatible the denitrogenation requirement could be decreased or eliminated with a proportionate increase in crew safety.

Also applies to the following hazard group: 7. Illness and Injury

HAZARD GROUP: Loss of Vital Supplies**NO.** 8.20**TITLE:** Pressure Suit/PLSS CO₂ Monitor**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS), Environmental Control/
Life Support System (EC/LSS)**SAFETY GUIDELINE:**

A visual and/or audible alarm should be provided to a pressure-suited crew member to warn him of excessive CO₂ concentration in the suit atmosphere. This alarm should also be provided at an EVA monitoring console.

REFERENCES:

1. D2-113070-11, Subsystem Analysis (CS), for potential hazard of EVA equipment failure.
2. D2-113070-9, Logic Diagram, Propositions 18D and 45E.

REMARKS:

The CO₂ removal capability of the PLSS is of limited duration. Therefore, it is important that a person using the PLSS and pressure suit be aware of excessive levels of CO₂ which could affect his safety. Sufficient warning should be given to allow the crew member to reach a safe haven. Procedures should also be established to ensure that a crew member using a PLSS knows what CO₂ removal capability is available.

Also applies to the following hazard group: 1. Contamination

HAZARD GROUP: Loss of Vital Supplies	NO. 8.21
TITLE: Pressure Suit/PLSS Oxygen Usage	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/ Life Support System (EC/LSS)	
SAFETY GUIDELINE: A visual and/or audible alarm should be provided to a pressure suited crew member to warn him of excessive oxygen use rates and low oxygen quantity for the PLSS. This alarm should also be provided at an EVA monitoring console.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure. 2. D2-113070-10, FT-1 (Decompression), 2-B, "Loss of pressure suit pressure retention results from suit assembly failure." 3. D2-113070-9, Logic Diagram, Proposition 15K.	
REMARKS: The PLSS used with the pressure suit has a limited duration capability. Therefore, it is important that a person using this equipment be aware of excessive usage rate of the oxygen supply and also of a low oxygen quantity. This should allow the crew member to reach a safe haven before the supply is depleted or to take any necessary corrective action. Procedures should also be established to ensure that a crew member using a PLSS knows what oxygen capability is available. Also applies to the following hazard group: 3. Decompression/Overpressure	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.22
TITLE: Pressure Suit/PLSS Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/ Life Support System (EC/LSS)	
SAFETY GUIDELINE: Redundant or spare pressure suits and PLSS's should be provided in each separately inhabited compartment of the space station.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure. 2. D2-113070-9, Logic Diagram, Propositions 8C, 10F and 33I.	
REMARKS: Emergency life support provisions in each inhabited compartment of the space station could include pressure suits and PLSS's. To ensure availability of operating equipment to all occupants of a compartment, a certain number of redundant (spare) pressure suits and PLSS's should be provided.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.23
TITLE: Pressure Suit Temperature and Humidity Monitoring	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Crew System (CS), Environmental Control/ Life Support System (EC/LSS)	
SAFETY GUIDELINE: A visual and/or audible alarm should be provided to a pressure-suited crew member to warn him of out-of-tolerance temperature or humidity levels in the suit atmosphere. This alarm should also be provided at an EVA monitoring console.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure. 2. D2-113070-9, Logic Diagram, Propositions 18D, 44B and 44D.	
REMARKS: The PLSS used with pressure suits is designed to keep the suit atmosphere within certain temperature and humidity ranges. These ranges are specified to ensure a suit environment that will effectively sustain a person during EVA. If these limits are exceeded the performance of the suited crew member may be degraded enough to endanger his safety.	

HAZARD GROUP: Loss of Vital Supplies		NO. 8.24
TITLE: Suit Loop Checkout		
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)		
SAFETY GUIDELINE: Procedures should be developed for a checkout of suit loop operation at regularly scheduled intervals.		
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of loss of suit loop. 2. D2-113070-10, FT-1 (Decompression), 1-F, "Decompression eventuates from loss of pressure suit supply"; and 1-G, "Decompression results from failure of pressure suit pressure retention." 3. D2-113070-9, Logic Diagram, Proposition 10G.		
REMARKS: The suit loop is usually used only in emergency situations as a backup to the EC/LSS. Since it is not used regularly and must be operational when needed, the suit loop operation must be checked out periodically to ensure that it will be available when required.		

HAZARD GROUP: Loss of Vital Supplies	NO. 8.25
TITLE: Suit Loop Components Maintenance	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: The suit loop should have the capability for easy isolation of, accessibility to and replacement of faulty components.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of loss of suit loop. 2. D2-113070-10, FT-1 (Decompression), 1-F, "Decompression eventuates from failure of pressure suit supply." 3. D2-113070-9, Logic Diagram, Propositions 10G and 48F.	
REMARKS: Since operation of the suit loop is critical to the safety of the crew, the system should be designed and the equipment installed so that a faulty component can be readily identified and replaced before the redundant unit malfunctions.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.26
TITLE: Suit Loop Component Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Redundancy should be provided for equipment which is essential to the operation of the suit loop.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS) for potential hazard of loss of suit loop. 2. D2-113070-10, FT-1 (Decompression), 1-F, "Decompression eventuates from failure of pressure suit supply." 3. D2-113070-9, Logic Diagram, Proposition 10F.	
REMARKS: The suit loop is usually used only in emergencies as a backup to the EC/LSS. Therefore, when its operation is needed, it is imperative that the suit loop perform continuously and satisfactorily. To ensure continuous operation of the suit loop, redundancy should be provided for the critical equipment in this system.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.27
TITLE: Suit Loop Manual Control	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: A capability for manually controlling operation of the equipment used in the suit loop should be considered.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of loss of suit loop. 2. D2-113070-10, FT-1 (Decompression), 1-F, "Decompression eventuates from loss of pressure suit supply." 3. D2-113070-9, Logic Diagram, Propositions 18E and 27E.	
REMARKS: Situations may arise where normal control of the suit loop is inoperative and it would be advantageous to have the capability to manually control the suit loop operation until normal control can be re-established.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.28
TITLE: Suit Loop Outlets	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Readily available suit loop outlets for the maximum number of crew members planned to occupy a given compartment at one time should be provided in that compartment.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of suit loop. 2. D2-113070-10, FT-1 (Decompression), 1-F, "Decompression eventuates from failure of pressure suit supply." 3. D2-113070-9, Logic Diagram, Proposition 45B.	
REMARKS: Emergency life support provisions in each inhabited compartment could include suit loop outlets which should be available in sufficient quantity that they can be used by all crew members that may be in the compartment. There should be a few extra (redundant) outlets provided to accommodate malfunctions or unanticipated crew members.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.29
TITLE: Suit Loop Pressure Monitor	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: While the suit loop is in operation, the suit loop pressure should be monitored continuously and a warning provided to the crew if the pressure deviates from prescribed limits.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of loss of suit loop. 2. D2-113070-10, FT-1 (Decompression), 1-F, "Decompression eventuates from failure of pressure suit supply." 3. D2-113070-9, Logic Diagram, Proposition 44E.	
REMARKS: Maintaining the suit loop pressure within prescribed limits is essential to proper operation of the suit loop. The crew should be warned of any deviation from these limits so that they can take the necessary corrective action.	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.30
TITLE: Warning System--Oxygen Pressure	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: A visual and audible warning and alarm system should be provided to warn of cabin oxygen partial pressure which is not within prescribed limits for crew safety. This alarm should be provided both in the affected space station compartment and at the command and control center(s).	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of oxygen. 2. D2-113070-10, FT-1 (Decompression), 1-E, "Decompression results from failure of spacecraft pressure retention." 3. D2-113070-9, Logic Diagram, Propositions 44C, 48H and 48I.	
REMARKS: The space station crew should be warned of out-of-tolerance oxygen partial pressures in any pressurized compartment which, if allowed to continue, could affect crew safety. Procedures should also be developed for controlling the space station atmosphere after this warning has been received. Also applies to the following hazard group: 3. Decompression/Overpressure	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.31
TITLE: Water Contamination Control Procedures	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Procedures and equipment should be provided for reclaiming or disposing of contaminated water, and restoring the equipment to acceptable cleanliness criteria.	
REFERENCES: 1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of water contamination. 2. D2-113070-9, Logic Diagram, Propositions 30D and 76C.	
REMARKS: If the water supply becomes contaminated the crew should be able to take the necessary corrective action to restore system cleanliness. Therefore, emergency procedures should be provided for reclaiming the water, if possible, or disposing of the water, eliminating the source of contamination, and restoring system cleanliness. Also applies to the following hazard group: 1. Contamination	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.32
TITLE: Water Sterilization Equipment Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Redundancy should be provided for equipment which is essential to maintaining acceptable sterility of the water supply.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of water contamination. 2. D2-113070-9, Logic Diagram, Propositions 10F and 30D.	
REMARKS: Water is used for a number of functions associated with crew life support and habitability. The sterility requirements for the water will differ depending upon its intended use. Water used for drinking and food preparation must be of good quality or crew illness may result. Therefore, to ensure continuous operation of the sterilization function for critical water supplies, redundancy should be provided for this equipment. Also applies to the following hazard group: 1. Contamination	

HAZARD GROUP: Loss of Vital Supplies	NO. 8.33
TITLE: Water Storage Tanks Redundancy	
APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS)	
SAFETY GUIDELINE: Water supplies should be stored in more than one tank or other storage device.	
REFERENCES: 1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of water contamination. 2. D2-113070-9, Logic Diagram, Propositions 31G and 59B.	
REMARKS: Water is vital to life of the crew and the water supply system should, therefore, be designed so that a single failure or contamination of one tank will not result in loss of the total water supply. Determination of the number and sizes of the water tanks to be used should involve consideration of the logistics resupply requirements. If water tanks are to be exchanged during resupply, the size of the tanks may dictate additional requirements for the handling and transfer of the water tanks from the resupply vehicle to the space station. Also applies to the following hazard group: 1. Contamination	