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# SPACE STATION

# SAFETY STUDY

## CREW SAFETY GUIDELINES

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

THE BOEING COMPANY
AEROSPACE SYSTEMS DIVISION, SEATTLE, WASHINGTON

NASA CR 108288

# SPACE STATION SAFETY STUDY

MSC-00189

# CREW SAFETY GUIDELINES

VOLUME II

**D2-113070-5**

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
Houston, Texas

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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

- 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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## 3.0 CREW SAFETY GUIDELINES

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

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| 3.2 | Debris and Meteoroid Impact | -- Nos. 2.1 through 2.4 |
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| | |
|---|---|
| **HAZARD GROUP:** Radiation | **NO.** 9.1 |
| **TITLE:** Controlled Access and Use of Radiation Sources | |
| **APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Experiments | |

**SAFETY GUIDELINE:**

Unauthorized personnel should be restricted from using radiation-producing equipment or handling and using on-board radioisotopes. Consider the installation of appropriate caution signs and/or other means of warning, featuring visible or audible signals.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 3-H, "Misapplication or misuse of on-board radiation source."

**REMARKS:**

The probability of misapplication or misuse of on-board radiation sources would be at a minimum if control of the accessibility and use is restricted to only qualified personnel.

**HAZARD GROUP:** Radiation

**NO.** 9.2

**TITLE:** Disposal of Radioactive Material

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Electrical Power (EP)

**SAFETY GUIDELINE:**

Safe procedures should be established for the disposal of radioactive waste or radiation-contaminated material. These procedures should also include the actions necessary for the disposal of a spent or failed nuclear power reactor.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 1-I, "Crew members are exposed to a radiation source."

**REMARKS:**

Safe methods of radioactive waste disposal should be consistent with standard laboratory practices. For low-level waste, consider returning it to Earth for disposal or destruction within the Earth's atmosphere. Special consideration should be given to the disposal of higher-level radiation waste where return to Earth or contamination of Earth's atmosphere may be hazardous.

Also applies to the following hazard group: 1. Contamination

**HAZARD GROUP:** Radiation

**NO.** 9.3

**TITLE:** Handling and Use of Radioactive Material

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Structures/Mechanical Systems, Experiments, Crew System

**SAFETY GUIDELINE:**

On-board handling and use of radioactive material or radiation-producing equipment should conform or be consistent with established NASA and Atomic Energy Commission policy and procedures for radiation protection standards.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 3-H, "Misapplication or misuse of on-board radiation source."
2. SP4-41-S, Radiological Safety Handbook, NASA Safety Office.

**REMARKS:**

Latest available established procedures in the handling and use of radioactive material should be made readily available to all parties involved in spacecraft planning and design where such materials are a factor. Final decisions and the means of implementing them should be subject to the approval of a control board.

| | |
|---|---|
| **HAZARD GROUP:** Radiation | **NO.** 9.4 |

**TITLE:** Microwave and X-Radiation Hazard

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Should radar and/or communications equipment exist on-board or within the vicinity of the spacecraft with effective radiated power sufficient to present a hazard from exposure to the produced RF or X-radiation, then positive protective measures should be taken to prevent accidental personnel exposure.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 1-C, "Crew members will be injured by non-ionizing radiation."

**REMARKS:**

Personnel protection measures may be utilized through the proper application of controlled access areas, equipment interlocks, and warning systems. Areas of particular attention should be the fields of radiation produced by any energized antenna, waveguide, feed-horn structure, transmission lines, or high-voltage electronic equipment.

**HAZARD GROUP:** Radiation

**NO.** 9.5

**TITLE:** Nuclear Power Radiation Protection

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power (EP), Structures/Mechanical

**SAFETY GUIDELINE:**

Nuclear powered electrical power sources should be located and shielded to protect crew members from accumulating excessive radiation dosage.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of power source radiation.
2. D2-113070-10, FT-3 (Radiation), 1-M, "Crew members lack radiation protection due to inadequate radiation shielding"; 3-K, "Nuclear power reactor provides a radiation source"; and 5-H, "Shielding is not adequate, by design, to protect against the expected environment.
3. D2-113070-6, Supporting Analyses, Section 3, "Analysis of Operations."
4. D2-113070-9, Logic Diagram, Propositions 57B, 57D, 57E and 57F.

**REMARKS:**

The protection afforded the crew from the space radiation environment by the basic structural and equipment arrangements will probably not be adequate for protection from the nuclear power source radiation. Furthermore, there are activities external to the space base, e.g., EVA, logistics support, free-flying experiments, etc., that must also be protected. Location and shielding of the nuclear power source must take these factors into account. Consideration in selection of the type of nuclear power to be used should be given to the types and quantities of radiation produced and the difficulty of providing adequate protection.

**HAZARD GROUP:** Radiation

**NO.** 9.6

**TITLE:** Nuclear Power Unit Radiation Protection

**APPLICABLE SUBSYSTEMS/FUNCTIONS.** Operations, Electrical Power System

**SAFETY GUIDELINE:**

Crew location during the Nuclear Power Unit activation should be restricted to refuge areas affording high protective shielding, until radiation levels have been checked in all habitable areas within the spacecraft and have been found to be within acceptable limits.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Paragraph 3.2.8, "Nuclear Power Unit."
2. D2-113070-10, FT-3 (Radiation), 3-K, "Nuclear power reactor provides a radiation source."

**REMARKS:**

No data exists on the use of a nuclear power unit in manned space operations. This guideline is suggested as a precautionary measure until sufficient data or experience has been accumulated, with hardware designed to afford radiation shielding for space crews from a nuclear power unit, to achieve a high level of confidence in crew protection during normal activities.

**HAZARD GROUP:** Radiation

**NO.** 9.7

**TITLE:** Nuclear Reactor Safety

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power (EP)

**SAFETY GUIDELINE:**

Spacecraft power or propulsion systems employing the nuclear reactor concept should provide fail-safe measures for emergency shut-down of a reactor and provide alternate methods of reactor heat dissipation in event of failure of the primary cooling system.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 3-K, "Nuclear power reactor provides a radiation source."
2. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
3. D2-113070-9, Logic Diagram, Propositions 8E, 57D and 58D.

**REMARKS:**

Any failure resulting in the reactor's critical mass becoming uncontrolled would be hazardous to personnel due to the increased gamma and neutron radiation.

Also applies to the following hazard group: 10. Temperature Extremes

| HAZARD GROUP: Radiation | NO. 9.8 |
|---|---|

**TITLE:** Orbital Path Radiation Environment

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System, Operations

**SAFETY GUIDELINE:**

The spacecraft radiation protection provisions should be consistent with the orbital flight path type, orbital height, and inclination selected.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 3-E, "An artificial radiation source external to the spacecraft is present."

**REMARKS:**

The near-Earth radiation environment is a function of the orbital inclination, height, and type of orbit (e.g., synchronous versus circular or elliptical orbit). Thus, the radiation shielding and protection provisions should be in accord with the selected orbital flight path.

**HAZARD GROUP:** Radiation

**NO.** 9.9

**TITLE:** Placement of Equipment and Stores

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Spacecraft design and layout should make maximum use of any on-board mass as radiation shielding.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 1-M, "Crew members lack radiation protection due to inadequate radiation shielding."
2. D2-113070-11, Subsystems Analysis (CS), for potential hazard of radiation.
3. D2-113070-9, Logic Diagram, Propositions 32E and 51B.

**REMARKS:**

Additional radiation shielding might be accomplished through strategic placement of spacecraft equipment, stores, tanks, etc., between the radiation source and the habitable volume.

**HAZARD GROUP:** Radiation

**NO.** 9.10

**TITLE:** Protection Against Nuclear Explosion Radiation

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS)

**SAFETY GUIDELINE:**

Protection of the space station crew against the effects of a nuclear device explosion in space that releases radiation into the space station's orbital path should be considered.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of radiation.
2. D2-113070-10, FT-3 (Radiation), 3-J, "A nuclear induced artificial orbital radiation environment is present."
3. D2-113070-9, Logic Diagram, Propositions 8E and 32E.

**REMARKS:**

There is a possibility that during a long-duration Earth orbital space mission a nuclear device may be exploded in space at an altitude which will release radiation into the orbital path of the space station. If the explosion takes place near enough to the space station it may not be possible to provide sufficient shielding for protection. Then consideration could be given to changing the orbit altitude. As a last resort, the space station would have to be abandoned and the crew returned to Earth. Procedures should be established to cover the various possible contingencies and the actions to be taken.

| | |
|---|---|
| **HAZARD GROUP:** Radiation | **NO.** 9.11 |

**TITLE:** Radiation Detectors Location and Characteristics

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management System, Crew System

**SAFETY GUIDELINE:**

The location and characteristics of the radiation detectors should be consistent with the expected radiation environment.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 4-0, "Radiation type present is incompatible with the warning system employed"; and 4-P, "The radiation level warning system is isolated from the radiation source."

**REMARKS:**

Due to anisotropy and the variation in energy, intensity, and types of radiation particles in the projected orbits for a spacecraft, considerable effort may be required to define the optimum detector characteristics and location for the radiation monitoring and warning system.

**HAZARD GROUP:** Radiation

**NO.** 9.12

**TITLE:** Radiation Effects upon Spacecraft Materials

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Radiation effects upon spacecraft electronic materials, microelectronic circuit elements, electrical systems, metals, ceramics, polymers, and other organic and inorganic materials should be thoroughly investigated for radiation-induced transient and permanent effects in terms of false signals, degradation, catastrophic failures, and contamination.

**REFERENCES:**

1. D2-113070-9, Logic Diagram, Propositions 9B and 32E.

**REMARKS:**

An analysis of spacecraft material response to the mission radiation environment should be required to insure safe and reliable system operation.

**HAZARD GROUP:** Radiation

**NO.** 9.13

**TITLE:** Radiation Environment Restrictions on EVA

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

In low-inclination (up to 60°), low-altitude orbits, Extra-Vehicular Activity should not be scheduled while the spacecraft is passing through the South Atlantic Anomaly. For polar orbit, the same guideline applies; but, in addition, the occurrence of a solar event should require that EVA be avoided for that portion of the orbit which is not protected by the magnetic field.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 5-F, "Exposure due to lack of shielding occurs during suited EVA operations.".

**REMARKS:**

Maximum expected radiation exposure of any personnel exposed outside the spacecraft would occur during passage through the above areas.

**HAZARD GROUP:** Radiation

**NO.** 9.14

**TITLE:** Radiation Exposure and Control Program

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

A mission radiation control program should be instituted to develop radiation exposure limits, procedures, design criteria, and responsibilities consistent with the expected mission environment and period of orbital stay.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 1-B, "Crew members will be injured by ionizing radiation."

**REMARKS:**

Radiation exposure and control is currently handled in accordance with NASA standards for radiation exposure. Yet a thorough investigation should be conducted to ensure that these standards are applicable to the Earth space system environment and the projected period of orbital stay.

| | |
|---|---|
| **HAZARD GROUP:** Radiation | **NO.** 9.15 |

**TITLE:** Radiation Exposure Record

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS), Operations

**SAFETY GUIDELINE:**

A cumulative radiation exposure record should be kept on each crew member, and personnel who have reached the limit of safe radiation exposure should be returned to Earth without delay.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 1-B, "Crew members will be injured by ionizing radiation"; and 4-G, "Accumulated radiation exposure not recognized."
2. D2-113070-11, Subsystems Analysis (CS), for potential hazard of radiation.
3. D2-113070-9, Logic Diagram, Proposition 32E.

**REMARKS:**

A cumulative radiation exposure record should be mai tained for each crew member and reviewed at periodic intervals in order to prevent overexposure to radiation and the potential ill effects of such overexposure.

**HAZARD GROUP:** Radiation

**NO.** 9.16

**TITLE:** Radiation Haven

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical Systems, Crew System (CS), Electrical Power System (EP)

**SAFETY GUIDELINE:**

Provision should be made in the spacecraft for a designated shelter that would serve as a haven for radiation protection against possible high-intensity radiation events. This shelter should contain the necessary life support equipment and provisions consistent with the maximum expected stay time for the particular mission profile.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 2-H, "Flare-produced high energy solar particles are present."
2. D2-113070-11, Subsystems Analysis (CS and EP), for potential hazards of solar and power source radiation.
3. D2-113070-9, Logic Diagram, Propositions 8E, 30C, 30D, 30E, 40C and 42D.

**REMARKS:**

During an extended orbital space mission, at least one high-intensity solar flare event may be expected to occur. Thus, if the spacecraft structure and equipment do not inherently provide the protection required, a special haven of maximum protection may be required. The haven should be self-sufficient so the crew can operate the necessary station functions and also take care of their own necessities for the maximum expected shelter time. The haven design should also take into account the possibility of crew protection against excessive radiation from a malfunctioning nuclear power source or failure of its shielding.

**HAZARD GROUP:** Radiation

**NO.** 9.17

**TITLE:** Radiation Monitoring

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS)

**SAFETY GUIDELINE:**

Radiation monitoring, including cumulative radiation level records, should be maintained to ensure the precise determination and provide clear notification of radiation conditions and warning of possible over-irradiation of the spacecraft. The detection system should continuously monitor the interior and exterior radiation levels and record the accumulated dosage for the mission.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 4-D, "Deficient personnel radiation exposure monitoring provisions (dosimetry)."
2. D2-113070-11, Subsystems Analysis (CS), for potential hazard of radiation.
3. D2-113070-9, Logic Diagram, Propositions 10F, 18D and 40B.

**REMARKS:**

As a suggested minimum, at least two types of radiation detection instrumentation should be used. One system would monitor continuously the radiation intensity or dose rates, and the other would measure the cumulative dose for the mission. The monitoring system should be redundant to ensure continuous operation. Also, continuous radiation monitoring should be conducted by Earth-based stations as added assurance of early detection of radiation.

**HAZARD GROUP:** Radiation

**NO.** 9.18

**TITLE:** Radiation Protection during EVA

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical Systems, Electrical Power System (EP)

**SAFETY GUIDELINE:**

Additional protection for crew members performing EVA in the proximity of a nuclear power source should be provided.

**REFERENCES:**

1. D2-113070-11, Subsystem Analysis (EP), for potential hazard of power source radiation.
2. D2-113070-10, FT-3 (Radiation), 5-C, "Crew members lack radiation shielding while exterior to the spacecraft."
3. D2-113070-9, Logic Diagram, Proposition 58D.

**REMARKS:**

Total shielding coverage of a nuclear power source may not be possible because of cooling requirements of the power source. This means there will be areas surrounding the power source that are not adequately shielded to protect EVA crew members. Therefore, consideration should be given to providing some additional temporary shielding to protect persons working near a nuclear power source.

**HAZARD GROUP:** Radiation

**NO.** 9.19

**TITLE:** Radioactive Stores

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System, Environmental Control/Life Support System

**SAFETY GUIDELINE:**

Areas where radioactive materials are used or stored should be monitored for radioactive contamination, and suitable warnings provided if radioactivity exceeds established limits.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 7-D, "Internal exposure results from inhalation of radiation particles."

**REMARKS:**

Also applies to the following hazard group: 1. Contamination

**HAZARD GROUP:** Radiation

**NO.** 9.20

**TITLE:** Spacecraft Radiation Shielding

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical Systems

**SAFETY GUIDELINE:**

Spacecraft provisions for radiation shielding should provide the effective shield thickness required to protect against exceeding an established mission radiation dose limit.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 1-M, "Crew members lack radiation protection due to inadequate radiation shielding."

**REMARKS:**

As a design goal, the interior of the spacecraft should be sufficiently shielded so that the radiation environment experienced by the crew within the spacecraft would be similar to the terrestrial radiation environment. This could be accomplished by either specific shielding material, equipment arrangement, or a combination of both.

| | |
|---|---|
| **HAZARD GROUP:** Radiation | **NO.** 9.21 |

**TITLE:** Selection of Materials for Use in Radiation Environment

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Precautions should be taken in the selection of spacecraft materials to ensure that the materials will not support induced radiation.

**REFERENCES:**

1. D2-113070-10, FT-3 (Radiation), 5-K, "Shielding becomes inadequate due to effect of induced radiation"; and 5-P, "Shielding material of a type that sustains radioactivity is used in the spacecraft."

**REMARKS:**

Certain metallic materials when exposed to radiation for a period of time will support radioactive production. The intent of this guideline is to ensure radiation compatibility with materials selected for the long-duration space mission.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.1

**TITLE:** $CO_2$ Control Equipment Maintenance

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

**SAFETY GUIDELINE:**

Maintenance procedures for $CO_2$ control equipment should take into account the possible high operating temperatures of the equipment and the possibility of release of contaminants during maintenance.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of excessive $CO_2$.
2. D2-113070-9, Logic Diagram, Propositions 10G, 32B, 48F and 61E.

**REMARKS:**

Many $CO_2$ control concepts involve operating temperatures of 500-1800$^\circ$F and the production of carbon, both of which have an adverse affect on maintenance. Consideration must be given in the design of this equipment to the problems of access, working on hot equipment or providing insulation, requirements for long cool-off periods, use of high temperature seals, carbon removal without contaminating the cabin atmosphere, evacuation of gases, and purging of equipment to preclude cabin air contacting hot gases or carbon.

Also applies to the following hazard group: 1. Contamination

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.2

**TITLE:** Combustible Waste Materials

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

The storage and disposal of combustible waste materials should be such that a fire hazard or traffic obstruction is not created.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 6-G, "Combustible materials are present," 9-E, "Impeded access prevents effective control of fire," and 19-F, "Physical object within compartment obstructs escape route."

**REMARKS:**

Storage and disposal of all waste materials can be expected to be a problem. Combustible waste, because of the fire hazard, is particularly critical. Consideration should be given to returning this material to Earth at frequent intervals.

| HAZARD GROUP: Temperature Extremes | NO. 10.3 |
| --- | --- |

**TITLE:** Containment of Fire

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Environmental Control/Life Support System, Structures/Mechanical Systems

**SAFETY GUIDELINE:**

Flame arresters should be provided in all ducting through which flame could propagate.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 19-E, "Compartment escape route is obstructed due to fire."

**REMARKS:**

Fire could spread from one compartment to another through the ECS or other ducting.

Also applies to the following hazard group: 1. Contamination

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.4

**TITLE:** Cryogenics

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Cryogenic piping systems should provide for both automatic and manual emergency shut-off.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 4-D, "Injury results from contact with cryogenic fluid."

**REMARKS:**

A leak or rupture in a cryogenic system could expose crew members to the cryogen. A means should be provided to stop the flow of the cryogen to the site of the leak. If the cryogen is essential to crew safety, a redundant system may be necessary.

Also applies to the following hazard groups: 1. Contamination
7. Illness and Injury

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.5

**TITLE:** Electrical Power Source Cooling

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power (EP)

**SAFETY GUIDELINE:**

Adequate cooling capability should be provided to prevent overheating of electrical power sources even during worst-case conditions.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
2. D2-113070-10, FT-2 (Temperature Extremes), 3-D, "Injury results from exposure to heat generated by chemical reaction"; and 15-G, "Operational breakdown results from high temperature exceeding functional capability of subsystem."
3. D2-113070-9, Logic Diagram, Propositions 8D and 16D.

**REMARKS:**

Some electrical power sources (e.g., battery, nuclear, radioisotope) require cooling systems to maintain correct operating temperatures for best efficiency. Overtemperatures can result in potentially hazardous situations; therefore, adequate cooling should be provided to handle the maximum expected operating temperatures. Redundancy of the cooling system should also be provided so continuous cooling will be available even though a failure in the primary cooling system occurs.

Also applies to the following hazard groups: 4. Electrical
6. Explosion

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.6

**TITLE:** Electrical Power System Location

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power (EP)

**SAFETY GUIDELINE:**

Power generating and distribution equipment which is a potential source of fire should be located in unpressurized areas of the space station.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
2. D2-113070-10, FT-2 (Temperature Extremes), 1-B, "Crew members are injured through exposure to potentially fatal heat."
3. D2-113070-9, Logic Diagram, Propositions 16D and 32D.

**REMARKS:**

Since most electrical power system power generating and distribution equipment could be a source of fire in an oxygen atmosphere, it is advantageous to locate this equipment in uninhabited and unpressurized areas of the station. Therefore, only that equipment which cannot, practically, be located elsewhere should be in inhabited areas, and then only if adequate shielding is provided. This will involve trade studies to determine the degree to which this concept is feasible, as consideration must be given to the reliability of the equipment and the need for redundancy when EVA would be required for maintenance.

Also applies to the following hazard groups: 4. Electrical
6. Explosion

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.7

**TITLE:** Fire Control

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Fire control equipment and/or methods should be provided which can be automatically initiated, or are readily accessible and can be manually controlled.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
2. D2-113070-10, FT-2 (Temperature Extremes), 7-B, "Injury results from failure to control fire," and 9-B, "Emergency fire control action is not facilitated by the fire emergency warning system."
3. D2-113070-9, Logic Diagram, Propositions 8D, 15K, 18E and 47E.

**REMARKS:**

There are many different types of fires that may occur in a space station. Assuming there are no self-propagating materials on-board the space station, the most effective method for extinguishing a fire might be decompression of the affected compartment. An intermediate method might provide for automatic and/or manual shut-down of ventilating equipment and oxygen supply to the affected compartment when a fire is detected. Another possibility is partial depressurization with crew using $O_2$ masks and then repressurizing with an inert gas to terminate or retard fire propagation. For cases where these methods are not warranted, fire extinguishing equipment should be provided that can cope with any possible fire, smoke, or toxicity problem. Evaluation of the potential condition should determine if an automatically controlled response is required or if manual operation of the equipment would be sufficient. Adequate training and procedures should be supplied the crew to ensure that the correct remedial action is taken for a particular fire. Rapid access should be provided to potential fire areas for fire extinguishing equipment, e.g., areas behind display panels frequently present accessibility problems.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.8

**TITLE:** Fire-Resistant Electrical Insulation

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Comm. and Data Mgmt., Electrical Power, Environmental Control/Life Support, Experiments, Stability and Control

**SAFETY GUIDELINE:**

Electrical insulation should be, as a minimum, self-extinguishing in the spacecraft atmosphere.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 19-E, "Compartment escape route is obstructed due to fire."

**REMARKS:**

Fire could spread through electrical cable conduit. High concentrations of oxygen may require a stringent limitation on the types of insulation material which would be permitted.

Also applies to the following hazard groups: 1. Contamination
4. Electrical

| HAZARD GROUP: Temperature Extremes | NO. 10.9 |
|---|---|
| TITLE: Fire Retardant Electrical Equipment | |
| APPLICABLE SUBSYSTEMS/FUNCTIONS: All | |

**SAFETY GUIDELINE:**

Power equipment racks and cables should be as resistant to fire as possible. Emergency equipment and casualty mode operations should be developed.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 15-K, "Fire results in failure of electric power system."

**REMARKS:**

A weight penalty must attend any redundancy in equipment. A casualty mode operation study might show that portions of the primary equipment could be utilized for a reduced capability during emergency conditions.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.10

**TITLE:** Freezing of Fluid Lines

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

All fluid lines should be adequately protected from freezing due to proximity to cryogenics, or exposure to space.

**REFERENCES:**

1. Space Flight Hazards Catalog, MSC 00134, September, 1969, Hazard No. 7.
2. D2-113070-10, FT-2 (Temperature Extremes), 4-D, "Injury results from direct contact with cryogenic fluid."

**REMARKS:**

Restricted flow of some fluids could cause equipment damage or equipment operation impairment. In addition, total freezing could possibly cause the line to rupture, thereby creating another hazard from fluid loss and the contamination effect of the spilled fluid.

| | |
|---|---|
| **HAZARD GROUP:** Temperature Extremes | **NO.** 10.11 |

**TITLE:** Heating Element Flame Suppression

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power, Environmental Control/ Life Support, Experiments

**SAFETY GUIDELINE:**

Heating elements which must be exposed to the atmosphere should be provided with a device to prevent the propagation of flame.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 5-B, "Electrical system component heated through normal system operations."

**REMARKS:**

Electrical devices (lights, heating elements, etc.) which generate heat could be a source of ignition.

Also applicable to the following hazard group: 6. Explosion

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.12

**TITLE:** Heat Monitoring in Operating Equipment

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power, Experiments, Structures/ Mechanical, Environ. Control/Life Support, Stability and Control

**SAFETY GUIDELINE:**

Components which could generate excessive heat due to friction should be automatically monitored for temperature increase and sealed from the atmosphere. An overheat warning signal should be provided.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 2-C, "Injury results from exposure to heat generated by mechanical source."

**REMARKS:**

Heat due to friction could prcvide injury to personnel or could provide a source of ignition.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.13

**TITLE:** Hypergolic and Pyrophoric Material

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control, Operations, Experiments

**SAFETY GUIDELINE:**

The amounts of hypergolic, pyrophoric, or other easily ignitable materials onboard the spacecraft should be restricted to the minimum necessary and close control should be exercised over their handling and use.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 6-D, "Fire occurs of a hypergolic or pyrophoric nature."

**REMARKS:**

Positive control over these materials is required because they are a serious fire hazard. The controls should include restrictions on the areas in which the materials are used and permit only authorized personnel to work with or handle them.

Also applies to the following hazard groups: 1. Contamination
6. Explosion

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.14

**TITLE:** Ignition Source Control

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Electrical Power (EP)

**SAFETY GUIDELINE:**

Potential ignition sources, such as lighted cigarettes or open flames, etc., should not be permitted within pressurized inhabited compartments of the space station unless rigid control can be exercised to insure that a fire hazard is not present.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
2. D2-113070-10, FT-2 (Temperature Extremes), 3-J, "Injury results from fire occurring within a normally manned area of spacecraft."
3. D2-113070-9, Logic Diagram, Proposition 16D.

**REMARKS:**

Smoking and use of open flames for heating are a definite hazard when used in an oxygen rich atmosphere. Ideally, no smoking or open flames should be allowed on-board the space station. However, because of the numerous activities and experiments that will occur during a long-duration mission, rigid adherence to this rule may not be practical. Therefore, if smcking or open flames are allowed, it should only be when protection is afforded by a device which will prevent propagation of flame to the ambient atmosphere.

Also applies to the following hazard groups: 1. Contamination
6. Explosion

| | |
|---|---|
| **HAZARD GROUP:** Temperature Extremes | **NO.** 10.15 |

**TITLE:** Isolation of Oxygen Source

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical Systems (S/M)

**SAFETY GUIDELINE:**

If absence of oxygen is utilized as a means of preventing fires, design should provide that no single failure could produce an oxygen atmosphere.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 6-H, "Sufficient oxygen is present to support combustion."

**REMARKS:**

An inert atmosphere or unpressurized area may be used for storage of flammable materials. In such cases, measures should be taken to ensure absence of oxygen in the area. For example, cryogenic oxygen should not be piped through such an area nor should entry to the area provide oxygen.

| HAZARD GROUP: Temperature Extremes | NO. 10.16 |
|---|---|

**TITLE:** Location of Combustibles

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Structures/Mechanical Systems

**SAFETY GUIDELINE:**

Passageways should be kept free of all combustible materials and oxidizers.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 19-I, "Fire occurs within the escape route."

**REMARKS:**

Fire could spread to other compartments through passageways, or crew movement in an emergency could be impeded, by burning material in a passageway.

| HAZARD GROUP: Temperature Extremes | NO. 10.17 |
|---|---|

**TITLE:** Lubricants

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Lubricants used in mechanical components which are essential for survival should be capable of withstanding extreme temperatures.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 2-J, "Subsystem failure results from the effects of low temperature," and 15-D, "Subsystem failure results from the effects of high temperature."

**REMARKS:**

Failure of a lubricant could in turn result in failure of the component. Loss of the component function could impact on safety or injury could be caused directly by the component failure.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.18

**TITLE:** Manual Control of Temperature Control Systems

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

**SAFETY GUIDELINE:**

A capability for manually controlling operation of the equipment used for cabin and equipment temperature control should be considered.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of thermal control.
2. D2-113070-9, Logic Diagram, Proposition 46D.

**REMARKS:**

Situations may arise where normal (automatic) control of the thermal control equipment is inoperative and it would be advantageous to have the capability to manually control the equipment until normal control can be re-established.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.19

**TITLE:** Over-current Protection

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power (EP), Comm. and Data Mgmt., Environmental Control/Life Support, Experiments, Stability and Control

**SAFETY GUIDELINE:**

Current limiting devices or techniques should be used to preclude hazardous over-currents. They should be readily accessible, provide visible indication of their state, and be resistant to inadvertent or accidental activation, fire, explosion, shock, and explosive decompression. They should provide protection both to the current source and to the "using" equipment.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 5-D, "Electrical system component heated through electrical system fault."
2. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
3. D2-113070-9, Logic Diagram, Proposition 8D.

**REMARKS:**

Over-current in an element of the electrical subsystem could produce sufficient heat to directly injure a crew member, provide an ignition source for a fire or explosion, cause damage to electrical equipment, or release contaminants that could endanger crew safety.

Also applies to the following hazard groups: 1. Contamination
4. Electrical
6. Explosion

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.20

**TITLE:** Personnel Protection from Heated Surfaces

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Design provisions should be made which assure that no heated surfaces would provide a source of injury to crew members or provide a source of ignition.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 1-G, "Injury results from direct exposure to high temperature element," and 6-I, "Ignition source is provided."

**REMARKS:**

Heated surfaces should be kept to a minimum; but, where required or unavoidable, they should be protected by insulation, guards, or the like.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.21

**TITLE:** Propellant Supply System Location

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Propellant supply system equipment and plumbing which uses toxic or potentially flammable fluids should be located in uninhabited areas.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of propellant leakage.
2. D2-113070-10, FT-2 (Temperature Extremes), 6-D, "Fire occurs of a hypergolic or pyrophoric nature"; 6-F, "Fuel, oxygen, and ignition source are provided as separate entities"; and 6-G, "Combustible materials are present (fuel source)."
3. D2-113070-9, Logic Diagram, Propositions 8D, 16D, 59D and 61D.

**REMARKS:**

Fluids which are toxic or a possible source of fire would be a threat to crew safety if located in pressurized inhabited areas of the spacecraft. Therefore, it is desirable that system equipment that might be sources of the fluid leakage be located in uninhabited areas, if at all possible. If this cannot be done, then adequate shielding and precautions must be taken to ensure crew safety. Propellant systems which use separate fuel and oxidizers should provide for enough separation or shielding of the two so that leakage of one cannot come into contact with the other.

Also applies to the following hazard groups: 1. Contamination
6. Explosion

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.22

**TITLE:** Protection of Temperature Critical Equipment

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Environmental Control/Life Support System (EC/LSS), Electrical Power, Crew System

**SAFETY GUIDELINE:**

Equipment which has a critical temperature requirement should be protected by a redundant or alternate temperature control capability.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of thermal control.
2. D2-113070-10, FT-2 (Temperature Extremes), 8-G, "Equipment is inoperative due to damage effects of fire."
3. D2-113070-9, Logic Diagram, Propositions 8D and 10F.

**REMARKS:**

The thermal control system may provide control for many components throughout the spacecraft. However, a failure may occur in the part of the thermal control system associated with a particular component. Therefore, additional protection of temperature critical equipment should be provided in the form of a redundant thermal control loop or an alternate method of temperature control. Consideration should also be given to providing a temperature controlled shut-off device that will shut down the component operation when out-of-tolerance temperatures occur.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.23

**TITLE:** Self-Propagation of Fires

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Materials which are capable of self-propagation of fire should not be on-board the space station in sufficient quantities or concentrations that ignition would result in a hazardous condition.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
2. D2-113070-10, FT-2 (Temperature Extremes), 7-B, "Injury results from failure to control fire."
3. D2-113070-9, Logic Diagram, Propositions 8D, 18E, 47E.

**REMARKS:**

Effective fire extinguishing equipment and methods can probably be developed for all but self-propagating materials. Ideally, there should be no self-propagating materials on-board a space station. Realistically, this may not be practical, considering the experimental and operational requirements. Therefore, rigid measures should be taken to ensure that any self-propagating materials on-board the space station are controlled so as to preclude the development of a hazardous situation.

Also applies to the following hazard groups: 1. Contamination
6. Explosion

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.24

**TITLE:** Slow Opening High Pressure Oxygen Valves

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

**SAFETY GUIDELINE:**

Valves for oxygen systems of 3000 psi or higher should be slow opening and closing to minimize the possibility of ignition of contaminants.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of loss of oxygen.
2. D2-113070-9, Logic Diagram, Proposition 16D.

**REMARKS:**

Fast operating valves in high pressure oxygen systems can possibly result in the ignition of contaminants that may be present in the valve or oxygen. This could result in fire or valve failure and subsequent loss of oxygen.

Also applies to the following hazard groups: 1. Contamination
8. Loss of Vital Supplies

| HAZARD GROUP: Temperature Extremes | NO. 10.25 |
|---|---|
| TITLE: Spacecraft Thermal Protection | |
| APPLICABLE SUBSYSTEMS/FUNCTIONS: Structures/Mechanical Systems (S/M) | |

**SAFETY GUIDELINE:**

The spacecraft thermal protection provisions should be consistent with the orbital flight path type, orbital height, and inclination selected.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 1-I, "Injury results from direct exposure to exterior solar heat environment."

**REMARKS:**

The near-Earth thermal environment is a function of flight path, orbital height and inclination. Design of thermal protection should provide for worst case possible, unplanned or planned.

| HAZARD GROUP: Temperature Extremes | NO. 10.26 |
|---|---|
| TITLE: Thermal Control Equipment Redundancy | |
| APPLICABLE SUBSYSTEMS/FUNCTIONS: Environmental Control/Life Support System (EC/LSS) | |

**SAFETY GUIDELINE:**

Thermal control equipment whose operation is critical to crew safety should have redundancy provided.

**REFERENCES:**

1. D2-113070-11, Subsystem Analysis (EC/LSS), for potential hazard of loss of thermal control.
2. D2-113070-9, Logic Diagram, Propositions 8D and 10F.

**REMARKS:**

Continuous operation of the thermal control system may be essential to the operation of some equipment. To ensure continuous operation, redundancy should be provided for critical thermal control equipment. The need for, and the type of, redundancy will be dependent on the corrective maintenance time required and its relation to the maximum allowable downtime for the equipment. In any case, equipment which is located in uninhabited areas of the space station and would require EVA to maintain should have redundancy provided.

| HAZARD GROUP: Temperature Extremes | NO. 10.27 |
|---|---|

**TITLE:** Thermal Control Temperature Sensors

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Environmental Control/Life Support System (EC/LSS), Crew System, Electrical Power

**SAFETY GUIDELINE:**

Temperature sensors should be provided at critical points in thermal control systems to detect out-of-tolerance temperatures. Detection of temperatures which deviate from the normal range should activate an alarm system to warn the crew of the need for remedial action.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EC/LSS) for potential hazard of loss of thermal control.
2. D2-113070-10, FT-2 (Temperature Extremes), 9-B, "Emergency fire control action is not facilitated by the fire emergency warning system."
3. D2-113070-9, Logic Diagram, Propositions 8D, 18D, 48H, 48I.

**REMARKS:**

Space station equipment that is designed to operate within specific temperature ranges may be seriously damaged if excessively high or low temperatures occur, e.g., thermal control fluids might freeze. Therefore, critical temperature locations in the system should be identified so they can be monitored with appropriate sensors. Procedures should also be developed to instruct the crew as to the corrective actions required when a critical temperature warning is received.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.28

**TITLE:** Thruster Location

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS), Communications and Data Management, Electrical Power

**SAFETY GUIDELINE:**

Attitude control thrusters should be located so that the exhaust will not cause damage to other equipment or space station structure.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of exhaust plume.
2. D2-113070-9, Logic Diagram, Proposition 9D.

**REMARKS:**

If the exhaust plume from attitude control thrusters is allowed to impinge on nearby equipment or structure, e.g., solar panels, antennas, experiment apparatus, serious damage may result. Therefore, the exhaust plume effects should be considered when determining the location of thrusters in relation to other equipment nearby.

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

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.29

**TITLE:** Thruster Operation during EVA

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS), Crew System, Operations

**SAFETY GUIDELINE:**

Procedures should be established and design safeguards provided that will preclude operation of thrusters when it might endanger crew members involved in EVA.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of exhaust plume.
2. D2-113070-9, Logic Diagram, Propositions 8D, 9E and 32D.

**REMARKS:**

Whenever crew members are performing EVA there is a possibility that they will, whether by necessity or inadvertently, get close enough to the thrusters that their operation could damage pressure suits or associated equipment. Therefore, procedures should be developed to ensure that the thrusters will not be operated when personnel are nearby and/or system design should incorporate provisions that will prevent the thrusters from being fired during any EVA.

**HAZARD GROUP:** Temperature Extremes

**NO.** 10.30

**TITLE:** Thruster Temperature Monitor

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Sensors should be provided to monitor the temperature of attitude control thruster assemblies. The sensors should activate a visual and/or audible alarm at the command and control center(s).

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Diagram, Propositions 8D, 18D, 48H, and 48I.

**REMARKS:**

Excessive temperatures can result in the failure of thrusters and possible explosion. Also, some types of thrusters may not operate satisfactorily if the temperature is too low or too high. The crew should be warned of any abnormal temperatures of the thrusters in time to take the necessary corrective action to ensure crew safety.

Also applies to the following hazard group: 6. Explosion

| HAZARD GROUP: Spacecraft Accelerations | NO. 11.1 |
|---|---|

**TITLE:** Angular Rate Monitor

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Angular rates of the spacecraft should be continuously monitored during attitude change maneuvers. Detection of excessive angular rates should result in automatic shut-down of operating thrusters.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.

2. D2-113070-9, Logic Diagram, Propositions 11E, 17E, 35E, 48H and 48I.

**REMARKS:**

A control system or thruster failure could result in angular rates for the spacecraft in excess of that considered acceptable for crew safety. Therefore, provisions should be made for automatically shutting down operating thrusters before this angular rate is attained. A visual/audible alarm indicating this action should be displayed at the command and control center(s). Consider providing manual override to the automatic controls.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.2

**TITLE:** Automatic Tumbling Correction

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

An automatic system for controlling thrusters to restore a tumbling spacecraft's stability should be provided.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.

2. D2-113070-9, Logic Diagram, Propositions 4D, 17E and 35E.

**REMARKS:**

A system failure could result in the spacecraft tumbling at a rate which could incapacitate the crew or inhibit crew movement. To recover from this contingency, a capability to automatically control the spacecraft until stability is restored should be provided. Therefore, an on-board automatic attitude control capability is required which can be activated by a ground station if the spacecraft crew is incapacitated, or, alternately, can be easily activated at the spacecraft command and control center(s) if some personnel movement is still possible.

| HAZARD GROUP: Spacecraft Accelerations | NO. 11.3 |
|---|---|

**TITLE:** Component Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Redundancy should be provided for all components that are located outside pressurized inhabited areas and failure of which could result in a loss of attitude control.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Diagram, Propositions 10F and 14B.

**REMARKS:**

EVA is a particularly hazardous activity which should be minimized. Therefore, equipment that would require EVA to accomplish replacement or repair should have redundancy provided to decrease the possibility of requiring EVA. The amount of redundancy provided should take into consideration the component reliability, accessibility for EVA replacement, maintenance time, and allowable downtime. If remote manipulation units are available, replacement of a component by remote manipulation could be considered. This may decrease the need for redundancy, if the downtime constraints can be met.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.4

**TITLE:** Component Replacement for CMG's

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Control moment gyros (CMG's) should be designed so that the components most subject to failure can be replaced.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Diagram, Propositions 10G and 18E.

**REMARKS:**

CMG's have been proposed for use in a number of space mission studies. Their large size and mass impose problems when attempting replacement of failed gyros or if spare gyros must be resupplied. The parts of the gyros most susceptible to failure are relatively small and should present no spares provisioning problems. Therefore, the CMG's should be designed for replacement of the components most subject to failure.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.5

**TITLE:** Crew Restrictions During Space Base Spin-Up

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Crew members not directly involved in the spin-up operation should be restricted either to refuge areas with unobstructed escape routes to docked logistic vehicles, or to the logistic vehicles themselves.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 3.0, "Analysis of Operations."

**REMARKS:**

The intent of this guideline is to maximize the survivability of the crew (or partial crew) in the event an emergency develops during the spin-up operation. This guideline recognizes that techniques to develop artificial gravity are major uninvestigated areas of manned space activity, and it is directed primarily at initial experiments. Also, this guideline assumes that experience with spin-up/spin-down will have demonstrated that it would not be necessary to evacuate the space base of all but essential personnel during these operations.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.6

**TITLE:** Damage-Induced Motion

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control (SCS), Structures/Mechanical

**SAFETY GUIDELINE:**

The SCS should have the capacity to counteract the undesired motion imparted by fluid escaping through a hole in a compartment or pressure vessel.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS) for potential hazard of loss of attitude control.

2. D2-113070-6, Supporting Analyses, Section 7, "Meteoroid Penetration."

**REMARKS:**

If damage to a pressurized volume resulted in a hole in the pressure wall, the escaping fluid would impart an undesired motion to the spacecraft. The magnitude of the motion would depend, among other things, on the volume of fluid which escaped. The SCS should have the capacity to counteract all the motion imparted by escape of all the fluid in that pressurized volume containing the greatest quantity of fluid. A stuck-open pressure vent valve is "damage" in the sense of this guideline.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.7

**TITLE:** Manual/Automatic Control Interlocks

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Interlocks should be provided to prevent simultaneous manual and automatic operation of the attitude control system.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.

2. D2-113070-9, Logic Diagram, Propositions 9C, 11E and 53D.

**REMARKS:**

If manual control were attempted while automatic control was still operating it is possible that the result could be a serious loss of attitude control. This could be prevented by the incorporation of an interlock device or circuit into the system.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.8

**TITLE:** Manual Control of SCS Thrusters

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

The spacecraft crew should be provided the capability to manually activate and control both primary and redundant thrusters.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Diagram, Propositions 17E, 18E and 35E.

**REMARKS:**

Control of spacecraft attitude would be expected normally to be done automatically. It is possible for failures to occur that could result in malfunction or failure of the automatic system. In this case, it would be advisable to have the crew able to manually activate and control both primary and redundant attitude control thrusters.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.9

**TITLE:** On-Board Crew Complement During Space Station Spin-Up

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Only those crew members directly involved with the operation should remain aboard the space station during spin-up, and until the station has been stabilized and considered safe.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, paragraph 3.2.9.

**REMARKS:**

The intent of this guideline is to minimize the number of crew members who are exposed to the hazards associated with the "spin-up" operation. Some of these hazards may include: (1) Loss of stability during the operation with possible excessive structural loads resulting in base destruction; (2) Failure of module interface seals resulting in loss of a habitable environment in one or more compartments; (3) Line rupture or interconnect failure of umbilicals carrying hazardous fluids; and (4) Failure of equipment restraints/tiedowns, allowing the equipment to shift or move uncontrollably about the station.

Depending upon an assessment of the initial spin-up, and the confidence level achieved, this guideline or some modification thereof may also be advisable during "spin-down," or subsequent spin-up operations.

This guideline could be implemented by initially launching only those crewmen essention to perform space station activation up to and including the spin-up. If excess personnel should already be aboard (e.g., prior to spin-down or a subsequent spin-up), they could be temporarily evacuated via a docked vehicle(s).

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|---|---|
| **HAZARD GROUP:** Spacecraft Accelerations | **NO.** 11.10 |

**TITLE:** Propellant Flow Shut-off Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

A means for stopping propellant flow to failed open thrusters should be provided.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Analysis, Propositions 11E, 17E and 35E.

**REMARKS:**

A thruster that fails to shut off after operating could result in tumbling of the spacecraft with consequent danger of incapacitating the crew. Therefore, some alternate means of shutting off the propellant flow should be provided. Consideration should be given to automatic monitoring of thruster firing duration and to providing visual/audible alarm or automatic shut-down of all thrusters if duration exceeds a specified limit.

**HAZARD GROUP:** Spacecraft Accelerations

**NO.** 11.11

**TITLE:** Torques from Venting

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control (SCS), Structures/ Mechanical

**SAFETY GUIDELINE:**

Outlets should be designed so that fluids being vented overboard do not impose any torque on the spacecraft.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS) for potential hazard of loss of attitude control.

**REMARKS:**

Fluids vented overboard could act to impart undesired and unexpected motion to the spacecraft. If this occurred during a hazardous operation, it could contribute to accidents.

| HAZARD GROUP: Spacecraft Accelerations | NO. 11.12 |
|---|---|

**TITLE:** Propellant Storage Tanks Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Propellants should be stored in more than one tank or other storage device.

**REFERENCES:**

1. D2-113070-11, Subsystem Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Diagram, Propositions 10F and 11E.

**REMARKS:**

An adequate supply of propellants is essential to continued operation of the SCS. Therefore, the propellant supply system should be designed so that a single failure will not result in a total loss of the propellant supply. Determination of the number and sizes of the propellant tanks to be used should involve consideration of the logistics resupply requirements. If propellant tanks are to be exchanged during resupply, the size of the tanks may dictate additional requirements for the handling and transfer of propellant tanks from the resupply vehicle to the space station.

Also applies to the following hazard group: 6. Explosion

**HAZARD GROUP:** General

**NO.** 12.1

**TITLE:** Accessways

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M)

**SAFETY GUIDELINE:**

Accessways between and within compartments should be sized in such a manner that an IVA-suited crew member will be allowed access to normally used areas.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Patterns Analysis."

**REMARKS:**

The intent of this guideline is to assure that accessway size does not restrict activities which require an IVA suit to be worn, e.g., escape through a hazardous area, and damage control. The term "compartment" in this guideline refers to the enclosed volume obtained when pressure-tight hatches are secured.

**HAZARD GROUP:** General

**NO.** 12.2

**TITLE:** Airlock Hatch Operation

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M)

**SAFETY GUIDELINE:**

Airlock hatches should be capable of being operated from either side and at least two methods for operating the hatches should be provided.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of no airlock capability.
2. D2-113070-9, Logic Diagram, Propositions 8C and 80B.

**REMARKS:**

There is a possibility that because of a failure or a crewman being injured, an airlock hatch could not be opened from one side. Therefore, the hatch should be capable of being operated from both sides. In the event of a failure which prevents a hatch from being opened from either side by the normal method, an alternate and separate means for emergency operation of the hatches should be provided.

**HAZARD GROUP:** General

**NO.** 12.3

**TITLE:** Airlock Pressurization Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M)

**SAFETY GUIDELINE:**

Space station airlocks should have redundant pressurization capability.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of no airlock capability.
2. D2-113070-9, Logic Diagram, Propositions 8C and 10F.

**REMARKS:**

A failure in the airlock pressurization system could result in crew members being unable to enter the space station without depressurizing the adjoining compartment. In case of an emergency, that procedure may take too much additional time and also would result in loss of atmosphere. To ensure use of the airlock at a critical time, i.e., entry from EVA, a redundant means for pressurizing the airlock should be provided.

**HAZARD GROUP:** General

**NO.** 12.4

**TITLE:** Airlock Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M)

**SAFETY GUIDELINE:**

A space station should be provided with more than one airlock leading to the exterior of the station.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of no airlock capability.

2. D2-113070-9, Logic Diagram, Proposition 80B.

**REMARKS:**

It is assumed that there will be redundant pressurization capability for airlocks, primarily to ensure re-entry of crew members on EVA. However, there are failures which could occur that would prevent use of the airlock for either exit or entry. To ensure an airlock capability at all times, more than one airlock should be provided. The number will depend upon the size and configuration of the space station, the crew size, and the amount of EVA expected.

**HAZARD GROUP:** General

**NO.** 12.5

**TITLE:** Alternate Command and Control Center

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

An alternate command and control center should be provided in the space base, possibly within the crew refuge area, to ensure continuation of a minimum number of functions which are vital for base control and crew life support, in the event the primary command and control center is rendered incapable of providing these functions.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 3.5, "Damage Containment and Control."

**REMARKS:**

A dual function of the alternate center could be to provide direction for implementing damage containment and control or emergency procedures as required. At a minimum, the center should be manned during all hazardous operations.

**HAZARD GROUP:** General

**NO.** 12.6

**TITLE:** Assistance to Injured Personnel

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Structures/Mechanical Systems

**SAFETY GUIDELINE:**

A capability should be provided to allow entry into a compartment, where fire or other emergency exists, to effect rescue of incapacitated crew members or to combat a fire. The means of entry and the procedures involved should assure that the emergency does not escalate or spread to other locations due to the entry.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 7-H, "Injuries to crew member retard escape, and rescue attempt is ineffective," and 19-E, "Compartment escape route is obstructed due to fire."

**REMARKS:**

An "injury" situation could escalate to a "fatal" situation if prompt assistance is not available to the injured member or if the rescue attempt is not conducted in a proper manner.

**HAZARD GROUP:** General

**NO.** 12.7

**TITLE:** Attitude Indication Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Redundancy should be provided for displays used to show spacecraft attitude or attitude changes.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Diagram, Proposition 10F.

**REMARKS:**

Continuous knowledge of the spacecraft's attitude and rates of attitude change is important in assessing the performance of the attitude control system. To ensure continuous display of accurate attitude information, even if a failure occurs, active redundant attitude indication should be provided. If a positive means of showing failure of the attitude indicator can be provided, stand-by redundancy should be considered.

**HAZARD GROUP:** General

**NO.** 12.8

**TITLE:** Authority to Proceed with Hazardous and Certain Other Operations

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Mission rules should include the requirement that control center "authority to proceed" be obtained immediately prior to the initiation (by any crewman) of any activity which is hazardous either by itself, or when performed in conjunction with other base activities being conducted simultaneously.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 3.0, "Analysis of Operations."

**REMARKS:**

The intent of this guideline is to ensure that control center operator(s) maintain cognizance of all hazardous or potentially hazardous activities being conducted aboard the station/base, and hence minimize the probability of occurrence of unforeseen hazards for which no emergency procedures exist.

**HAZARD GROUP:** General

**NO.** 12.9

**TITLE:** Cargo Transfer Equipment Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical (S/M)

**SAFETY GUIDELINE:**

Redundancy should be provided for equipment required for resupply cargo transfer.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (S/M), for potential hazard of cannot transfer resupply cargo.
2. D2-113070-10, FT-1 (Decompression), 7-G, "Damage results from logistic support operations."
3. D2-113070-9, Logic Diagram, Proposition 48E.

**REMARKS:**

Special equipment or permanently installed means may be used to transfer resupply cargo from a logistics vehicle to the space station; e.g., pumping of fluids through interconnecting plumbing. If this method fails the resupply vehicle would be unable to transfer its cargo. Therefore, an alternate method should be provided for transferring supplies in that type of situation.

**HAZARD GROUP:** General

**NO.** 12.10

**TITLE:** Closed Circuit Television Monitoring

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management (CDM) Operations, Experiments

**SAFETY GUIDELINE:**

A closed circuit television system with strategically located cameras should be provided command and control center operator(s) real-time visual information on hazardous activities/operations.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 3.0, "Analysis of Operations;" and Section 5, "Traffic Pattern Analysis."

**REMARKS:**

The intent of this guideline is to provide a visual back-up system which would complement other instrumentation at the command and control center(s) to alert operators of impending hazards. Monitoring by optical means could also be considered.

| HAZARD GROUP: General | NO. 12.11 |
|---|---|

**TITLE:** Command Personnel Location Restrictions

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Simultaneous occupancy (other than momentary) by the Spacecraft Commander and his Deputy, of those compartments or locations which are judged to have the highest safety risk probability should be minimized, or precluded if possible.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 3.0, "Analysis of Operations."

**REMARKS:**

The intent of this guideline is to avert the possibility of serious injury to or loss of both commanders in the event of an emergency. This guideline could be implemented by prudent preparation of crew timelines, in which this guideline would become a prime consideration.

**HAZARD GROUP:** General

**NO.** 12.12

**TITLE:** Communication Equipment Commonality

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management (CDM)

**SAFETY GUIDELINE:**

Equipment in the space station for external voice and data communications should have as much commonality as practicable with the equipment used in the logistics vehicles and Earth-return vehicles.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CDM), for potential hazards of loss of external voice and data communications.

2. D2-113070-9, Logic Diagram, Proposition 9D.

**REMARKS:**

Equipment for external voice and data communications will be required on all vehicles used to transport men and supplies between the Earth and space stations. By using the same equipment in all the vehicles, a built-in emergency or backup communications capability will be available to the space station. In some situations, the common equipment in one vehicle might even be used as a source for a needed replacement in another vehicle. Trade studies or an analysis of each space system concept will be required to determine if this commonality of equipment would satisfy redundancy requirements.

**HAZARD GROUP:** General

**NO.** 12.13

**TITLE:** Compartmentation

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

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.

**REFERENCES:**

1. D2-113070-10, FT-1 (Decompression), 1-C, "Crew members are exposed to decompression;" and 8-H, "Compartment hatch hinders escape due to hatch failure or improper design."
2. D2-113070-11, Subsystems Analysis (EP and EC/LS), for potential hazards of fire, smoke, toxicity and loss of cabin pressure.
3. D2-113070-9, Logic Diagram, Proposition 34C.

**REMARKS:**

This guideline represents a conclusion reached independently by most of the tasks in the study, in addition to those referenced. The term "compartment" as used here, and generally in the study, refers to a volume which can be pressurized and depressurized independently of the rest of the station. In this sense, of course, an "airlock" is a "compartment." No conclusion was reached as to the specific number of compartments except that the number should probably be greater than two. Extensive trade studies will be necessary to establish the optimum number.

**HAZARD GROUP:** General

**NO.** 12.14

**TITLE:** Compartment Environmental Status

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management System, Operations, Experiments

**SAFETY GUIDELINE:**

Means should be provided for determining the conditions existing in an environmentally isolated area before it is entered. Environmental conditions (particularly pressure) should be equalized on both sides of the compartment hatch prior to its being opened.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."

2. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard No. 64.

**REMARKS:**

It is assumed that the station/base will have compartments which can be completely isolated from the rest of the station. In such cases, before a crewman enters the compartment, he should be able to determine that no hazardous conditions have developed, and that no intercompartmental pressure differential exists which would set up a pressure gradient at the hatch. Opening a sealed hatch which leads to a compartment of either higher or lower pressure could create a hazard for the crew member(s) involved.

**HAZARD GROUP:** General

**NO.** 12.15

**TITLE:** Computer Equipment Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

The principal space station/base computer and the associated equipment, e.g., data adapter, that is essential to the computer operation should have redundancy provided.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CDM), for potential hazard of loss of computer function.
2. D2-113070-9, Logic Diagram, Proposition 10F.

**REMARKS:**

It is assumed that the space station/base will have a computerized capability which is essentially the "brains" of all systems. Loss of this capability could seriously degrade operations and jeopardize crew safety. Therefore, it is necessary that the computer functions and associated equipment be capable of continuous operation, which can be provided through redundancy. For additional backup protection, alternate modes of operation for critical computer functions should be provided.

**HAZARD GROUP:** General | **NO.** 12.16

**TITLE:** Continuous Attitude Indication

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Continuous indication of spacecraft attitude or attitude changes should be provided the control center operator.

**REFERENCES:**

1. D2-113070-11, Subsystem Analysis (SCS), for potential hazard of loss of attitude control.

2. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard No. 6.

**REMARKS:**

To protect against either a failure in the primary attitude display system, or a necessity for the crew to temporarily switch the primary system to display other than basic flight parameters, a form of redundancy should be considered to ensure that a continuous indication of these basic parameters is available.

**HAZARD GROUP:** General

**NO.** 12.17

**TITLE:** Crew Activity Restrictions

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Crew activity should be restricted during transfer of volatile, flammable, or explosive materials either between docked spacecraft or within a space vehicle. These restrictions should apply to the use of high voltage equipment, conduct of high temperature experiments, or other activity which would involve a potential source of ignition in the immediate neighborhood of the material transfer route.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Paragraph 3.1.6, "Additional Manning or Crew Rotation Missions."

**REMARKS:**

This guideline could be partially implemented by strict adherence to crew timelines and also by rules and safety regulations.

**HAZARD GROUP:** General

**NO.** 12.18

**TITLE:** Crew Distribution

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

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

**REFERENCES:**

1. D2-113070-6, Supporting Analysis, Section 5, "Traffic Pattern Analysis."

2. D2-113070-10, FT-1 (Decompression), 1-I, "Portion of crew is exposed to decompression."

**REMARKS:**

In the event of a serious emergency it will probably not be possible to absolutely guarantee that all crew members will survive. This guideline is intended to provide for survival of the maximum number. The term "compartment" in this guideline refers to the enclosed volume obtained when pressure-tight hatches are secured. It is recognized that operational factors may lead to the gathering of several crew members for recreational or other purposes (e.g., briefings). Also, crew-oriented activities, such as eating and sleeping, may result in undesirable concentrations of crew in areas devoted to those purposes.

| HAZARD GROUP: General | NO. 12.19 |
|---|---|

**TITLE:** Crew Movement

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Crew members should be restricted from movement about the station other than within specified and assigned areas.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."

**REMARKS:**

Uncontrolled and random crew movement could result in undesirable concentrations of the crew. Also, it could unnecessarily expose crew members to hazardous operations or locations and could cause distraction and mistakes on the part of others.

**HAZARD GROUP:** General

**NO.** 12.20

**TITLE:** Crew-Oriented Areas

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

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.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."

**REMARKS:**

About two-thirds of crew members' time will be spent in activities oriented to crew health and well being. Crew members will of necessity congregate in the areas devoted to those activities which may give, from the safety viewpoint, an undesirable concentration of the crew in those areas. Many inherently hazardous conditions, activities, materials or equipment will necessarily exist in the space station, but proper design should place many of them in areas other than those devoted to high crew concentrations.

**HAZARD GROUP:** General

**NO.** 12.21

**TITLE:** Crew Performance of Complex Tasks

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System, Operations

**SAFETY GUIDELINE:**

Tasks and schedules should be designed so that complex or highly skilled performance is not required of crew members immediately upon arousal from sleep, and to the maximum extent possible, do not require more than one work period to complete. The responsibility for critical actions in emergencies should be assigned to on-duty personnel.

**REFERENCES:**

1. Aerospace Medicine, Volume 40, No. 7, page 723, July 1969.
2. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard No. 38.

**REMARKS:**

Experience and observation, confirmed by the study of Reference 1, indicate that performance tends to be poor and relatively unpredictable, especially in the case of sudden arousal from sleep in an emergency condition, for the first few minutes after awakening. Furthermore, when relieving work crews are required to continue complex tasks already in progress, they frequently commit procedural errors or make incorrect judgment decisions due to misunderstanding of the work already done. If a multi-shift task is unavoidable, crew rotation should be staggered such that at least part of the crew is thoroughly familiar with work done by the previous shift.

**HAZARD GROUP:** General

**NO.** 12.22

**TITLE:** Critical Caution and Warning Alarms

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communication and Data Management (CDS)
Crew System (CS)

**SAFETY GUIDELINE:**

Critical visual/audible caution and warning alarms should be displayed in all inhabited compartments.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of crew injury or illness.

2. D2-113070-9, Logic Diagram, Propositions 18D, 45E, 48H and 48I.

**REMARKS:**

Some hazardous situations or events that occur may have the potential of affecting a number, or all, of the space station inhabited areas. The caution and warning alarms associated with these events should therefore be displayed in all inhabited areas so the crew can take the necessary emergency or remedial action.

**HAZARD GROUP:** General

**NO.** 12.23

**TITLE:** Docking Mechanism Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/ Mechanical Systems

**SAFETY GUIDELINE:**

The docking mechanism should include redundant or secondary features so that docking can be completed if the primary mechanism fails.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 3, "Analysis of Operations."

**REMARKS:**

Docking mechanisms could be damaged during docking or could fail otherwise. Redundancy or secondary mechanisms would permit docking to be completed even though the primary system had failed. This feature may not be necessary if there are sufficient docking ports available to ensure that docking can be completed at another port if the mechanism fails in one.

**HAZARD GROUP:** General

**NO.** 12.24

**TITLE:** Emergency Communications System

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management (CDM)

**SAFETY GUIDELINE:**

An independent emergency communications system should be provided for directing and controlling operational activities in emergency situations.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CDM), for potential hazard of loss of internal voice communications.

2. D2-113070-9, Logic Diagram, Proposition 10F.

**REMARKS:**

An emergency situation may occur that results in the normal intercom system being inoperative; e.g., power failure or failure at main intercom station at the command and control center(s). If this happens, it would be essential that some means of communication throughout the space station compartments be provided so an organized and coordinated effort can be initiated toward correcting the emergency. Therefore, an emergency communications system should be provided which is totally independent of the normal system.

**HAZARD GROUP:** General

**NO.** 12.25

**TITLE:** Emergency Crew Evacuation

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

A sufficient number of operable logistic vehicles should be docked to the space station at all times to accommodate every on-board crew member in the event emergency evacuation is required.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Paragraph 3.3, "Logistic Vehicle/Tug Operation."

2. D2-113070-9, Logic Diagram, Proposition 10F.

**REMARKS:**

Initially, experimental programs involving high crew risks should include provisions for emergency rescue of the entire crew. As confidence levels, reliability of equipment, procedures, etc., increase with experience, this approach may be revised.

**HAZARD GROUP:** General

**NO.** 12.26

**TITLE:** Emergency EVA Communications

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS), Communications and Data Management

**SAFETY GUIDELINE:**

An independent, emergency communications capability should be provided between EVA personnel and the personnel monitoring the EVA.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure.

2. D2-113070-9, Logic Diagram, Propositions 18D, 18E, 45E, 48H and 48 I.

**REMARKS:**

An emergency situation may occur that results in the normal EVA-space station voice communications system becoming inoperative. Since EVA is a particularly hazardous activity, there should be provided an emergency backup method of communicating with EVA personnel.

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| **HAZARD GROUP:** General | **NO.** 12.27 |

**TITLE:** Emergency Lighting for EVA

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS), Operations

**SAFETY GUIDELINE:**

An emergency lighting system should be provided to assist EVA personnel in performing their tasks or to facilitate rescue of EVA personnel.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure.

2. D2-113070-9, Logic Diagram, Propositions 46B, 78G and 80B.

**REMARKS:**

An emergency situation may occur where it is necessary to provide assistance to, or rescue, personnel involved in EVA. If this situation occurs during the dark part of an orbit and the normal lighting system is inadequate or inoperative, a means of providing emergency lighting would be required to properly carry out rescue operations or assist the EVA personnel in continuing their planned tasks.

**HAZARD GROUP:** General

**NO.** 12.28

**TITLE:** Emergency Procedures and Training

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Periodic drills for all personnel should be devised, and conducted in response to unscheduled simulated emergencies, so that crew proficiency is maintained in emergency procedures.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 3, "Analysis of Operations;" and Section 5, "Traffic Pattern Analysis."
2. D2-113070-10, FT-1 (Decompression), 6-F, "Procedures are inadequate due to lack of emergency training;" and FT-2 (Temperature Extremes), 7-I, "Escape action is not facilitated by fire emergency procedures."
3. D2-113070-11, Subsystems Analysis (EP), for potential hazard of fire, smoke, toxicity.
4. D2-113070-9, Logic Diagram, Proposition 4C.

**REMARKS:**

There is a strong possibility that a portion of the crew on large future spacecraft may have minimal astronaut training, including use of and adherence to emergency procedures. Periodic drills should at least partially compensate for their limited emergency situation training. Further, such drills would permit evaluation of drill conduct and the results should provide indications as to the efficacy of operational safety measures.

**HAZARD GROUP:** General

**NO.** 12.29

**TITLE:** Emergency Procedures (Fire)

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

"Fire resistant" areas should be established to provide haven from fire. Emergency procedures should be established to identify such things as optimum routes to haven from any area and all personnel should be trained in these emergency procedures.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes),

   7-F, "An external area does not exist to provide a safe haven from fire."
   7-N, "Established fire emergency escape procedures are not adhered to."
   7-P, "Fire emergency procedures do not exist."

**REMARKS:**

Panic engendered by fire frequently becomes a more serious problem and leads to more deaths than do direct physical effects of the fire itself. While it is probable that the selected and disciplined personnel aboard a spacecraft would not permit themselves to become panic-stricken in times of stress, familiarity with emergency procedures will enhance confidence and increase the likelihood of surviving a potentially catastrophic situation.

| HAZARD GROUP: General | NO. 12.30 |
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**TITLE:** Escape Routes

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical Systems, Environmental Control/Life Support System (EC/LSS)

**SAFETY GUIDELINE:**

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

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."

**REMARKS:**

The intent of this guideline is to minimize the possibility of a crewman becoming isolated in a compartment by an emergency which blocks his escape. The term "compartment" in this guideline refers to the enclosed volume obtained when pressure-tight hatches are secured. The term "escape route" in this guideline refers to any route that can effectively be used to escape from an emergency condition.

**HAZARD GROUP:** General | **NO.** 12.31

**TITLE:** EVA Emergency Procedures

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS), Operations

**SAFETY GUIDELINE:**

Procedures should be established and training provided the crew which will enable them to cope with any foreseeable contingency that might arise during EVA.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure.

2. D2-113070-9, Logic Diagram, Proposition 12E.

**REMARKS:**

In the event of an emergency during EVA operations, emergency procedures should be in effect to ensure that the necessary actions are taken to preclude a hazardous situation from developing further until remedial measures can be taken to restore normal operations.

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| HAZARD GROUP: General | NO. 12.32 |

TITLE: External Communications Redundancy

APPLICABLE SUBSYSTEMS/FUNCTIONS: Communications and Data Management (CDM)

SAFETY GUIDELINE:

External communications--e.g., voice and data between the space station and the Earth, logistics vehicles, independent modules, and EVA personnel--equipment, the operation of which is essential to crew safety, should have redundancy provided.

REFERENCES:

1. D2-113070-11, Subsystems Analysis (CSM), for potential hazards of loss of external voice and data communications.

2. D2-113070-9, Logic Diagram, Propositions 4D and 10F.

REMARKS:

Essentially continuous operation, i.e., operation which cannot tolerate the downtime required to replace a faulty component, of some external communications equipment may be necessary to ensure crew safety. Redundancy should be provided for this equipment and, in particular, redundancy should be provided for equipment located in uninhabited areas, or exterior to the space station, that would require EVA to replace or maintain; e.g., antennas.

**HAZARD GROUP:** General

**NO.** 12.33

**TITLE:** Fire Alarm

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

An adequate fire warning system should be provided. The warning should be activated by smoke or fumes, as well as heat, and should warn the entire station. The precise location of the fire should be provided, as a minimum, to the command and control center(s). All segments of the warning system should be resistant to temperature extremes, decompression/overpressure or shock and should be self-indicating when failed.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 9-C, "Emergency manual procedures are inadequate to control fire;" and 10-D, "The fire warning system is inadequate at the time required."
2. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."
3. D2-113070-11, Subsystem Analysis (EP), for potential hazard of fire, smoke, toxicity.
4. D2-113070-9, Logic Diagram, Propositions 8D, 8H and 45E.

**REMARKS:**

Due to the possible seriousness of a fire, all occupants should be warned of the situation as soon as possible. The command and control center(s), which is knowledgeable of conditions in all areas, should be responsible to direct combating of the fire and rescue of personnel as required. This does not preclude delegation (or automatic delegation) of that responsibility to another authority or location if it is expedient under the circumstances. Smoke or fumes may indicate the existence of an overheated condition which has not yet broken out into actual flame. Therefore, any warning alarm system should be capable of responding to these factors.

**HAZARD GROUP:** General

**NO.** 12.34

**TITLE:** Fluid Quantity Usage Monitor

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

**SAFETY GUIDELINE:**

A means for monitoring fluid quantity usage should be provided to permit the crew to detect excessive consumption rates and low remaining supply levels.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of fluid leakage.
2. D2-113070-9, Logic Diagram, Proposition 9E.

**REMARKS:**

The space station crew should be able to monitor the fluid quantity regularly to determine if an excessive amount of fluid is being used; e.g., due to leakage. Although an atmosphere contaminants detection system should detect contamination due to fluid leakage within the spacecraft, a means of detecting leakage external to the pressurized portion of the spacecraft is desirable.

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| **HAZARD GROUP:** General | **NO.** 12.35 |

**TITLE:** Hazardous Resupply Operations Monitoring

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Communications and Data Management System

**SAFETY GUIDELINE:**

The commencement, behavior, and completion of all remote hazardous resupply operations (e.g., pressurized liquid or gas resupply) should be positively indicated at the command and control center(s).

**REFERENCES:**

1. D2-113070-10, FT-1 (Decompression), 7-M, "Damage occurs during liquid or gas transfer."

**REMARKS:**

The intent of this guideline is to provide monitoring for all remote resupply operations considered to be hazardous if not controlled. Context of this guideline may be extended to include monitoring of all hazardous spacecraft operations.

**HAZARD GROUP:** General

**NO.** 12.36

**TITLE:** Health and Safety Officer

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System, Operations

**SAFETY GUIDELINE:**

Overall health and safety considerations and responsibility should be assigned to specific members of the crew.

**REFERENCES:**

1. AFSC Design Handbook, System Safety, AFSCDH 1-6, Headquarters, AF Systems Command, January 20, 1969.
2. MIL-S-38130, Safety Engineering of Systems and Associated Subsystems and Equipment, General Requirements, 1 March 1967.
3. AFSCM 127-1, Safety Systems Management, April 7, 1967.
4. System Safety Data Plan CDRL 68-01-T, NASA Manned Spacecraft Center, Houston, August 15, 1968.

**REMARKS:**

The burden of identifying and enforcing health and safety considerations in a mission should rest with specific crew members. Continuity of this responsibility should be assured by the spacecraft commander.

**HAZARD GROUP:** General

**NO.** 12.37

**TITLE:** Incoming Vehicle Emergency

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

Standard operating procedure should include the provisions for abort for all incoming vehicles having an emergency on-board which would jeopardize the parent spacecraft.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 3-L, "Fire occurs in logistics vehicle."

**REMARKS:**

It is desirable to prevent the spread to the parent spacecraft of emergency conditions occurring aboard incoming vehicles. Consistent with this guideline, escape/rescue capabilities for the incoming vehicle should also be developed.

**HAZARD GROUP:** General

**NO.** 12.38

**TITLE:** Independent Emergency Power Source

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Electrical Power

**SAFETY GUIDELINE:**

An emergency power source which is completely independent of the primary power source 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, Proposition 6B.

**REMARKS:**

Because of the extremely critical relationship of electrical power to the total operation of the space station and safety of the crew, it is suggested that an independent emergency power source be provided. This power source would be used only in emergencies (loss of primary power source) and would have the capability to power the minimum equipment requirements for crew safety.

**HAZARD GROUP:** General

**NO.** 12.39

**TITLE:** Initial Manning of Space Station/Base

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations

**SAFETY GUIDELINE:**

An advance inspection team composed of a minimum number of the initial manning crew should check the habitability of an unmanned spacecraft before the remaining crew members transfer into it.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Paragraph 3.1.4, "Crew Transfer."

**REMARKS:**

This guideline would also apply to a manned space vehicle with which communications have been lost on both the docking vehicle and ground tracking stations. It implies also that appropriate protective gear be provided the inspection team.

**HAZARD GROUP:** General

**NO.** 12.40

**TITLE:** Inoperative Sensing Systems

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

A capability should be provided for the crew to immediately detect a failed (or faulty) sensing device or measurement system which provides critical operating information.

**REFERENCES:**

1. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard No. 214.
2. D2-113070-11, Subsystems Analysis (EC/LSS), for potential hazard of atmosphere contamination.

**REMARKS:**

Inability to differentiate between a detection or measurement system failure, and an actual equipment malfunction, could precipitate improper and possibly hazardous crew reaction.

**HAZARD GROUP:** General

**NO.** 12.41

**TITLE:** Intercom Station Monitor

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management (CDM)

**SAFETY GUIDELINE:**

A visual warning should be provided at a central control console to alert the operator whenever an intercom station failure occurs.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CDM), for potential hazard of loss of internal voice communications.
2. D2-113070-9, Logic Diagram, Proposition 18D.

**REMARKS:**

To provide the desired degree of crew safety it is necessary that the intercom system operate when needed. Therefore, if an intercom station is not operating satisfactorily, this information should be provided to the crew so corrective action can be initiated.

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| **HAZARD GROUP:** General | **NO.** 12.42 |

**TITLE:** Intercom System

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations, Communications and Data Management

**SAFETY GUIDELINE:**

A highly reliable intercommunication system should be provided within the spacecraft. System features should include positive measures to protect the system integrity against those events, e.g., fire, which would tend to disable or jeopardize the spacecraft.

**REFERENCES:**

1. D2-113070-10, FT-2 (Temperature Extremes), 15-H, "Fire results in failure of communications and data management," and 15-E, "Failure of a function necessary for crew well-being results in injury to personnel."

**REMARKS:**

Should an emergency condition develop aboard the spacecraft, good communications between all areas would enhance the coordinated effort needed to contain and control the event.

**HAZARD GROUP:** General

**NO.** 12.43

**TITLE:** Lighting

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Adequate lighting should be provided to enable crew members to perform all expected operational and maintenance tasks both inside and outside the space station.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of crew injury or illness.
2. D2-113070-9, Logic Diagram, Propositions 10G, 46B, 48F, 48H and 78G.

**REMARKS:**

There are many not normally lighted areas in a space station where operational and maintenance tasks might be performed. Therefore, some method of lighting (permanently installed or portable) should be provided to allow the crew to safely perform their activities. Emergency lighting provisions should be located at all critical operational areas to ensure capability of carrying on basic space station functions even if failure of the primary lighting system occurs. This should also include battery powered lights, e.g., flashlights, that are located strategically throughout the space station.

**HAZARD GROUP:** General

**NO.** 12.44

**TITLE:** Location of Intercom Stations

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management (CDM)

**SAFETY GUIDELINE:**

At least one intercom station should be provided in each separately pressurizable space station compartment that will be occupied by the crew.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CDM), for potential hazard of loss of internal voice communications.
2. D2-113070-9, Logic Diagram, Proposition 9C.

**REMARKS:**

Continuous awareness of the status of the crew is necessary to ensure the safety of the crew. Therefore, a communications capability between each separate compartment that will be occupied by the crew and the command and control center(s) should be required.

**HAZARD GROUP:** General

**NO.** 12.45

**TITLE:** Maintenance Capability

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

The maintenance equipment, procedures, and skills required to competently analyze and isolate component failures and accomplish the needed replacement or repair should be provided.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of inadequate maintenance capability.

2. D2-113070-9, Logic Diagram, Propositions 9F, 10G, 18D, 18E, 47E and 50E.

**REMARKS:**

It is assumed that suitable provisioning of replacement components (spares) will be done. Satisfactory use of these spares is dependent on having the correct maintenance equipment and tools to accomplish the replacement or repair, and adequate skills and equipment to analyze failure situations and to locate the failed component. Therefore, the on-board crew should be trained to handle any anticipated failures; easily used maintenance procedures should be available. Fault isolation capability should be provided for rapid detection of faulty components, and equipment should be provided to permit easy replacement of failed components with a very low possibility of human error. Qualified technicians for all space station systems should be available on the Earth for consultation with space station crews whenever required.

**HAZARD GROUP:** General

**NO.** 12.46

**TITLE:** Minimizing EVA Requirements

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Space station equipment, systems and configurations should be designed to minimize the requirements for EVA operations.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of crew injury or illness.

2. D2-113070-9, Logic Diagram, Propositions 10G and 28G.

**REMARKS:**

EVA is a particularly hazardous aspect of space missions. Therefore, the space station design should strive to minimize the requirements for EVA and to enhance the safe accomplishment of any EVA that is necessary. The requirements for EVA could be minimized through use of high reliability equipment, redundancy, backup modes of operation, etc. The time needed to accomplish EVA tasks can be minimized by designing equipment for easy replacement by a pressure-suited crewman. Replacement through the use of a remote manipulator unit could also be considered.

**HAZARD GROUP:** General

**NO.** 12.47

**TITLE:** Monitoring of Docked Vehicles

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management

**SAFETY GUIDELINE:**

Critical subsystems of docked logistic vehicles/tugs should be continuously monitored in the parent spacecraft by control center operator(s), with appropriate aural/visual warning provisions to indicate out-of-tolerance conditions.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Paragraph 3.3, "Logistic Vehicle/Tug Operations."

**REMARKS:**

Space vehicles with potential escape/rescue capabilities, such as the logistic vehicle/tug, should be maintained at a high degree of readiness in the event emergency evacuation of the crew is required.

**HAZARD GROUP:** General

**NO.** 12.48

**TITLE:** Monitoring of EVA/IVA

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

**SAFETY GUIDELINE:**

All EVA and IVA activities shall be backed up and monitored by a suited crew member who is positioned to assist immediately, if necessary, and by another crew member in a responsible position within the pressurized area of the spacecraft who is also monitoring the activities.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."
2. D2-113070-11, Subsystems Analysis (CS), for potential hazard of EVA equipment failure.
3. D2-113070-10, FT-1 (Decompression), 1-G, "Decompression results from failure of pressure suit pressure retention."
4. D2-113070-9, Logic Diagram, Propositions 18D, 28C, 28G, 48H and 48I.

**REMARKS:**

The intent of this guideline is to maximize awareness of an emergency and the ability of the remainder of the crew to aid in the event the EVA crewman encounters an emergency or faces a hazardous condition.

**HAZARD GROUP:** General

**NO.** 12.49

**TITLE:** Periodic Communications Subsystem Check

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management, Operations

**SAFETY GUIDELINE:**

A two-way communications check should be made between the control center and all occupied compartments, logistic vehicles or free-flying laboratories in the event a "no-communications" period exceeds some specified time.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Paragraph 3.1.4, "Crew Transfer."

**REMARKS:**

The int nt of this guideline is to verify the continual operability of the basic ommunications Subsystem, as well as to keep the control center apprised of crew disposition and status. This guideline could be implemented by incorporating it into the crew's mal operating procedures.

See also Guideline 12.63.

**HAZARD GROUP:** General

**NO.** 12.50

**TITLE:** Premature Subsystem Arming or Delayed Disarming

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Spacecraft subsystems should be armed only when they are to be used, and immediately disarmed when their function is no longer required, or subsequent use will not be for a prolonged period.

**REFERENCES:**

1. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard Nos. 1 and 62.

2. D2-113070-11, Subsystem Analysis (SCS), for potential hazard of exhaust plume.

**REMARKS:**

Premature arming or delayed disarming creates the risk of inadvertent and possibly undesirable operation of that equipment. Furthermore, it needlessly increases the possibility of stray currents or transient voltages which could cause a crew hazard, damage other equipment or interfere with the normal operation of that equipment.

**HAZARD GROUP:** General

**NO.** 12.51

**TITLE:** Pressurized Free Volume

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System (CS), Structures/Mechanical

**SAFETY GUIDELINE:**

The pressurized compartments of a space station should have adequate free volume (not occupied by equipment or structure) to provide the crew freedom of movement and a psychological and physiological environment that is commensurate with their orbital stay duration.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of crew injury or illness.
2. D2-113070-9, Logic Diagram, Propositions 48B and 48E.

**REMARKS:**

Many studies have been made into the free space volumetric requirements to provide a satisfactory habitable environment for the crew members. Careful consideration should be given to the results of these in the design of space stations, giving particular attention to the expected mission duration and/or maximum expected orbital stay time of individual crew members.

**HAZARD GROUP:** General

**NO.** 12.52

**TITLE:** Propellant Leak Detection

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

**SAFETY GUIDELINE:**

Leak detectors should be provided for propellant handling equipment located in unpressurized areas of the space station. The detectors should activate an alarm at the command and control center(s).

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of propellant leakage.

2. D2-113070-9, Logic Diagram, Propositions 8H and 48H.

**REMARKS:**

It is assumed that there will be equipment and procedures for detecting atmosphere contamination, including fluid leakage, in pressurized areas of the space station. In unpressurized areas, leakage could go undetected for some time if a method of detection is not used. Therefore, leakage detectors should be provided at potential leakage points. The detector should warn the crew when leakage occurs so that the appropriate corrective action can be initiated.

**HAZARD GROUP:** General

**NO.** 12.53

**TITLE:** Propellant Quantity and Usage

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

A visual/audible alarm should be provided to warn the crew of excessive propellant use rates and low propellant quantity.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of propellant leakage.
2. D2-113070-9, Logic Diagram, Propositions 9E, 9G and 48H.

**REMARKS:**

The space station crew needs to be aware of excessive propellant usage which, if allowed to continue, would affect crew safety by depleting the propellant supply until loss of attitude control results. Procedures should also be developed for correcting excessive use of propellants.

**HAZARD GROUP:** General

**NO.** 12.54

**TITLE:** Qualitative and Quantitative Personnel Requirements (QQPR)

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Crew System, Operations

**SAFETY GUIDELINE:**

Selection of personnel to man a space station/base should be preceded by a comprehensive analysis of all the candidates' background and the skills required, in order to satisfy the objectives of the mission.

**REFERENCES:**

1. MIL D-26239A, Qualitative and Quantitative Personnel Requirements Information Data, April 14, 1961, AF Systems Command.

**REMARKS:**

The qualitative and quantitative analysis of candidate crew members should include the education, professional history, health history, motivation, and any other parameter that impacts on the skills required to satisfy the cross-section of disciplines needed to operate a space station/base. A product of this analysis would be a determination of the different skills and numbers that should be part of a crew, such as professionals (e.g., doctors, dentists, nurses, engineers, etc.); technicians (e.g., machinists, clinical chemists, electricians, mechanics, etc.); non-technical workers (e.g., cooks, general repairmen, janitors, etc.).

**HAZARD GROUP:** General

**NO.** 12.55

**TITLE:** Replacement Component Installation

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Replacement components should be designed so that it is physically impossible to inadvertently install a component incorrectly.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of inadequate maintenance capability.

2. D2-113070-9, Logic Diagram, Proposition 10D.

**REMARKS:**

In the past there have been numerous incidents of components being inadvertently installed wrong with subsequent harmful and sometimes disastrous results. Therefore, components which are replaceable should have an installation designed that makes it physically impossible to incorrectly install the component, or that prevents a system from being operated if a component is inadvertently installed incorrectly.

**HAZARD GROUP:** General

**NO.** 12.56

**TITLE:** Replacement Component Provisioning

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

Spares should be provided for all components that have been designed to be replaceable and for which there is a probability of failure.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CS), for potential hazard of inadequate maintenance capability.

2. D2-113070-9, Logic Diagram, Propositions 9G and 18E.

**REMARKS:**

Past studies have shown that the success of long-duration manned space missions will depend on full utilization of man's capability for isolating failures and replacing faulty components. Therefore, it is necessary that adequate spares by provided on-board the space station to ensure that crew safety and the mission will not be endangered because a needed spare is not available. An inventory control system should also be provided for all spares to permit rapid acquisition of a spare when it is required.

**HAZARD GROUP:** General

**NO.** 12.57

**TITLE:** SCS Component Commonality

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Stability and Control System (SCS)

**SAFETY GUIDELINE:**

Stability and control system components in the space station should have as much commonality as practicable with components used in the logistics vehicles, Earth-return vehicles, and independent modules.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (SCS), for potential hazard of loss of attitude control.
2. D2-113070-9, Logic Diagram, Proposition 9D.

**REMARKS:**

Stability and control system equipment will be required on all vehicles used to transport men and supplies between the Earth and space stations, and independently controlled modules. Whenever the same equipment can be used in more than one vehicle, a built-in emergency or backup spares source will be available to each vehicle. Trade studies will be required to determine which equipment could effectively be common to more than one vehicle.

**HAZARD GROUP:** General

**NO.** 12.58

**TITLE:** Survival Device Availability

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Environmental Control/Life Support System

**SAFETY GUIDELINE:**

Universally sized, minimum time to don or place, survival devices should be made available to the crew.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis."

**REMARKS:**

The intent of this guideline is to provide a means by which crew members can survive when the compartment environment becomes uninhabitable. The device should give crew members time in which to evacuate the compartment, correct the emergency situation or take other action as appropriate.

**HAZARD GROUP:** General

**NO.** 12.59

**TITLE:** Switch Design and Location

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** All

**SAFETY GUIDELINE:**

All switches should be designed and located so that the possibility of inadvertent activation or improper selection is minimized.

**REFERENCES:**

1. Space Flight Hazards Catalog, MSC 00134, September 1969, Hazard Nos. 53 and 197.

2. D2-113070-11, Subsystems Analysis, All Sections.

**REMARKS:**

Such features as switchguards, lockwires, panel recesses, etc. should be considered in the switch design to minimize inadvertent activation. Switch location on the panel should take into account frequency of use, function similarity, quadrant location of operating equipment, etc. Careful attention to human engineering design practices will be required in this regard.

**HAZARD GROUP:** General

**NO.** 12.60

**TITLE:** Timing Equipment Redundancy

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management (CDM)

**SAFETY GUIDELINE:**

The central timing unit and equipment associated with keeping it up-to-date should have redundancy provided.

**REFERENCES:**

1. D2-113070-11, Subsystems Analysis (CDM), for potential hazard of loss of time reference.
2. D2-113070-9, Logic Diagram, Proposition 10F.

**REMARKS:**

A central timing unit furnishes essential time information to all on-board equipment which is dependent upon accurate time signals for its operation; e.g., computer functions and a.c. power regulation. Since some of the time-referenced equipment could affect crew safety if it did not operate satisfactorily, redundancy should be provided for the central timing function and the equipment necessary to keep the timing function up-to-date.

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| **HAZARD GROUP:** General | **NO.** 12.61 |
| **TITLE:** Traffic Flow in Work Areas | |
| **APPLICABLE SUBSYSTEMS/FUNCTIONS:** Operations | |

**SAFETY GUIDELINE:**

Traffic flow other than that necessary to complete the work objective should be held to a minimum through areas with work in progress.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis," Paragraph 2.2.

**REMARKS:**

The intent of this guideline is to protect the worker from distraction, and to protect the other crew members in the event of a work-associated hazard.

**HAZARD GROUP:** General

**NO.** 12.62

**TITLE:** Traffic Routes

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Structures/Mechanical Systems

**SAFETY GUIDELINE:**

Traffic routes should be configured in such a manner that traffic congestion is minimized during emergency conditions.

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Section 5, "Traffic Pattern Analysis," Paragraph 4.3.

**REMARKS:**

The intent of this guideline is to reduce escape time to a haven by minimizing traffic congestion. It is assumed that the conditions involved are such that minimizing traffic congestion will significantly reduce the escape time to a haven; further, that reducing escape time to a haven will increase the probability of crew survival. If escape routes are lengthy, such as tunnels or passages, consideration should be given to making them of a size such as to permit two-way traffic or traffic direction reversal.

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| **HAZARD GROUP:** General | **NO.** 12.63 |

**TITLE:** Voice Communications with Command and Control Center(s)

**APPLICABLE SUBSYSTEMS/FUNCTIONS:** Communications and Data Management

**SAFETY GUIDELINE:**

Upon entrance to an unoccupied compartment, logistic vehicle or free-flying laboratory, for purposes requiring more than momentary occupancy, the crew should immediately establish two-way communications with the command and control center(s).

**REFERENCES:**

1. D2-113070-6, Supporting Analyses, Paragraph 3.1.4, "Crew Transfer."

**REMARKS:**

The intent of this guideline is to verify operability of the Communications Subsystem in the visited compartment or module, and to contribute to control center cognizance of total crew disposition and dispersion. This guideline could be implemented by incorporating it as part of the subsystems periodic check-out procedure.

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# 4.0 CROSS INDEXES

## 4.1 CROSS INDEX BY HAZARD GROUPS

The guidelines which are prime to a hazard group are filed numerically under that group and are listed here in the same sequence. It will be noticed that the serial numbers correspond with alphabetical placement of the first words of their titles. Following the list of prime guidelines in each group is a cross-reference, in numerical sequence, to all other guidelines filed elsewhere which are applicable to the hazard group.

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## 4.1.1 CONTAMINATION

### PRIME

1.1 Airflow Cutoff to Enclosed Contamination Sources
1.2 Battery Venting
1.3 Contaminant and Waste Products Collection
1.4 Contaminant Control Equipment Redundancy
1.5 Control Procedures for Excessive Contamination
1.6 $CO_2$ Partial Pressure Monitor
1.7 $CO_2$ Removal Equipment
1.8 Equipment Contamination by Propellants
1.9 Fluid/Debris Collection and/or Containment
1.10 Fluid Leak Isolation
1.11 Fluid Lines Contamination
1.12 Food Storage Container Redundancy
1.13 Food Storage Sterilization
1.14 Food Supplies Refrigeration System Redundancy
1.15 Hazardous Materials--Quantities
1.16 Human Tolerance to Atmosphere Contaminants, Long-Term
1.17 Insect Control
1.18 Material-Configuration Control
1.19 Mercury Metal
1.20 Ozone
1.21 Plumbing Connectors--Minimum Loss
1.22 Plumbing Connectors--Minimum Quantity
1.23 Toxic or Flammable Fluids
1.24 Warning System--Contaminants Detection and Alarm
1.25 Warning System--Fluid Systems Contamination
1.26 Warning System--Hazardous Materials
1.27 Warning System--Relative Humidity
1.28 Waste Byproducts Control
1.29 Water Contamination
1.30 Water Sterilization
1.31 Water Storage Isolation
1.32 Water Supply Location

### ALSO APPLICABLE

3.9 Hatchway Airlocks
3.22 Venting of Pressure Relief Devices
3.25 Warning Systems, Fail-Safe
6.1 Electrical Ignition
6.5 Pressure Subsystem Interconnection
6.9 Pressure Tank Relief Protection Redundancy
6.11 Protection of Pressure Vessels
7.5 Burns, Chemical and Thermal
7.8 Crew Restrictions During Internal Hazardous Operations

7.10 Death of Experimental Plants and Animals
7.13 Hazardous Materials Accessibility
7.16 Medical Emergencies
8.7 Emergency Life Support Provisions
8.10 Interlocks for Equipment with Critical Operating Ranges
8.14 Oxygen Storage Tanks Redundancy
8.20 Pressure Suit/PLSS $CO_2$ Monitor
8.31 Water Contamination Control Procedures
8.32 Water Sterilization Equipment Redundancy
8.33 Water Storage Tanks Redundancy
9.2 Disposal of Radioactive Material
9.19 Radioactive Stores
10.1 $CO_2$ Control Equipment Maintenance
10.3 Containment of Fire
10.4 Cryogenics
10.8 Fire-Resistant Electrical Insulation
10.13 Hypergolic and Pyrophoric Material
10.14 Ignition Source Control
10.19 Over-current Protection
10.21 Propellant Supply System Location
10.23 Self-Propagation of Fires
10.24 Slow Opening High Pressure Oxygen Valves

## 4.1.2 DEBRIS AND METEOROID IMPACT

**PRIME**

2.1 Component Design for Meteoroid Impact Protection
2.2 Flight Path Orbit Selection
2.3 Insulation Material
2.4 Window Replacement

**ALSO APPLICABLE**

3.5 Hatch Closure
3.17 Primary Structure Inspection and Repair
5.9 Mechanical Shielding of Electrical Equipment
6.7 Pressure Systems Location
6.10 Propellant Tank Protection
7.17 Protective Clothing

4.1.3 DECOMPRESSION/OVERPRESSURE

PRIME

3.1 Compartment Integrity
3.2 Crack Propagation in Primary Structure
3.3 Equipment Design for Rapid Decompression
3.4 Hatch Automatic Closure
3.5 Hatch Closure
3.6 Hatch Positive Closure
3.7 Hatch Pressure Loading
3.8 Hatch Seal Leakage Rate
3.9 Hatchway Airlocks
3.10 Leakage Repair System
3.11 Medical Equipment for Emergencies
3.12 Pressure Regulator Failure
3.13 Pressure Relief for Trapped Fluids
3.14 Pressure System Depressurization
3.15 Pressurizable Volume Relief Protection
3.16 Pressurized Gas Flow Restriction
3.17 Primary Structure Inspection and Repair
3.18 Rapid Decompression Effects
3.19 Spacecraft Structural Strength
3.20 Vented Component Replacement
3.21 Venting of Cabin Pressure
3.22 Venting of Pressure Relief Devices
3.23 Venting Provisions
3.24 Warning Systems, Cabin Pressure
3.25 Warning Systems, Fail-Safe

ALSO APPLICABLE

1.5 Control Procedures for Excessive Contamination
4.3 Potential Difference, Docking Spacecraft
5.2 Crew Restrictions During Docking
5.12 Rotating Machinery Shielding
6.5 Pressure Subsystem Interconnection
6.11 Protection of Pressure Vessels
7.8 Crew Restrictions During Internal Hazardous Operations
7.16 Medical Emergencies
8.2 Airlock Oxygen Monitor
8.5 Continuous Control of Cabin Pressure
8.7 Emergency Life Support Provisions
8.8 Emergency Pressurization Oxygen Supply
8.17 Pressure Leak Detection
8.18 Pressure Relief Valve Repair Procedures
8.21 Pressure Suit/PLSS Oxygen Usage
8.30 Warning System--Oxygen Pressure

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4.1.4 ELECTRICAL

**PRIME**

4.1 Cable Insulation Damage
4.2 Connector Mismating
4.3 Electrical Arcing
4.4 Electrical Connections
4.5 Electrical Cable Shorts
4.6 Electrical Connector Checks
4.7 Grounding of Spacecraft and Equipment
4.8 Potential Differences--Docking Spacecraft
4.9 Power Distribution Paths Redundancy
4.10 Power Source Monitors
4.11 Power Sources Redundancy
4.12 Protective Covers for Electrical Equipment
4.13 Redundant Circuits
4.14 Routing of Power Distribution Lines

**ALSO APPLICABLE**

5.9 Mechanical Shielding of Electrical Equipment
6.1 Electrical Ignition
6.7 Pressure Systems Location
7.5 Burns, Chemical and Thermal
10.5 Electrical Power Source Cooling
10.6 Electrical Power System Location
10.8 Fire Resistant Electrical Insulation
10.19 Over-current Protection

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4.1.5 EQUIPMENT IMPACT

PRIME

5.1 Bulk Cargo Restraint
5.2 Crew Restrictions During Docking
5.3 Docking Closure Rate Control
5.4 Docking Light Redundancy
5.5 Docking Port Redundancy
5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage From Spacecraft Equipment
5.9 Mechanical Shielding of Electrical Equipment
5.10 Mobility Aids, Zero Gravity
5.11 Pressure Suit Repair
5.12 Rotating Machinery Shielding

ALSO APPLICABLE

1.23 Toxic or Flammable Fluid
2.4 Window Replacement
3.5 Hatch Closure
3.17 Primary Structure Inspection and Repair
6.10 Propellant Tank Protection
7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.16 Medical Emergencies
10.28 Thruster Location

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4.1.6 EXPLOSION

PRIME

6.1 Electrical Ignition
6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.4 Hazardous Mixtures
6.5 Pressure Subsystem Interconnection
6.6 Pressure System Dynamics
6.7 Pressure Systems Location
6.8 Pressure System Safing
6.9 Pressure Tank Relief Protection Redundancy
6.10 Propellant Tank Protection
6.11 Protection of Pressure Vessels
6.12 Shrouding and Shielding of Pressure Lines
6.13 Water Electrolysis Unit Cell Reversed Polarity

ALSO APPLICABLE

1.10 Fluid Leak Isolation
1.21 Plumbing Connectors--Minimum Loss
1.22 Plumbing Connectors--Minimum Quantity
1.23 Toxic or Flammable Fluids
1.24 Warning Systems--Contaminants Detection and Alarm
1.26 Warning Systems--Hazardous Materials
3.5 Hatch Closure
3.9 Hatchway Airlocks
3.15 Pressurizable Volume Relief Protectors
3.17 Primary Structure Inspection and Repair
4.2 Connector Mismating
4.3 Electrical Arcing
4.4 Electrical Connections
4.6 Electrical Connector Checks
4.7 Grounding of Spacecraft and Equipment
4.8 Potential Difference--Docking Spacecraft
4.9 Protective Covers for Electrical Equipment
5.9 Mechanical Shielding of Electrical Equipment
7.17 Protective Clothing
8.14 Oxygen Storage Tanks Redundancy
10.5 Electrical Power Source Cooling
10.6 Electrical Power System Location
10.11 Heating Element Flame Suppression
10.13 Hypergolic and Pyrophoric Material
10.14 Ignition Source Control
10.19 Over-current Protection
10.21 Propellant Supply System Location
10.23 Self-propagation of Fire
10.30 Thruster Temperature Monitor
11.12 Propellant Storage Tanks Redundancy

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4.1.7 ILLNESS AND INJURY

PRIME

7.1 Angular Velocity Upper Limit
7.2 Artificial-Gravity Limits
7.3 Bacteriological Monitoring of the Crew
7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.6 Communicable Disease Control
7.7 Compartment Orientation within Artificial-Gravity Environment
7.8 Crew Restrictions During Internal Hazardous Operations
7.9 Death of Crew members
7.10 Death of Experimental Plants and Animals
7.11 Emotional Disturbances
7.12 Gastrointestinal and Urinary Tract Disorders
7.13 Hazardous Materials Accessibility
7.14 Health and Safety Officer(s) Training
7.15 Irrational Crew Member Restraint
7.16 Medical Emergencies
7.17 Protective Clothing
7.18 Quarantine Regulations
7.19 Radial Traffic in Artificial-Gravity Environment
7.20 Radiation Casualty Evacuation
7.21 Rotation Radius Lower Limit
7.22 Sanitation Standards
7.23 Work Station Position for Artificial-Gravity Station

ALSO APPLICABLE

1.12 Food Storage Containers Redundancy
1.13 Food Storage Sterilization
1.14 Food Supplies Refrigeration System Redundancy
1.27 Warning System--Relative Humidity
1.28 Waste By-products Control
1.29 Water Contamination
1.30 Water Sterilization
1.31 Water Storage Isolation
1.32 Water Supply Location
3.9 Hatchway Airlocks
3.11 Medical Equipment for Emergencies
4.3 Electrical Arcing
5.8 Injury or Damage From Spacecraft Equipment
5.10 Mobility Aids, Zero Gravity
8.19 Pressure Suit/PLSS Atmosphere Composition
10.4 Cryogenics

4.1.8 LOSS OF VITAL SUPPLIES

**PRIME**

8.1 Air Circulation
8.2 Airlock Oxygen Monitor
8.3 Airlock Suit Loop Connectors
8.4 Autonomous Operation of Suit Loop
8.5 Continuous Control of Cabin Pressure
8.6 Crew Shower Failure Protection
8.7 Emergency Life Support Provisions
8.8 Emergency Pressurization Oxygen Supply
8.9 Environmental Control/Life Support System Redundancy
8.10 Interlocks for Equipment with Critical Operating Ranges
8.11 Oxygen Leak Isolation
8.12 Oxygen Quantity and Usage
8.13 Oxygen Regulation Component Redundancy
8.14 Oxygen Storage Tanks Redundancy
8.15 Oxygen Usage Manual Control
8.16 PLSS Emergency Backup
8.17 Pressure Leak Detectors
8.18 Pressure Relief Valve Repair Procedures
8.19 Pressure Suit/PLSS Atmosphere Composition
8.20 Pressure Suit/PLSS $CO_2$ Monitor
8.21 Pressure Suit/PLSS Oxygen Usage
8.22 Pressure Suit/PLSS Redundancy
8.23 Pressure Suit Temperature and Humidity Monitoring
8.24 Suit Loop Check-out
8.25 Suit Loop Components Maintenance
8.26 Suit Loop Component Redundancy
8.27 Suit Loop Manual Control
8.28 Suit Loop Outlet
8.29 Suit Loop Pressure Monitor
8.30 Warning System--Oxygen Pressure
8.31 Water Contamination Control Procedures
8.32 Water Sterilization Equipment Redundancy
8.33 Water Storage Tanks Redundancy

**ALSO APPLICABLE**

1.1 Airflow Cutoff to Enclosed Contamination Sources
1.12 Food Storage Containers Redundancy
1.13 Food Storage Sterilization
1.14 Food Supplies Refrigeration System Redundancy
1.24 Warning System--Contaminants Detection and Alarm
1.29 Water Contamination
1.30 Water Sterilization
1.31 Water Storage Isolation
1.32 Water Supply Location
6.13 Water Electrolysis Unit Cell Reversed Polarity
10.24 Slow Opening High Pressure Oxygen Valves

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4.1.9 RADIATION

PRIME

9.1 Controlled Access and Use of Radiation Sources
9.2 Disposal of Radioactive Material
9.3 Handling and Use of Radioactive Material
9.4 Microwave and X-radiation Hazard
9.5 Nuclear Power Radiation Protection
9.6 Nuclear Power Unit Radiation Protection
9.7 Nuclear Reactor Safety
9.8 Orbital Path Radiation Environment
9.9 Placement of Equipment and Stores
9.10 Protection Against Nuclear Explosion Radiation
9.11 Radiation Detectors Location and Characteristics
9.12 Radiation Effects upon Spacecraft Materials
9.13 Radiation Environment Restrictions on EVA
9.14 Radiation Exposure and Control Program
9.15 Radiation Exposure Record
9.16 Radiation Haven
9.17 Radiation Monitoring
9.18 Radiation Protection During EVA
9.19 Radioactive Stores
9.20 Spacecraft Radiation Shielding
9.21 Selection of Materials for Use in Radiation Environment

ALSO APPLICABLE

3.25 Warning Systems, Fail-Safe
7.8 Crew Restrictions During Internal Hazardous Operations
7.20 Radiation Casualty Evacuation

4.1.10 TEMPERATURE EXTREMES

PRIME

10.1 $CO_2$ Control Equipment Maintenance
10.2 Combustible Waste Materials
10.3 Containment of Fire
10.4 Cryogenics
10.5 Electrical Power Source Cooling
10.6 Electrical Power System Location
10.7 Fire Control
10.8 Fire Resistant Electrical Insulation
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.11 Heating Element Flame Suppression
10.12 Heat Monitoring in Operating Equipment
10.13 Hypergolic and Pyrophoric Material
10.14 Ignition Source Control
10.15 Isolation of Oxygen Source
10.16 Location of Combustibles
10.17 Lubricants
10.18 Manual Control of Temperature Control Systems
10.19 Over-current Protection
10.20 Personnel Protection for Heated Surfaces
10.21 Propellant Supply System Location
10.22 Protection of Temperature Critical Equipment
10.23 Self-propagation of Fires
10.24 Slow Opening High Pressure Oxygen Valves
10.25 Spacecraft Thermal Protection
10.26 Thermal Control Equipment Redundancy
10.27 Thermal Control Temperature Sensors

ALSO APPLICABLE

1.5 Control Procedures for Excessive Contamination
1.10 Fluid Leak Isolation
1.21 Plumbing Connectors, Minimum Loss
1.22 Plumbing Connectors, Minimum Quantity
1.23 Toxic or Flammable Fluids
1.26 Warning System--Hazardous Materials
2.3 Insulating Material
3.5 Hatch Closure
3.9 Hatchway Airlocks
3.15 Pressurizable Volume Relief Protection
3.25 Warning Systems, Fail-Safe
4.1 Cable Insulation Damage
4.2 Connector Mismating
4.3 Electrical Arcing

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| 4.4 | Electrical Connections |
| 4.5 | Electrical Cable Shorts |
| 4.6 | Electrical Connector Checks |
| 4.7 | Grounding of Spacecraft and Equipment |
| 4.8 | Potential Difference--Docking Spacecraft |
| 4.9 | Protective Covers for Electrical Equipment |
| 5.9 | Mechanical Shielding of Electrical Equipment |
| 5.12 | Rotating Machinery Shielding |
| 6.7 | Pressure Systems Location |
| 7.5 | Burns, Chemical and Thermal |
| 7.8 | Crew Restrictions During Internal Hazardous Operations |
| 7.16 | Medical Emergencies |
| 7.17 | Protective Clothing |
| 8.7 | Emergency Life Support Provisions |
| 10.28 | Thruster Location |
| 10.29 | Thruster Operation During EVA |
| 10.30 | Thruster Temperature Monitor |

## 4.1.11 SPACECRAFT ACCELERATIONS

### PRIME

11.1 Angular Rate Monitor
11.2 Automatic Tumbling Correction
11.3 Component Redundancy
11.4 Component Replacement for CMG's
11.5 Crew Restrictions During Space Station Spin-up
11.6 Damage-Induced Motion
11.7 Manual/Automatic Control Interlocks
11.8 Manual Control of SCS Thrusters
11.9 On-board Crew Complement During Space Base Spin-up
11.10 Propellant Flow Shut-off Redundancy
11.11 Torques from Venting
11.12 Propellant Storage Tanks Redundancy

### ALSO APPLICABLE

5.3 Docking Closure Rate Control
5.9 Mechanical Shielding of Electrical Equipment
6.1 Electrical Ignition

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4.1.12 GENERAL

PRIME

12.1 Accessways
12.2 Airlock Hatch Operation
12.3 Airlock Pressurization Redundancy
12.4 Airlock Redundancy
12.5 Alternate Command and Control Center
12.6 Assistance to Injured Personnel
12.7 Attitude Indication Redundancy
12.8 Authority to Proceed with Hazardous and Certain Other Operations
12.9 Cargo Transfer Equipment Redundancy
12.10 Closed Circuit Television Monitoring
12.11 Command Personnel Location Restrictions
12.12 Communication Equipment Commonality
12.13 Compartmentation
12.14 Compartment Environmental Status
12.15 Computer Equipment Redundancy
12.16 Continuous Attitude Indication
12.17 Crew Activity Restrictions
12.18 Crew Distribution
12.19 Crew Movement
12.20 Crew-oriented Areas
12.21 Crew Performance of Complex Tasks
12.22 Critical Caution and Warning Alarms
12.23 Docking Mechanism Redundancy
12.24 Emergency Communications System
12.25 Emergency Crew Evacuation
12.26 Emergency EVA Communications
12.27 Emergency Lighting for EVA
12.28 Emergency Procedures and Training
12.29 Emergency Procedures (Fire)
12.30 Escape Routes
12.31 EVA Emergency Procedures
12.32 External Communications Redundancy
12.33 Fire Alarm
12.34 Fluid Quantity Usage Monitor
12.35 Hazardous Resupply Operations Monitoring
12.36 Health and Safety Officer
12.37 Incoming Vehicle Emergency
12.38 Independent Emergency Power Source
12.39 Initial Manning of Space Station/Base
12.40 Inoperative Sensing Systems
12.41 Intercom Station Monitor
12.42 Intercom System
12.43 Lighting
12.44 Location of Intercom Stations
12.45 Maintenance Capability
12.46 Minimizing EVA Requirements

12.47 Monitoring of Docked Vehicles
12.48 Monitoring of EVA/IVA
12.49 Periodic Communication Subsystem Check
12.50 Premature Subsystem Arming or Delayed Disarming
12.51 Pressurized Free Volume
12.52 Propellant Leak Detection
12.53 Propellant Quantity and Usage
12.54 Qualitative and Quantitative Personnel Requirements
12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.57 SCS Component Commonality
12.58 Survival Device Availability
12.59 Switch Design and Location
12.60 Timing Equipment Redundancy
12.61 Traffic Flow in Work Areas
12.62 Traffic Routes
12.63 Voice Communication with Command and Control Center(s)

ALSO APPLICABLE

Does not apply.

## 4.2 CROSS INDEX BY SUBSYSTEMS

The guidelines applicable tc a given subsystem are referenced in numerical order in this section. The subsystems are arranged alphabetically for convenience. A category entitled "Operations" has been included to pick up guidelines which are more oriented toward procedures than to hardware. It is apparent that many guidelines pertain to more than one subsystem and, therefore are duplicated between subsystem listings. The following subsystem categories have been used:

4.2.1 Communications and Data Management (CDM)

4.2.2 Crew System (CS)

4.2.3 Electrical Power System (EPS)

4.2.4 Environmental Control/Life Support System (EC/LSS)

4.2.5 Experiments (EX)

4.2.6 Operations (OP)

4.2.7 Stability and Control System (SCS)

4.2.8 Structures/Mechanical Systems (S/M)

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4.2.1 COMMUNICATIONS AND DATA MANAGEMENT

1.18 Materials--Configuration Control
1.19 Mercury Metal

2.1 Component Design for Meteoroid Impact Protection

3.3 Equipment Design for Rapid Decompression
3.14 Pressure System Depressurization

4.1 Cable Insulation Damage
4.2 Connector Mismating
4.3 Electrical Arcing
4.5 Electrical Cable Shorts
4.6 Electrical Connector Checks
4.7 Grounding of Spacecraft and Equipment
4.9 Power Distribution Paths Redundancy
4.12 Protective Covers for Electrical Equipment

5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.9 Mechanical Shielding of Electrical Equipment

6.1 Electrical Ignition
6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.5 Pressure Subsystem Interconnection

7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.13 Hazardous Materials Accessibility

9.9 Placement of Equipment and Stores
9.10 Radiation Detectors Location and Characteristics
9.12 Radiation Effects upon Spacecraft Materials
9.21 Selection of Materials for Use in Radiation Environment

10.4 Cryogenics
10.7 Fire Control
10.8 Fire Resistant Electrical Insulation
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.17 Lubricants
10.19 Over-current Protection
10.20 Personnel Protection for Heated Surfaces
10.23 Self-propagation of Fires
10.28 Thruster Location

12.10 Closed Circuit Television Monitoring
12.12 Communications Equipment Commonality
12.13 Compartmentation
12.14 Compartment Environmental Status
12.15 Computer Equipment Redundancy
12.22 Critical Caution and Warning Alarms
12.24 Emergency Communication System
12.26 Emergency EVA Communications
12.32 External Communications Redundancy
12.33 Fire Alarm
12.35 Hazardous Resupply Operations Monitoring
12.40 Inoperative Sensing Systems
12.41 Intercom Station Monitor
12.42 Intercom System
12.43 Lighting
12.44 Location of Intercom Stations
12.45 Mainteancne Capability
12.46 Minimizing EVA Requirements
12.47 Monitoring of Docked Vehicles
12.49 Periodic Communications Subsystem Check
12.50 Premature Subsystem Arming or Delayed Disarming
12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.59 Switch Design and Location
12.60 Timing Equipment Redundancy
12.62 Voice Communications with Command and Control Centers

4.2.2 CREW SYSTEM (CM)

1.9 Fluid/Debris Collection and/or Containment
1.12 Food Storage Container Redundancy
1.13 Food Storage Sterilization
1.14 Food Supplies Refrigeration System Redundancy
1.15 Hazardous Materials, Quantities
1.17 Insect Control
1.18 Materials--Configuration Control
1.19 Mercury Metal
1.20 Ozone
1.22 Plumbing Connectors--Minimum Quantity
1.24 Warning System Contaminants Detection and Alarm
1.25 Warning System--Fluid Systems Contamination
1.28 Waste By-products Control
1.29 Water Contamination
1.30 Water Sterilization
1.31 Water Storage Isolation
1.32 Water Supply Location

2.1 Component Design for Meteoroid Impact Protection

3.3 Equipment Design for Rapid Decompression
3.10 Leakage Repair System
3.11 Medical Equipment for Emergencies
3.12 Pressure Regulator Failure
3.14 Pressure System Depressurization
3.18 Rapid Decompression Effects

4.5 Electrical Cable Shorts
4.7 Grounding of Spacecraft and Equipment
4.9 Power Distribution Paths Redundancy
4.13 Redundant Circuits

5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.10 Mobility Aids, Zero-Gravity
5.11 Pressure Suit Repair

6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.4 Hazardous Mixtures
6.5 Pressure Subsystem Interconnection
6.6 Pressure System Dynamics
6.8 Pressure System Safing

7.3 Bacteriological Monitoring of the Crew
7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal

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| 7.6 | Communicable Disease Control |
| 7.9 | Death of Crew Members |
| 7.10 | Death of Experimental Plants and Animals |
| 7.11 | Emotional Disturbances |
| 7.12 | Gastrointestinal and Urinary Tract Disorders |
| 7.13 | Hazardous Materials Accessibility |
| 7.14 | Health and Safety Officer(s) Training |
| 7.15 | Irrational Crew Member Restraint |
| 7.16 | Medical Emergencies |
| 7.17 | Protective Clothing |
| 7.18 | Quarantine Regulations |
| 7.20 | Radiation Casualty Evacuation |
| 7.22 | Sanitation Standards |
| 8.3 | Airlock Suit Loop Connections |
| 8.6 | Crew Shower Failure Protection |
| 8.7 | Emergency Life Support Provisions |
| 8.16 | PLSS Emergency Backup |
| 8.19 | Pressure Suit/PLSS Atmosphere Composition |
| 8.20 | Pressure Suit/PLSS $CO_2$ Monitor |
| 8.21 | Pressure Suit/PLSS Oxygen Usage |
| 8.22 | Pressure Suit/PLSS Redundancy |
| 8.23 | Pressure Suit Temperature and Humidity Monitoring |
| 8.31 | Water Contamination Control Procedures |
| 8.32 | Water Sterilization Equipment Redundancy |
| 8.33 | Water Storage Tanks Redundancy |
| 9.3 | Handling and Use of Radioactive Material |
| 9.9 | Placement of Equipment and Stores |
| 9.10 | Protection Against Nuclear Explosion Radiation |
| 9.11 | Radiation Detection Location and Characteristics |
| 9.12 | Radiation Effects upon Spacecraft Materials |
| 9.15 | Radiation Exposure Record |
| 9.16 | Radiation Haven |
| 9.17 | Radiation Monitoring |
| 9.19 | Radioactive Stores |
| 9.21 | Selection of Materials for Use in Radiation Environment |
| 10.4 | Cryogenics |
| 10.7 | Fire Control |
| 10.9 | Fire Retardant Electrical Equipment |
| 10.10 | Freezing of Fluid Lines |
| 10.17 | Lubricants |
| 10.20 | Personnel Protection for Heated Surfaces |
| 10.22 | Protection of Temperature Critical Equipment |
| 10.23 | Self-Propagation of Fire |
| 10.27 | Thermal Control Temperature Sensors |
| 10.29 | Thruster Operation During EVA |

12.13 Compartmentation
12.15 Computer Equipment Redundancy
12.21 Crew Performance of Complex Tasks
12.22 Critical Caution and Warning Alarms
12.26 Emergency EVA Communications
12.27 Emergency Lighting for EVA
12.31 EVA Emergency Procedures
12.33 Fire Alarm
12.36 Health and Safety Officer
12.40 Inoperative Sensing Systems
12.43 Lighting
12.45 Maintenance Capability
12.46 Minimizing EVA Requirements
12.48 Monitoring of EVA/IVA
12.50 Premature Subsystem Arming or Delayed Disarming
12.51 Pressurized Free Volume
12.54 Qualitative and Quantitative Personnel Requirements
12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.58 Survival Device Availability
12.59 Switch Design and Location

4.2.3 ELECTRICAL POWER SYSTEM (EPS)

1.2 Battery Venting
1.8 Equipment Contamination by Propellants
1.18 Materials--Configuration Control
1.19 Mercury Metal
1.20 Ozone
1.22 Plumbing Connectors--Minimum Quantity
1.23 Toxic or Flammable Fluids

2.2 Component Design for Meteoroid Impact Protection

3.3 Equipment Design for Rapid Decompression
3.14 Pressure System Depressurization
3.21 Venting of Cabin Pressure

4.1 Cable Insulation Damage
4.2 Connector Mismating
4.3 Electrical Arcing
4.4 Electrical Connections
4.5 Electrical Cable Shorts
4.6 Electrical Connector Checks
4.7 Grounding of Spacecraft and Equipment
4.9 Power Distribution Paths Redundancy
4.10 Power Source Monitors
4.11 Power Sources Redundancy
4.12 Protective Covers for Electrical Equipment
4.13 Redundant Circuits
4.14 Routing of Power Distribution Lines

5.6 Equipment Operations During EVA
4.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.9 Mechanical Shielding of Electrical Equipment
5.12 Rotating Machinery Shielding

6.1 Electrical Ignition
6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.5 Pressure Subsystem Interconnection
6.6 Pressure System Dynamics
6.8 Pressure System Safing

7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.13 Hazardous Materials Accessibility

9.2 Disposal of Radioactive Material
9.5 Nuclear Power Radiation Protection
9.6 Nuclear Power Unit Radiation Protection

9.7 Nuclear Reactor Safety
9.9 Placement of Equipment and Stores
9.12 Radiation Effects upon Spacecraft Materials
9.16 Radiation Haven
9.18 Radiation Protection During EVA
9.21 Selection of Materials for Use in Radiation Environment

10.4 Cryogenics
10.5 Electrical Power Source Cooling
10.6 Electrical Power System Location
10.7 Fire Control
10.8 Fire Resistant Electrical Insulation
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.11 Heating Element Flame Suppression
10.12 Heat Monitoring in Operating Equipment
10.14 Ignition Source Control
10.17 Lubricants
10.19 Over-current Protection
10.20 Personnel Protection for Heated Surfaces
10.22 Protection of Temperature Critical Equipment
10.23 Self-Propagation of Fire
10.27 Thermal Control Temperature Sensors
10.28 Thruster Location

12.13 Compartmentation
12.15 Computer Equipment Redundancy
12,33 Fire Alarm
12.38 Independent Emergency Power Source
12.40 Inoperative Sensing System
12.43 Lighting
12.45 Maintenance Capability
12.46 Minimizing EVA requirements
12.50 Premature Subsystem Arming or Delayed Disarming
12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.59 Switch Design and Location

4.2.4 ENVIRONMENTAL CONTROL/LIFE SUPPORT SYSTEM (EC/LSS)

1.1 Airflow Cutoff to Enclosed Contamination Sources
1.3 Contaminant and Waste Products Collection
1.4 Contaminant Control Equipment Redundancy
1.5 Control Procedures for Excessive Contamination
1.6 $CO_2$ Partial Pressure Monitor
1.7 $CO_2$ Removal Equipment
1.9 Fluid/Debris Collection and/or Containment
1.10 Fluid Leak Isolation
1.11 Fluid Lines Contamination
1.12 Food Storage Container Redundancy
1.13 Food Storage Sterilization
1.14 Food Supplies Refrigeration System Redundancy
1.16 Human Tolerance to Atmosphere Contaminants, Long-term
1.18 Materials--Configuration Control
1.19 Mercury Metal
1.21 Plumbing Connectors--Minimum Loss
1.22 Plumbing Connectors--Minimum Quantity
1.23 Toxic or Flammable Fluids
1.24 Warning System--Contaminants Detection and Alarm
1.25 Warning System--Fluid Systems Contamination
1.26 Warning System--Hazardous Materials
1.27 Warning System--Relative Humidity
1.28 Waste By-products Control
1.29 Water Contamination
1.30 Water Sterilization
1.31 Water Storage Isolation
1.32 Water Supply Location

2.1 Component Design for Meteoroid Impact Protection

3.3 Equipment Design for Rapid Decompression
3.12 Pressure Regulator Failure
3.13 Pressure Relief for Trapped Fluids
3.14 Pressure System Depressurization
3.15 Pressurizable Volume Relief Protection
3.16 Pressurized Gas Flow Restriction
3.17 Primary Structure Inspection and Repair
3.20 Vented Component Replacement
3.21 Venting of Cabin Pressure
3.22 Venting of Pressure Relief Devices
3.23 Venting Provisions
3.24 Warning Systems, Cabin Pressure
3.25 Warning Systems, Fail-Safe

4.1 Cable Insulation Damage
4.2 Connector Mismating
4.3 Electrical Arcing
4.5 Electrical Cable Shorts

4.6 Electrical Connector Checks
4.7 Grounding of Spacecraft and Equipment
4.9 Power Distribution Paths Redundancy
4.12 Protective Cover for Electrical Equipment
4.13 Redundant Circuits

5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.9 Mechanical Shielding of Electrical Equipment
5.11 Pressure Suit Repair
5.12 Rotating Machinery Shielding

6.1 Electrical Ignition
6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.4 Hazardous Mixtures
6.5 Pressure Subsystem Interconnections
6.6 Pressure System Dynamics
6.7 Pressure Systems Location
6.8 Pressure System Safing
6.9 Pressure Tank Relief Protection Redundancy
6.13 Water Electrolysis Unit Cell Reversed Polarity

7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.6 Communicable Disease Control
7.9 Death of Crew Members
7.12 Gastrointestinal and Urinary Tract Disorders
7.13 Hazardous Materials Accessibility
7.16 Medical Emergencies
7.22 Sanitation Standards

8.1 Air Circulation
8.4 Autonomous Operation of Suit Loop
8.5 Continuous Control of Cabin Pressure
8.7 Emergency Life Support Provisions
8.8 Emergency Pressurization Oxygen Supply
8.9 Environmental Control/Life Support System Redundancy
8.10 Interlocks for Equipment with Critical Operating Ranges
8.11 Oxygen Leak Isolation
8.12 Oxygen Quantity and Usage
8.13 Oxygen Regulation Component Redundancy
8.14 Oxygen Storage Tanks Redundancy
8.15 Oxygen Usage Manual Control
8.16 PLSS Emergency Backup
8.17 Pressure Leak Detection
8.18 Pressure Relief Valve Repair Procedures
8.19 Pressure Suit/PLSS Atmosphere Composition
8.20 Pressure Suit/PLSS $CO_2$ Monitor

8.21 Pressure Suit/PLSS Oxygen Usage
8.22 Pressure Suit/PLSS Redundancy
8.23 Pressure Suit Temperature and Humidity Monitoring
8.24 Suit Loop Checkout
8.25 Suit Loop Components Maintenance
8.26 Suit Loop Component Redundancy
8.27 Suit Loop Manual Control
8.28 Suit Loop Outlet
8.29 Suit Loop Pressure Monitor
8.30 Warning System--Oxygen Pressure
8.31 Water Contamination Control Procedures
8.32 Water Sterilization Equipment Redundancy
8.33 Water Storage Tanks Redundancy

9.9 Placement of Equipment and Store
9.12 Radiation Effects upon Spacecraft Materials
9.19 Radioactive Stores
9.21 Selection of Materials for Use in Radiation Environment

10.1 $CO_2$ Control Equipment Maintenance
10.3 Containment of Fire
10.4 Cryogenics
10.7 Fire Control
10.8 Fire Resistant Electrical Insulation
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.11 Heating Element Flame Suppression
10.12 Heat Monitoring in Operating Equipment
10.17 Lubricants
10.18 Manual Control of Temperature Control Systems
10.19 Over-current Protection
10.20 Personnel Protection for Heated Surfaces
10.22 Protection of Temperature Critical Equipment
10.23 Self-Propagation of Fires
10.24 Slow Opening High Pressure Oxygen Valves
10.26 Thermal Control Equipment Redundancy
10.27 Thermal Control Temperature Sensors

12.13 Compartmentation
12.15 Computer Equipment Redundancy
12.30 Escape Routes
12.33 Fire Alarm
12.34 Fluid Quantity Usage Monitor
12.40 Inoperative Sensing Systems
12.43 Lighting
12.45 Maintenance Capability
12.46 Minimizing EVA Requirements
12.48 Monitoring of EVA/IVA
12.50 Premature Subsystem Arming or Delayed Disarming
12.52 Propellant Leak Detection

12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.58 Survival Device Availability
12.59 Switch Design and Location

4.2.5 EXPERIMENTS (EX)

1.15 Hazardous Materials--Quantities
1.17 Insect Control
1.18 Materials--Configuration Control
1.19 Mercury Metal
1.20 Ozone

2.1 Component Design for Meteoroid Impact Protection

3.3 Equipment Design for Rapid Decompression
3.12 Pressure Regulator Failure
3.13 Pressure Relief for Trapped Fluids
3.14 Pressure System Depressurization
3.21 Venting of Cabin Pressure

4.1 Cable Insulation Damage
4.3 Electrical Arcing
4.4 Electrical Connections
4.5 Electrical Cable Shorts
4.6 Electrical Connector Checks
4.7 Grounding of Spacecraft and Equipment
4.9 Power Distribution Paths Redundancy
4.12 Protective Covers for Electrical Equipment

5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.9 Mechanical Shielding of Electrical Equipment

6.1 Electrical Ignition
6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.4 Hazardous Mixtures
6.5 Pressure Subsystem Interconnection
6.6 Pressure System Dynamics
6.8 Pressure System Safing

7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.8 Crew Restrictions During Internal Hazardous Operations
7.10 Death of Experimental Plants and Animals
7.13 Hazardous Materials Accessibility

9.1 Controlled Access and Use of Radiation Sources
9.3 Handling and Use of Radioactive Material
9.9 Placement of Equipment and Stores
9.12 Radiation Effects upon Spacecraft Materials
9.21 Selection of Materials for Use in Radiation Environment

10.4 Cryogenics
10.7 Fire Control
10.8 Fire Resistant Electrical Insulation
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.11 Heating Element Flame Suppression
10.12 Heat Monitoring in Operating Equipment
10.13 Hypergolic and Pyrophoric Material
10.17 Lubricants
10.19 Over-current Protection
10.20 Personnel Protection for Heated Surfaces
10.23 Self-propagation of Fires

12.10 Closed Circuit Television Monitoring
12.13 Compartmentation
12.14 Compartment Environmental Status
12.15 Computer Equipment Redundancy
12.33 Fire Alarm
12.40 Inoperative Sensing Systems
12.43 Lighting
12.45 Maintenance Capability
12.46 Minimizing EVA Requirements
12.50 Premature Subsystem Arming or Delayed Disarming
12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.59 Switch Design and Location

4.2.6 OPERATIONS (OP)

1.15 Hazardous Materials--Quantities
1.17 Insect Control
1.18 Materials--Configuration Control
1.19 Mercury Metal
1.27 Warning System--Relative Humidity

2.1 Component Design for Meteoroid Impact Protection
2.2 Flight Path Orbit Selection

3.3 Equipment Design for Rapid Decompression
3.5 Hatch Closure
3.9 Hatchway Airlocks
3.14 Pressure System Depressurization
3.17 Primary Structure Inspection and Repair

4.1 Cable Insulation Damage
4.4 Electrical Connections
4.5 Electrical Cable Shorts
4.7 Grounding of Spacecraft and Equipment
4.9 Power Distribution Paths Redundancy

5.1 Bulk Cargo Restraint
5.2 Crew Restrictions During Docking
5.4 Docking Light Redundancy
5.5 Docking Port Redundancy
5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.10 Mobility Aids, Zero Gravity

6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.5 Pressure Subsystem Interconnection

7.1 Angular Velocity Upper Limit
7.2 Artificial-Gravity Limits
7.3 Bacteriological Monitoring of the Crew
7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.6 Communicable Disease Control
7.7 Compartment Orientation within Artificial-Gravity Environment
7.8 Crew Restrictions During Internal Hazardous Operations
7.11 Emotional Disturbances
7.13 Hazardous Materials Accessibility
7.14 Health and Safety Officer(s) Training
7.15 Irrational Crew Member Restraint
7.16 Medical Emergencies
7.18 Quarantine Regulations

7.19 Radial Traffic in Artificial-Gravity Environment
7.20 Radiation Casualty Evacuation
7.21 Rotation Radius Lower Limit
7.22 Sanitation Standards
7.23 Work Station Position for Artificial-Gravity Station

8.16 PLSS Emergency Backup
8.19 Pressure Suit/PLSS Atmosphere Composition

9.1 Controlled Access and Use of Radiation Sources
9.2 Disposal of Radioactive Material
9.3 Handling and Use of Radioactive Material
9.4 Micro-wave and X-Radiation Hazard
9.6 Nuclear Power Unit Radiation Protection
9.8 Orbital Path Radiation Environment
9.9 Placement of Equipment and Stores
9.12 Radiation Effects upon Spacecraft Materials
9.13 Radiation Environment Restrictions on EVA
9.14 Radiation Exposure and Control Program
9.15 Radiation Exposure Record
9.21 Selection of Materials for Use in Radiation Environment

10.2 Combustible Waste Material
10.4 Cryogenics
10.7 Fire Control
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.13 Hypergolic and Pyrophoric Materials
10.14 Ignition Source Control
10.16 Location of Combustibles
10.17 Lubricants
10.20 Personnel Protection for Heated Surfaces
10.23 Self-propagating Fires
10.29 Thruster Operation During EVA

11.5 Crew Restrictions During Space Station Spin-up
11.9 On-board Crew Complement During Space Base Spin-up

12.5 Alternate Command and Control Center
12.6 Assistance to Injured Personnel
12.8 Authority to Proceed with Hazardous and Certain Other Operations
12.10 Closed Circuit Television Monitoring
12.11 Command Personnel Location Restrictions
12.13 Compartmentation
12.14 Compartment Environmental Status
12.15 Computer Equipment Redundancy
12.17 Crew Activity Restrictions
12.18 Crew Distribution
12.19 Crew Movement
12.20 Crew-oriented Areas

12.21 Crew Performance of Complex Tasks
12.25 Emergency Crew Evacuation
12.27 Emergency Lighting for EVA
12.28 Emergency Procedures and Training
12.29 Emergency Procedures (Fire)
12.30 Escape Routes
12.31 EVA Emergency Procedures
12.33 Fire Alarm
12.35 Hazardous Resupply Operations Monitoring
12.36 Health and Safety Officer
12.37 Incoming Vehicle Emergency
12.39 Initial Manning of Space Station/Base
12.40 Inoperative Sensing Systems
12.42 Intercom System
12.43 Lighting
12.45 Maintenance Capability
12.46 Minimizing EVA Requirements
12.48 Monitoring of EVA/IVA
12.49 Periodic Communications Subsystem Check
12.50 Premature Subsystem Arming or Delayed Disarming
12.54 Qualitative and Quantitative Personnel Requirements
12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.59 Switch Design and Location
12.61 Traffic Flow in Work Areas

4.2.7 STABILITY AND CONTROL SYSTEM (SCS)

1.8 Equipment Contamination by Propellants
1.9 Fluid/Debris Collection and/or Containment
1.10 Fluid Leak Isolation
1.11 Fluid Lines Contamination
1.18 Materials--Configuration Control
1.19 Mercury Metal
1.21 Plumbing Connectors--Minimum Loss
1.22 Plumbing Connectors--Minimum Quantity
1.23 Toxic or Flammable Fluids
1.24 Warning System--Contaminants Detection and Alarm
1.25 Warning Systems--Fluid Systems Contamination

2.1 Component Design for Meteoroid Impact Protection
2.2 Flight Path Orbit Selection

3.3 Equipment Design for Rapid Decompression
3.12 Pressure Regulator Failure
3.13 Pressure Relief for Trapped Fluids
3.14 Pressure System Depressurization
3.15 Pressurizable Volume Relief Protection
3.16 Pressurized Gas Flow Restrictions
3.21 Venting of Cabin Pressure
3.22 Venting of Pressure Relief Devices

4.1 Cable Insulation Damage
4.2 Connector Mismating
4.3 Electrical Arcing
4.5 Electrical Cable Shorts
4.6 Electrical Connector Checks
4.7 Grounding of Spacecraft and Equipment
4.9 Power Distribution Paths Redundancy
4.12 Protective Covers for Electrical Equipment
4.13 Redundant Circuits

5.3 Docking Closure Rate Control
5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.9 Mechanical Shielding of Electrical Equipment
5.12 Rotating Machinery Shielding

6.1 Electrical Ignition
6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.4 Hazardous Mixtures
6.5 Pressure Subsystem Interconnection
6.6 Pressure System Dynamics
6.7 Pressure Systems Location

6.8 Pressure System Safing
6.9 Pressure Tank Relief Protection Redundancy
6.10 Propellant Tank Protection

7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.13 Hazardous Materials Accessibility

9.8 Orbital Path Radiation Environment
9.9 Placement of Equipment and Stores
9.12 Radiation Effects upon Spacecraft Materials
9.21 Selection of Materials for Use in Radiation Environment

10.4 Cryogenics
10.7 Fire Control
10.8 Fire Resistant Electrical Insulation
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.12 Heat Monitoring in Operating Equipment
10.13 Hypergolic and Pyrophoric Material
10.17 Lubricants
10.19 Over-current Protection
10.20 Personnel Protection for Heated Surfaces
10.21 Propellant Supply System Location
10.23 Self-Propagation of Fires
10.28 Thruster Location
10.29 Thruster Operation During EVA
10.30 Thruster Temperature Monitor

11.1 Angular Rate Monitor
11.2 Automatic Tumbling Correction
11.3 Component Redundancy
11.4 Component Replacement for CMG's
11.6 Damage-Induced Motion
11.7 Manual/Automatic Control Interlocks
11.8 Manual Control of SCS Thrusters
11.10 Propellant Flow Shut-off Redundancy
11.11 Torques from Venting
11.12 Propellant Storage Tanks Redundancy

12.7 Attitude Indication Redundancy
12.13 Compartmentation
12.15 Computer Equipment Redundancy
12.16 Continuous Attitude Indication
12.33 Fire Alarm
12.34 Fluid Quantity Usage Monitor
12.40 Inoperative Sensing Systems
12.43 Lighting
12.45 Maintenance Capability
12.46 Minimizing EVA Requirements

12.50 Premature Subsystem Arming or Delayed Disarming
12.52 Propellant Leak Detection
12.53 Propellant Quantity and Usage
12.55 Replacement Component Installation
12.56 Replacement Component Provisioning
12.57 SCS Component Commonality
12.59 Switch Design and Location

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4.2.8 STRUCTURES/MECHANICAL SYSTEMS (S/M)

1.5 Control Procedures for Excessive Contamination
1.18 Materials--Configuration Control
1.19 Mercury Metal

2.1 Component Design for Meteoroid Impact Protection
2.3 Insulating Material
2.4 Window Replacement

3.1 Compartment Integrity
3.2 Crack Propagation in Primary Structure
3.3 Equipment Design for Rapid Decompression
3.4 Hatch Automatic Closure
3.5 Hatch Closure
3.6 Hatch Positive Closure
3.7 Hatch Pressure Loading
3.8 Hatch Seal Leakage Rate
3.9 Hatchway Airlocks
3.10 Leakage Repair System
3.11 Medical Equipment for Emergencies
3.14 Pressure System Depressurization
3.17 Primary Structure Inspection and Repair
3.18 Rapid Decompression Effects
3.19 Spacecraft Structural Strength
3.23 Venting Provisions

4.1 Cable Insulation Damage
4.5 Electrical Cable Shorts
4.7 Grounding of Spacecraft and Equipment
4.8 Potential Difference--Docking Spacecraft
4.9 Power Distribution Paths Redundancy

5.2 Crew Restrictions During Docking
5.3 Docking Closure Rate Control
5.4 Docking Light Redundancy
5.5 Docking Port Redundancy
5.6 Equipment Operation During EVA
5.7 Exterior Equipment Design and Location
5.8 Injury or Damage from Spacecraft Equipment
5.10 Mobility Aids, Zero Gravity

6.2 Explosion-proof Electrical Equipment
6.3 Flammable/Explosive Material Exterior to Spacecraft
6.4 Hazardous Mixtures
6.5 Pressure Subsystem Interconnection
6.6 Pressure System Dynamics
6.8 Pressure System Safing
6.11 Protection of Pressure Vessels
6.12 Shrouding and Shielding of Pressure Lines

7.1 Angular Velocity Upper Limit
7.2 Artificial Gravity Limits
7.4 Bodily Injuries: Cuts, Contusions, Fractures, Sprains, etc.
7.5 Burns, Chemical and Thermal
7.6 Communicable Disease Control
7.7 Compartment Orientation within Artificial-Gravity Environment
7.9 Death of Crew Members
7.13 Hazardous Materials Accessibility
7.16 Medical Emergencies
7.19 Radial Traffic in Artificial-Gravity Environment
7.21 Rotation Radius Lower Limit
7.22 Sanitation Standards

8.2 Airlock Oxygen Monitor
8.17 Pressure Leak Detectors
8.18 Pressure Relief Valve Repair Procedures

9.3 Handling and Use of Radioactive Material
9.5 Nuclear Power Radiation Protection
9.9 Placement of Equipment and Stores
9.10 Protection Against Nuclear Explosion Radiation
9.12 Radiation Effects upon Spacecraft Materials
9.16 Radiation Haven
9.18 Radiation Protection During EVA
9.20 Spacecraft Radiation Shielding
9.21 Selection of Materials for Use in Radiation Environment

10.3 Containment of Fire
10.4 Cryogenics
10.7 Fire Control
10.9 Fire Retardant Electrical Equipment
10.10 Freezing of Fluid Lines
10.12 Heat Monitoring in Operating Equipment
10.14 Isolation of Oxygen Source
10.16 Location of Combustibles
10.17 Lubricants
10.20 Personnel Protection for Heated Surfaces
10.23 Self-Propagating Fires
10.25 Spacecraft Thermal Protection

11.6 Damage-Induced Motion
11.11 Torques from Venting

12.1 Accessways
12.2 Airlock Hatch Operation
12.3 Airlock Pressurization Redundancy
12.4 Airlock Redundancy
12.6 Assistance to Injured Personnel
12.9 Cargo Transfer Equipment Redundancy
12.13 Compartmentation

| | |
|---|---|
| 12.15 | Computer Equipment Redundancy |
| 12.23 | Docking Mechanism Redundancy |
| 12.30 | Escape Routes |
| 12.33 | Fire Alarm |
| 12.40 | Inoperative Sensing Systems |
| 12.43 | Lighting |
| 12.45 | Maintenance Capability |
| 12.46 | Minimizing EVA Requirements |
| 12.50 | Premature Subsystem Arming or Delayed Disarming |
| 12.51 | Pressurized Free Volume |
| 12.55 | Replacement Component Installation |
| 12.56 | Replacement Component Provisioning |
| 12.59 | Switch Design and Location |
| 12.62 | Traffic Routes |

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## 4.3 CROSS INDEX BY KEY WORDS

Key words constitute one of the principal data retrieval methods. Accordingly, certain words common to space system terminology were selected, under which the several guidelines have been identified. In making their selection, the hazard groups and subsystem designations were generally avoided since those terms are also used in this document as indexing categories. In some cases a key word that identifies a guideline does not necessarily appear in the guideline title or text, but is considered to be appropriate in conveying the necessary thought. Guidelines have been identified by number only, under the following key words:

access
alarm system
atmosphere
compartments
contamination
control
cracks
crew
detection
equipment
escape
EVA
fluids
hatch
leakage
maintenance
materials
medical
monitoring
nuclear power
orbital parameters
oxygen
pressure wall
procedures
restraint
seals
storage
traffic flow

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| KEY WORD | | GUIDELINE NUMBER |
|---|---|---|
| Contamination | 1. | All numbers 1 through 32 |
| | 3. | 5, 16, 21, 22, 25 |
| | 4. | 9 |
| | 6. | 1, 2, 3, 4, 9, 11 |
| | 7. | 3, 6, 8, 10, 16, 22 |
| | 8. | 1, 10, 20, 31, 32, 33 |
| | 9. | 2, 12, 19 |
| | 10. | 1, 3, 4, 8, 13, 14, 21, 23, 24 |
| | 12. | 33 |
| Control | 1. | 4, 5, 7, 10, 15, 17, 18, 28 |
| | 3. | 12 |
| | 5. | 3 |
| | 6. | 9 |
| | 7. | 14 |
| | 8. | 5, 13, 15, 18, 21, 23, 27 |
| | 10. | 13, 14, 18, 19, 22, 24, 26, 27, 28, 29, 30 |
| | 11. | 1, 2, 6, 7, 8, 10, 11 |
| | 12. | 4, 8, 10, 15, 16, 40, 59 |
| Cracks | 2. | 4 |
| | 3. | 1, 2, 10, 17, 19 |
| Crew | 1. | 9, 12, 14, 23, 29 |
| | 3. | 18 |
| | 5. | 2, 6, 8, 11 |
| | 7. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 14, 15, 16, 17, 23 |
| | 8. | 6 |
| | 9. | 6, 15 |
| | 11. | 5, 9 |
| | 12. | 11, 17, 18, 19, 21, 28, 54, 58, 61 |
| Detection | 1. | 4, 6, 24, 25, 26 |
| | 3. | 6, 24, 25 |
| | 5. | 3 |
| | 7. | 3 |
| | 8. | 1, 2, 12, 17, 23, 30, 31 |
| | 9. | 11, 17, 19 |
| | 10. | 12, 27 |
| | 11. | 1 |
| | 12. | 7, 14, 16, 22, 33, 34, 40, 41, 47, 52, 53 |
| Device | | See "Equipment" |
| Equipment | 1. | 1, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 25, 28, 30 |
| | 2. | 1, 3 |

| KEY WORD | | GUIDELINE NUMBER |
|---|---|---|
| Seals | 1. | 12 |
| | 2. | 3, 4 |
| | 3. | 3, 5, 8, 9, 10, 17 |
| | 4. | 8 |
| | 5. | 11 |
| | 6. | 1, 2, 6 |
| | 8. | 2, 17 |
| | 10. | 1 |
| Storage | 1. | 3, 12, 13, 14, 15, 23, 26, 30, 31, 32 |
| | 5. | 1 |
| | 6. | 10, 11 |
| | 7. | 9, 10, 13, 22 |
| | 8. | 8, 11, 14, 33 |
| | 9. | 3, 19 |
| | 10. | 2, 13, 15, 16, 21, 23 |
| | 11. | 12 |
| | 12. | 9, 34, 52 |
| Traffic Flow | 5. | 2, 10 |
| | 7. | 2, 4, 7, 19, 21, 23 |
| | 9. | 5, 6 |
| | 10. | 2, 16 |
| | 11. | 5, 9 |
| | 12. | 1, 3, 4, 14, 17, 18, 19, 30, 61 62 |

## CROSS INDEX BY DAMAGE CONTAINMENT AND CONTROL

The following list of guidelines are those which are pertinent to the detection, containment and control of damage. It should be noted, however, that the study was oriented toward crew safety. Its emphasis was, therefore, on preventing or reducing the probability of occurrence of any event which would impose a hazard on the crew, rather than on the remedial action to be taken after the event occurred.

## 5.0 REFERENCES

The following references are the master list of the principal sources of information used in the Space Station Safety Study. It includes all references which are cited in the study report documents and also references which, although not specifically cited, were used as background or supporting material. Individual report documents each contain a list of references appropriate to that document, this list being an extract from, and with the same reference numbers as, the master list.

| No. | Title | Report No. | Source | Date | Contract No. | Cl. |
|---|---|---|---|---|---|---|
| 1 | AAP Crew Operations--Crew Safety Analysis, Cluster Mission AAP Flight #2, Vehicle AS 209 (Including experiment hazards) | ED-2002-24, Revision A | Martin | 2/10/67 | NAS8-21004 | U |
| 2 | AAP Payload Integration--Contingency Analysis, Crew Procedures, Fire and Loss of Pressure | ED-2002-387, Part II | Martin | 4/8/68 | NAS8-24000 | U |
| 3 | AAP Payload Integration--Orbital Workshop Crew Hazard Analysis | ED-2002-284, Revision C | Martin | 7/31/68 | NAS8-24000 | U |
| 4 | AAP Payload Integration--Radiation Analysis for the Apollo Applications Program | ED-2002-42 | Martin | 3/15/67 | NAS8-21004 | U |
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