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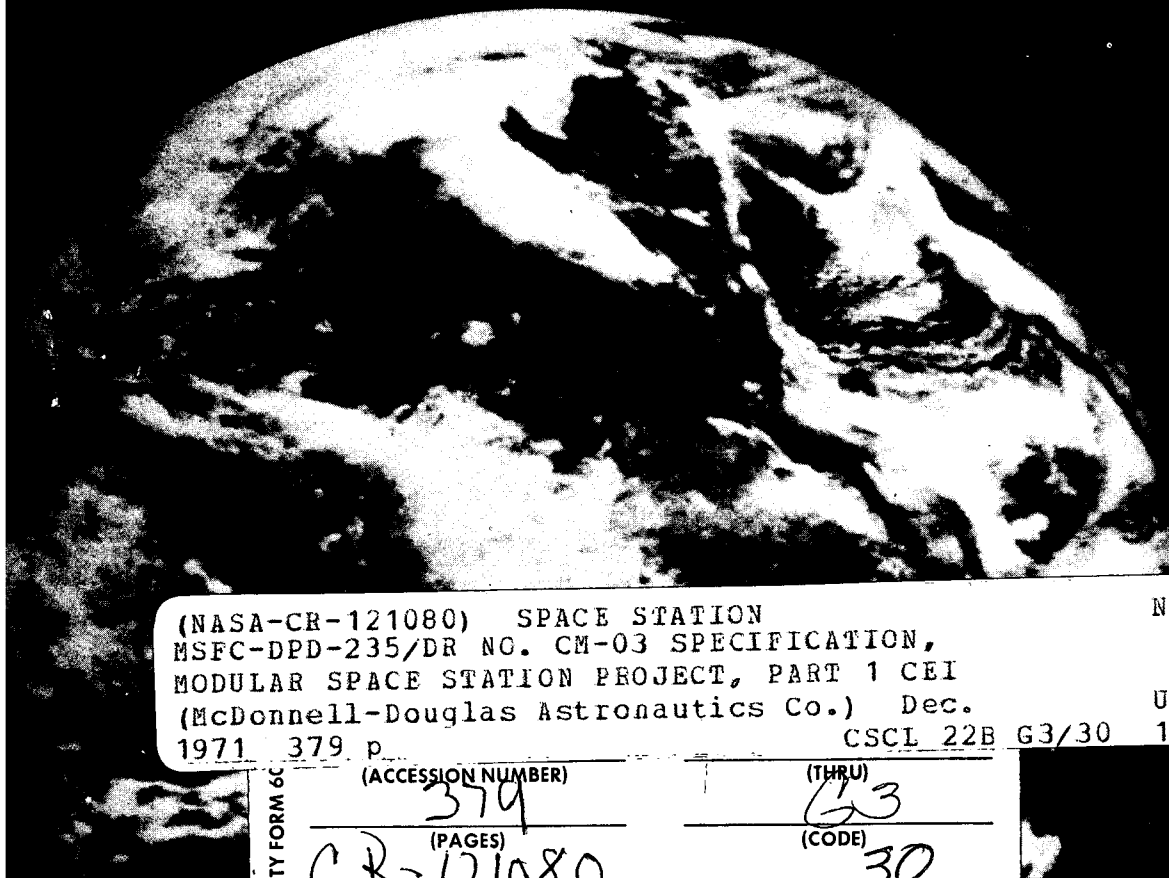
# SPACE STATION

## MSFC-DPD-235/DR NO. CM-03

### SPECIFICATION,

### MODULAR SPACE STATION PROJECT PART I CEI

CONTRACT NAS8-25140



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1971 379 p.

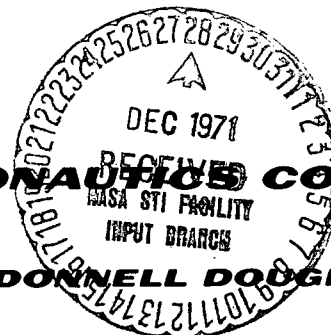
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MSFC-DPD-235/DR NO. CM-03  
SPECIFICATION, MODULAR SPACE STATION PROJECT  
PART I CEI

DECEMBER 1971

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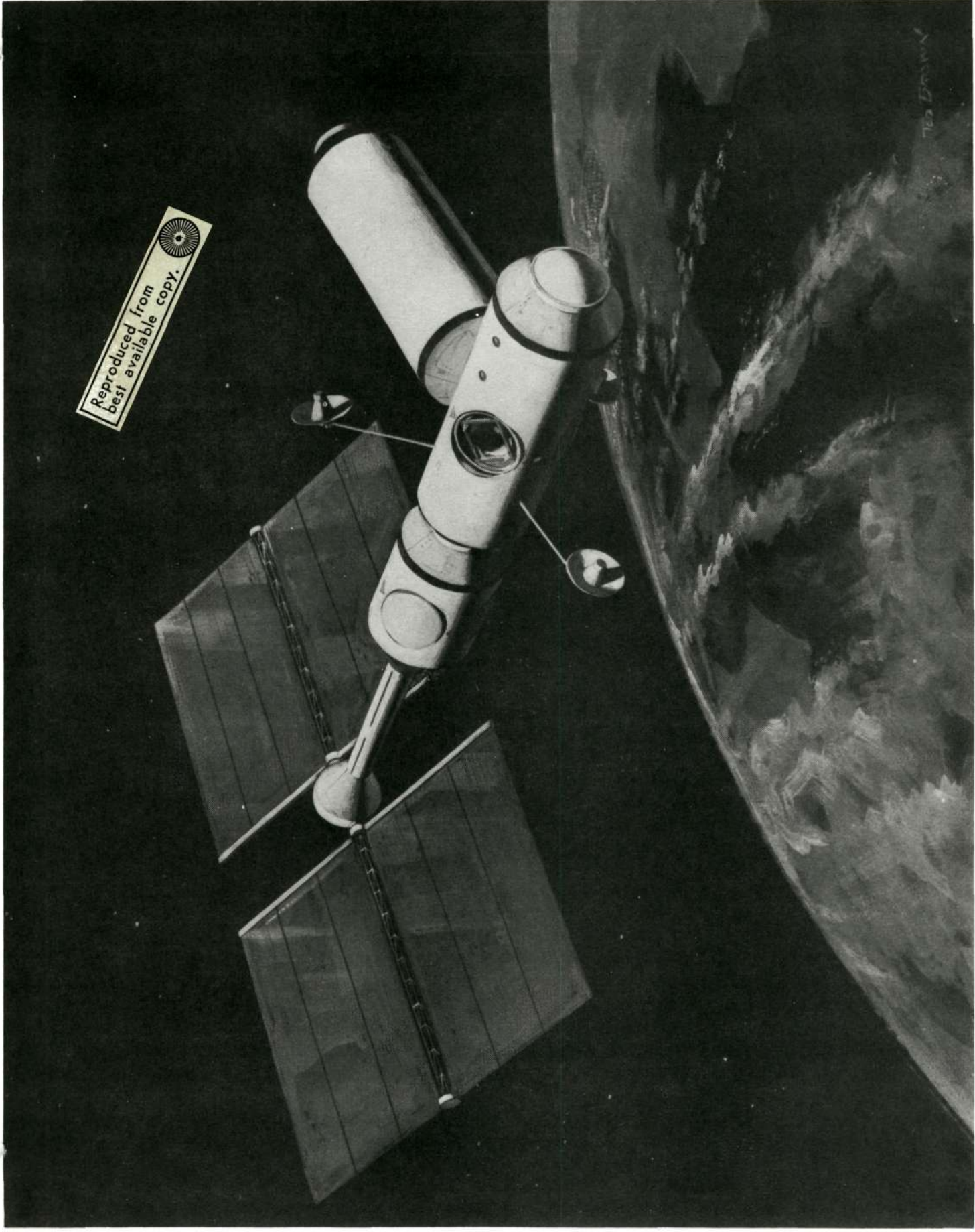
A handwritten signature in cursive script, appearing to read "T. D. Smith".

T. D. SMITH  
VICE PRESIDENT—GENERAL MANAGER  
SPACE STATIONS

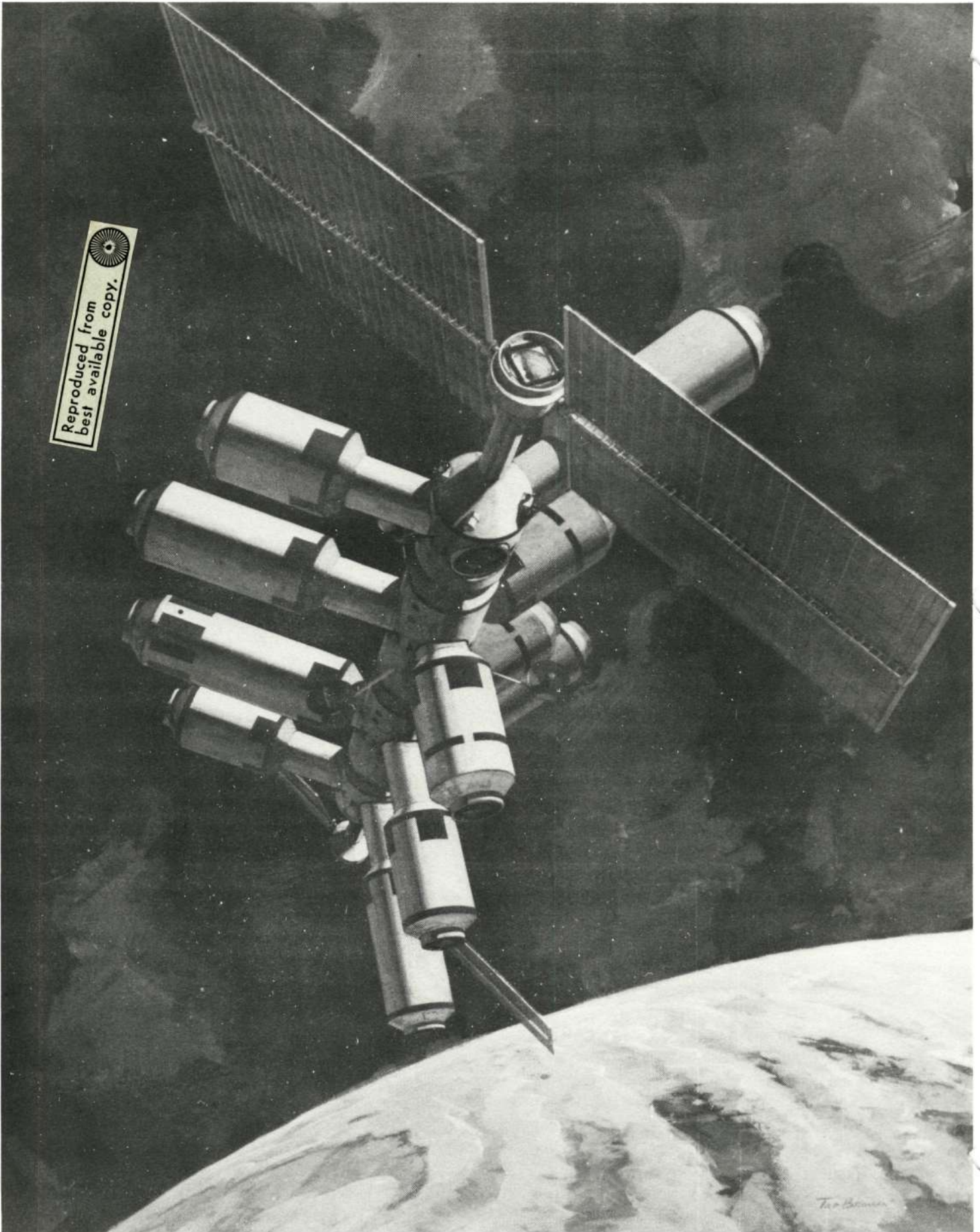
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## PREFACE

The work described in this document was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the extension period has been to develop the Phase B definition of the Modular Space Station. The modular approach selected during the option period (characterized by low initial cost and incremental manning) was evaluated, requirements were defined, and program definition and preliminary design were accomplished to the depth necessary for a Phase B exit.

The initial 2-1/2 month effort of the extension period was used for analyses of the requirements associated with Modular Space Station Program options. During this time, a baseline, incrementally manned program and attendant experiment program options were derived. In addition, the features of the program that significantly affect initial development and early operating costs were identified, and their impacts on the program were assessed. This assessment, together with a recommended program, was submitted for NASA review and approval on 15 April 1971.

The second phase of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

A subject reference matrix is included on page v to indicate the relationship of the study tasks to the documentation.

This report is submitted as Data Requirement CM-03.

DATA REQUIREMENTS (DR's)  
MSFC-DPD-235/DR NOs.  
(contract NAS8-25140)

Category	Designation	DR Number	Title
Configuration Management	CM	CM-01	Space Station Program (Modular) Specification
		CM-02	Space Station Project (Modular) Specification
		CM-03	Modular Space Station Project Part 1 CEI Specification
		CM-04	Interface and Support Requirements Document
Program Management	MA	MA-01	Space Stations Phase B Extension Study Plan
		MA-02	Performance Review Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase C/D Program Development Plan
		MA-06	Program Option Summary Report
Manning and Financial	MF	MF-01	Space Station Program (modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternate Bay Sizes



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## Section 1 INTRODUCTION

### 1.1 BACKGROUND

With the advent of the Space Shuttle in the late 1970's, providing a low cost means for inserting large payloads into various earth orbits, a long-term manned scientific laboratory in Earth orbit will become feasible. Using the shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community, and will make available to the United States a platform for application to the solution of national problems such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12 crewmen, has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Modular Space Station comprised of smaller, shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as envisioned for the 33-foot-diameter Space Station—but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by adding modules and crewmen on a flexible schedule.

The Modular Space Station conceptual analyses are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is a volume.

The Space Station will provide laboratory areas which, like similar facilities on Earth, will be designed for flexible, efficient changeover as research and experimental programs proceed. Provisions will be included for such

functions as data processing and evaluation, astronomy support, and test and calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program.

The Initial Space Station (ISS) will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the Shuttle orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip Shuttle flights using Logistics Modules (Log M's) for transport and on-orbit storage of cargo. Of the four Log M's required, one will remain on orbit at all times.

Experiment modules will be delivered to the Space Station by the Shuttle as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen, and wastes.

The ISS configuration rendering is shown in the frontispiece. The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General Purpose Laboratory (GPL) Module. This configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (frontispiece), which will house a crew of 12 and provide a capability equivalent to the 33-foot INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module capable of transporting a crew of six.

During ISS operations, a total of five Research Applications Modules (RAM's) will be attached to the Space Station for various intervals. Three of these will be returned prior to completion of the GSS. During GSS operations, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules. The GSS has the capability for accommodating as many as ten RAM's simultaneously.

During the baseline 10-year program, the Space Station will be serviced by Shuttle-supported Logistics Module or Crew Cargo Module flights.

## 1.2 SCOPE OF THIS VOLUME

The Program, Project and CEI Specifications and Interface Support Requirements Documentation, the major output of Phase B, constitute the baseline for all Phase C/D activities and thus Space Station Program development. As shown by Figure 1, these specifications have resulted from the orderly development and allocation of requirements which are concise statements of performance or constraints on performance. Guidelines, established by NASA Headquarters, formed the basis for program definition. This definition was evaluated and further expanded by a systematic development of requirements and collected in Sections 3.1 through 3.5. As this process continued, requirements that affected an interface with other programs were identified in Section 3.6; and requirements which are to be accomplished by a program element (i. e., project) were allocated to that element through Section 3.7. The methods of verifying compliance with these requirements are forth in Section 4 of the specification.

The requirements identified in Section 3.7 of the Program Specification formed the basis for project definition as the Headquarters Guidelines did for program definition. These requirements were further evaluated and expanded resulting in the allocation of requirements to project elements (i. e., system or CEI) and their interfaces. In a like manner, Section 3.7 of the Project Specification contains those allocated requirements which define system or CEI functional performance. These, in turn, were evaluated and expanded in each CEI Specification, Part I. Requirements for the verification of design solutions compliance are established in Section 4 of both project and CEI Specifications.

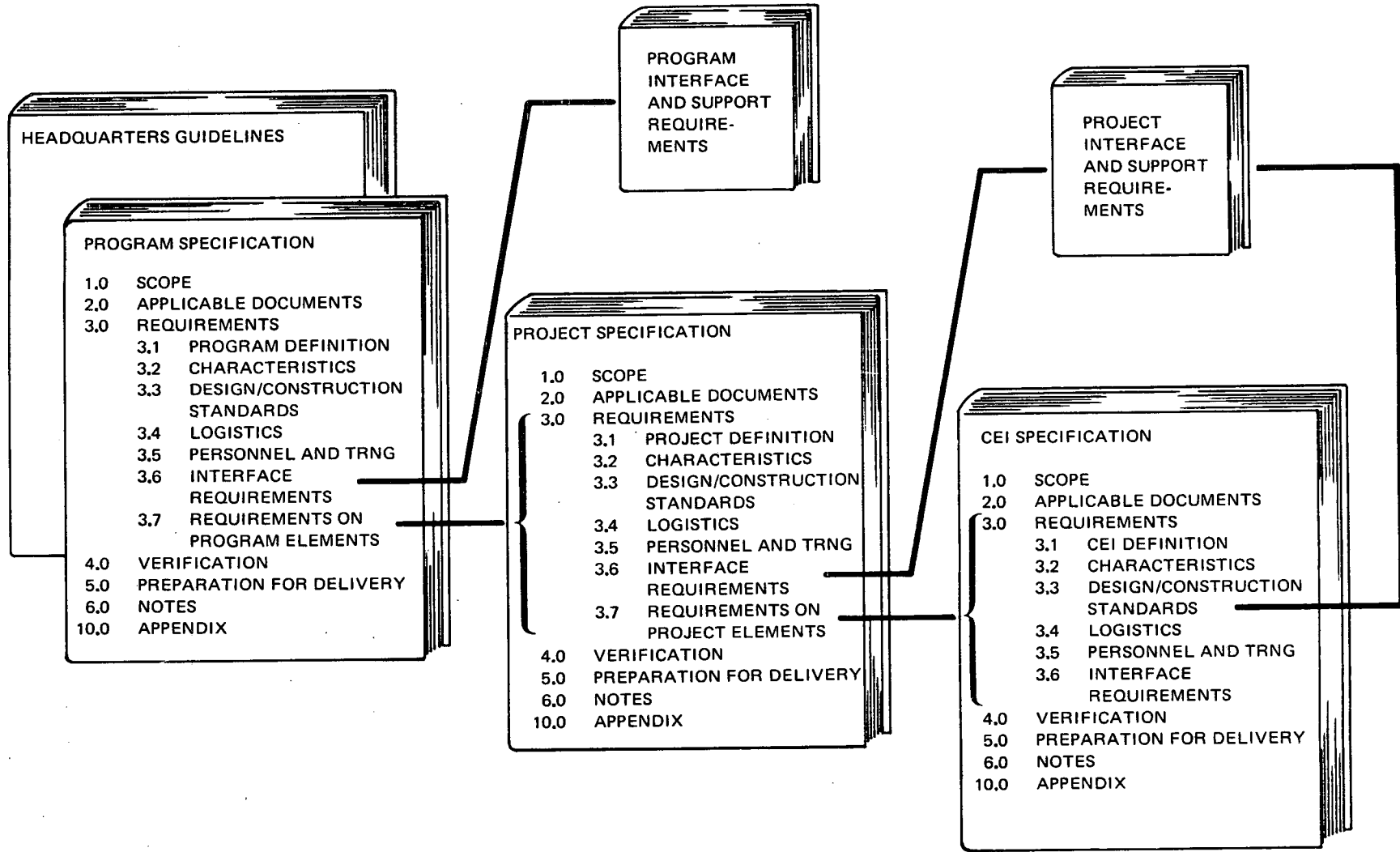


Figure 1. Specification Relationships

The development and structuring of requirements is vital to the interrelationship of management analyses and controls and performance measurement at various management levels and thus warrants a joint contractor-customer responsibility for the process. The Performance Requirements Document (PRD) was an evolutionary document updated by the Phase B Study Contractor, but under MSFC control, which contains all identifiable Space Station Program (Modular), project and system requirements that are defined at any point in time during the study.

This volume contains the Part I CEI Specifications for the Modular Space Station Project. Other requirements are contained in:

- CM-01, Space Station (Modular) Program Specification
- CM-02, Space Station Project (Modular) Project Specification
- CM-04, Interface and Support Requirements

Figure 2 illustrates the specification hierarchy and the various levels of Interface Requirements for the Space Station Program (Modular).

### 1.3 GLOSSARY OF TERMS

ISS	Initial Space Station
CEI	Contract Eng Item
GSS	Growth Space Station
WBS	Work Breakdown Structure
FM	Functional Model
FIT	Flight Integration Tool
PRR	Preliminary Requirement Review
PDR	Preliminary Design Review
RAM	Research and Application Module
CPCEI	Computer Program Contract End Item
CDR	Critical Design Review
CPC	Computer Program Component
FACI	First Article Configuration Inspection
PPP	Phased Planning Project
FM	Functional Model

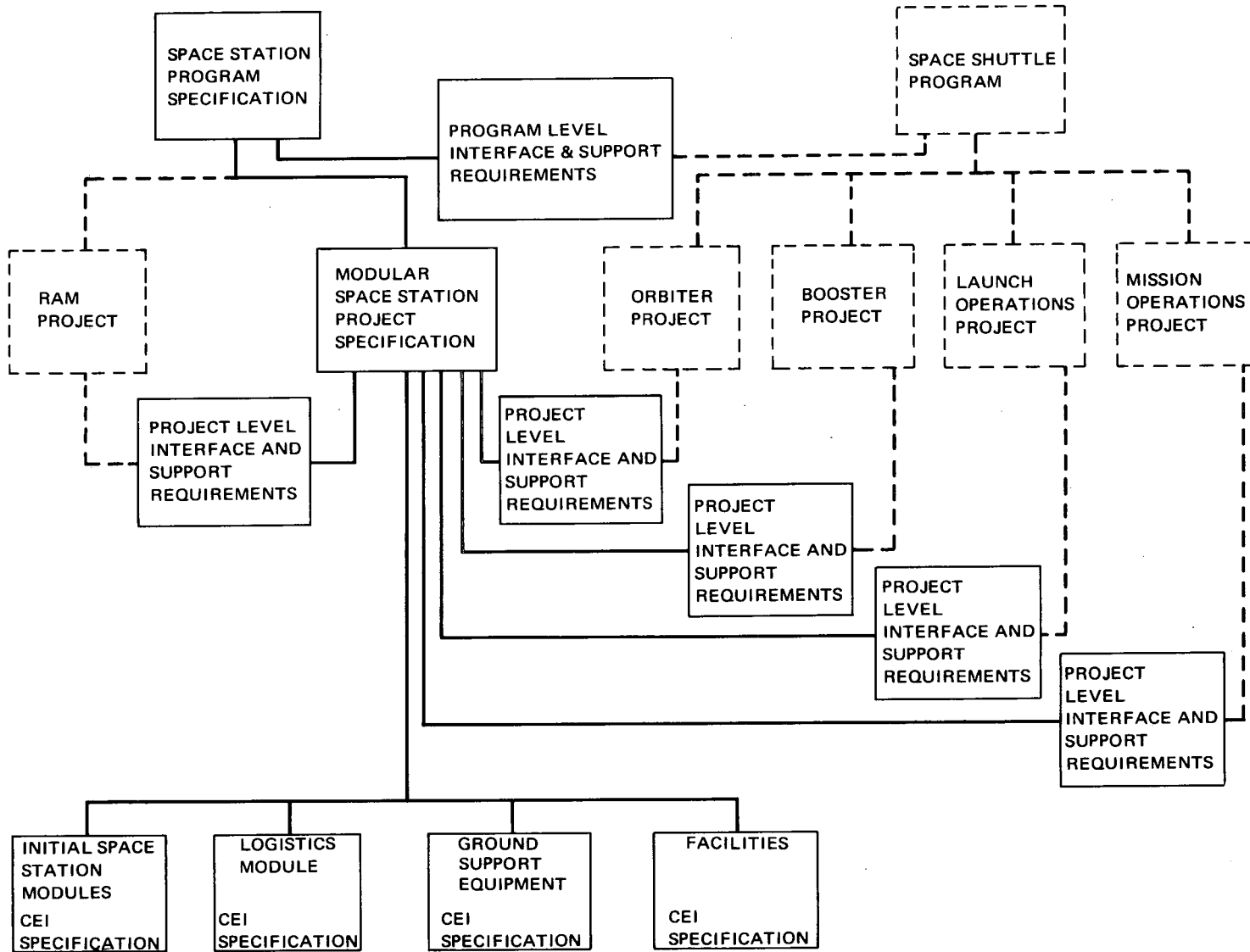


Figure 2. Space Station Program Specification Hierarchy



ICD	Interface Control Document
ER	Engineering Release
CMG	Control Moment Gyro
CH&P	Crew Habitability and Protection
GPL	General Purpose Laboratory
KSC	Kennedy Space Center
CDRL	Contract Data Requirements List
MSFN	Manned Space Flight Network
OCS	Onboard Checkout System
CIF	Central Instrumentation Facility
MSOB	Manned Spacecraft Operations Building
TDRSS	Tracking Data Relay Satellite System
DRS	Data Relay Satellite
ETR	Eastern Test Range
GBL	Government Bill of Lading
BOD	Beneficial Occupancy Date
FCEI	Facility Contract End Item
LV	Launch Vehicle
GOWG	Ground Operations Working Group
FMEA	Failure Mode, Effect Analysis
I&SR	Interface and Support Requirements
CII	Configuration Identification Index
CSAR	Configuration Status Accounting Report
DRD	Data Requirement Description
IMM	Integrated Mission Management
JOA	Joint Operating Agreement
JOP	Joint Operation Procedures
TWG	Test Working Group
GSI	Government Source Inspection
MRB	Material Review Board
COQ	Certification of Quality

PRIME EQUIPMENT DETAIL SPECIFICATION  
PART I OF TWO PARTS  
PERFORMANCE, DESIGN AND VERIFICATION REQUIREMENTS  
FOR  
INITIAL SPACE STATION  
(CEI NUMBER CP-02929)  
FOR  
MODULAR SPACE STATION PROJECT

APPROVED BY J.D. Smith  
(Preparing Activity)

APPROVED BY W.A. Brinkley  
(NASA Office)

DATE 15 December 1971

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1. SCOPE

This part of this specification establishes the requirements for performance, design, and verification for one type-model-series of equipment identified as the Initial Space Station (ISS), CEI.

It constitutes the major system of the Modular Space Station Project of the Modular Space Station Program. Other systems of the Modular Space Station Project include the integral experiments which are accommodated in the ISS, the Logistics Module (Log M), the Ground Support Equipment and Facilities which support the project from development through operations.

The Modular Space Station Project, when integrated with the Research and Application Module (RAM) Project and supported by the Space Shuttle Program, forms the Space Station Program, providing a laboratory in Earth orbit to conduct and support scientific and technological experiments for beneficial application and for further development of space exploration capability.

This document is subordinate and constrained by the requirements specified in MSFC Data Procurement Document 235, Data Requirement CM-02, Specification, Space Station Project (Modular).

2. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced, and other detailed contents of this specification, the detailed requirements herein shall be considered superseding.

SPECIFICATIONS

Text Reference

Military

MIL-E-6051D,  
Electromagnetic Compatibility Requirements  
System, 5 July 1968

3.3.5.1

<u>Military</u>	<u>Text Reference</u>
MIL-H-25475A, Hydraulic Systems, Missile, Design, Installation Tests, and Date Requirements, General Requirements for, 19 January 1961	3.3.6.3
*MIL-B-7883B, Brazing of Steels, Copper Alloys, Nickel Alloys, Aluminum and Aluminum Alloys.	3.3.6.7
MIL-C-17D(1), Cables, Radiofrequency, Coaxial, Dual Coaxial, Twin Conductor, and Twin Lead.	3.3.5.10
MIL-W-16878D(1), Wire Electrical, Insulated, High Temperature	3.3.5.12
MIL-E-45782B, Electrical Wiring, Procedures for.	3.3.5.11
MIL-C-55543, Cable, Electrical, Flat, Multiconductor, Flexible Unshielded	3.3.5.14
MIL-C-55544, Connectors, Electrical, Environment Resistant, For Use With Flexible Flat Conductor Cable and Round Wire, General Specification for.	3.3.5.14
MIL-T-23648A(2), Thermistors (Thermally Sensitive Resistor), Insulated, General Specification for.	3.3.5.15
*MIL-D-1000, Drawings, Engineering and Associated Lists. (SE-02, SE-03, and SE-13)	3.3.2.3.1
MIL-H-46855(1), Human Engineering Requirements for Military Systems, Equipment and Facilities	3.3.15
*MIL-M-38310A, Weight and Mass Properties. (SE-04)	3.3.2.3.2
MIL-A-8421, Air Transportability Requirements, General Specification for.	3.3.2.3.3
MIL-S-7742B, Screw Threads, Standard, Optimum Selected Series General Specification for.	3.3.6.2.4

<u>Military</u>	<u>Text Reference</u>
MIL-S-8879, Screw Threads, Controlled Radius Root with Increased Minor Diameter.	3.3.6.2.4
MIL-C-5541A, Chemical Films and Chemical Film Materials for Aluminum and Aluminum Alloys.	3.3.9.1
*MIL-H-6088D(2), Heat Treatment of Aluminum Alloys.	3.3.6.4
MIL-H-5440, Hydraulic Systems, Aircraft Type I and II, Design, Installation, and Data Requirements for.	3.3.6.3
MIL-H-5606B(3), Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance.	3.3.6.3
MIL-I-22129C(1) Insulation Tubing, Electrical Polytetrafluoroethylene Resin, Non-Rigid.	3.3.5.20
MIL-L-8937A, Lubricant, Solid Film, Heat Cured.	3.3.2.5
MIL-L-46010A, Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting.	3.3.2.5
MIL-L-81329A, Lubricant, Solid Film, Extreme Environment.	3.3.2.5
MIL-W-6858C, Welding, Resistance, Aluminum, Magnesium, Non-hardening Steels or Alloys, Nickel Alloys, Heat-Resisting Alloys, and Titanium Alloys, Spot and Seam.	3.3.6.5
<u>MSFC</u>	
MSFC-SPEC-135, Welding Fusion	3.2.1.3.4.8 3.3.6.5
MSFC-SPEC-250, Protective Finishes for Space Vehicle Structures, February, 1964.	3.3.9.1
MSFC-SPEC-491, Space Vehicle Ordnance Systems, January 1970	3.3.2.2.5, 3.2.1.3.4.7



<u>MSFC</u>	<u>Text Reference</u>
*MSFC-SPEC-445, Adhesive Bonding, Process and Inspection, Requirements for.	3.3.6.6
*MSFC-SPEC-164A, Cleanliness of Components for Oxygen and Pneumatic Systems.	3.3.10.8
*MSFC-SPEC-119A, Connectors, Printed-Wiring Board, Edge-Type	3.3.5.7
*MSFC-SPEC-332C(1), Cables, Electrical, General Specification for.	3.3.5.10
MSFC-SPEC-494, Installation of Harness Assembly (Electrical Wiring), Space Vehicle, General Specification for.	3.3.5.11
*MSFC-SPEC-278B(1), Terminals, Solder, Swage-Types and Insulated Screw-Types	3.3.5.8
Proposed *MSFC-SPEC-136, Parts mounting requirements.	3.3.5.9
*MSFC-SPEC-143C(1), Fittings, Flared Tube, Pressure Connections.	3.3.6.2.3
*MSFC-SPEC-101B, Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments which Support Combustion.	3.3.9.1 3.3.2.2.1 3.3.10.10
*MSFC-SPEC-106B(1), Testing Compatibility of Materials for Liquid Oxygen Systems.	3.3.9.1 3.3.2.3.4
MSFC-SPEC-233, Nitrogen, Instrument Grade.	3.3.2.4
*MSFC-SPEC-234A, Nitrogen, Space Vehicle Grade.	3.3.2.4
*MSFC-SPEC-264C, Helium	3.3.2.4
*MSFC-SPEC-399A, Oxygen	3.3.2.4

<u>MSFC</u>	<u>Text Reference</u>
*MSFC-SPEC-469, Titanium and Titanium Alloys, Heat Treatment of	3.3.6.4
*MSFC-SPEC-502, Lubricant, Dry Film, Ceramic, MLF-5, Preparation and Application of.	3.3.2.5
*MSFC-SPEC-131D, Tubing, Steel, Corrosion Resistant.	3.3.9.1
*MSFC-SPEC-248, Tubing, Steel, Corrosion and Heat Resistant	3.3.9.1
MSFC-SPEC-202B(1), Compound, Potting and Molding, Elastomeric	3.3.5.6
MSFC-SPEC-222C(1), Resin Compounds, Electrical and Environmental Insulation.	3.3.5.4 3.3.5.6
MSFC-SPEC-379B(1), Compounds, Potting and Encapsulating, Silicone.	3.3.5.6
MSFC-SPEC-393B(1), Compound, PC Board, Conformal Coating Elastomeric.	3.3.5.6
MSFC-SPEC-411(1), Adhesive, Epoxy Resin.	3.3.5.6
MSFC-SPEC-418(2), Polyurethane Foams for Electronic Equipment.	3.3.5.6
MSFC-SPEC-259A, Radiographic Inspection Requirements for Fusion Welds in Aluminum	4.2.3.2.2
*MSFC-SPEC-283A, Testing, Ultrasonic, Aluminum Alloy Plate, Bar.	4.2.3.4.2
MSFC-SPEC-384A, Leak Test Compound, LOX Compatible.	4.2.3.4.1
MSFC-SPEC-504, Welding, Aluminum and Aluminum Alloys.	3.3.6.5

STANDARDS	<u>Text Reference</u>
<u>Military</u>	
MIL-STD-143B, Standards and Specifications, Order of Precedence for the Selection of, 12 November 1969	3.3.1
MIL-STD-810B, Environmental Test Method	3.3.8 4.2.2.4
MIL-STD-1472A, Human Engineering Design Criteria for Military Systems, Equipment and Facilities.	3.3.15
MIL-STD-889, Dissimilar Metals.	3.3.9.1 3.3.9.2
MIL-STD-1247B, Marking, Functions and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missile, and Space Vehicle.	3.3.13
MIL-STD-202D, Test Methods for Electronic and Electrical Component Parts.	4.2.2.4
MIL-STD-1261A, Welding Procedures for Constructional Steels.	3.3.6.5
*MIL-STD-499 (Change 1), System Engineering Management.	3.1.5
MIL-STD-461A, Electromagnetic Interference Characteristics Requirements for Equipment, August 1968.	3.3.5.1
MIL-STD-462, Electromagnetic Interference Characteristics Measurement of, July 31, 1967.	3.3.5.1
MIL-STD-129E, Marking for Shipment and Storage 20 April 1970.	3.3.13
MIL-STD-130, Identification Marking of U. S. Military Property, 29 September 1967.	3.3.13

<u>Federal</u>	<u>Text Reference</u>
FED-STD-595A, Colors.	3.3.2.7
 <u>MSFC</u>	
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3. REQUIREMENTS

3.1 CEI Definition

The Initial Space Station, when docked to a Logistics Module (Specification No. CP-02930), shall be a completely self-contained system with a general purpose laboratory and all subsystems and provisions necessary for a six-man crew. It shall serve as a control and data-handling center and provide support for onboard experiments and up to four RAM's in the attached mode of operation, docked to the ISS.

In order to achieve a high degree of program flexibility, the ISS shall:

- a) Be capable of operating for five years without module replacement.
- b) Be capable of being integrated, after five years of operation, with two additional Space Station modules to form the Growth Space Station (GSS), capable of operation with a twelve-man crew and supporting up to seven attached RAM's and TBD free-flying RAM's.



- c) Be capable of having new experiments, subsystems and laboratory equipments integrated into the system without extensive modification and with a minimum of effort, in a manner similar to an Earth-based laboratory.

3.1.1 General Description

The Initial Space Station system shall consist of three modules, designated Power/Subsystems, Crew/Operations and General Purpose Laboratory, orbitally assembled in the configuration and sequence shown in Figure 1 below:

3.1.1.1 Functional Allocation

The Initial Space Station system shall provide functions generally allocated to the three modules as shown in typical arrangement profile Figure 2 and as described below:

CP-02929

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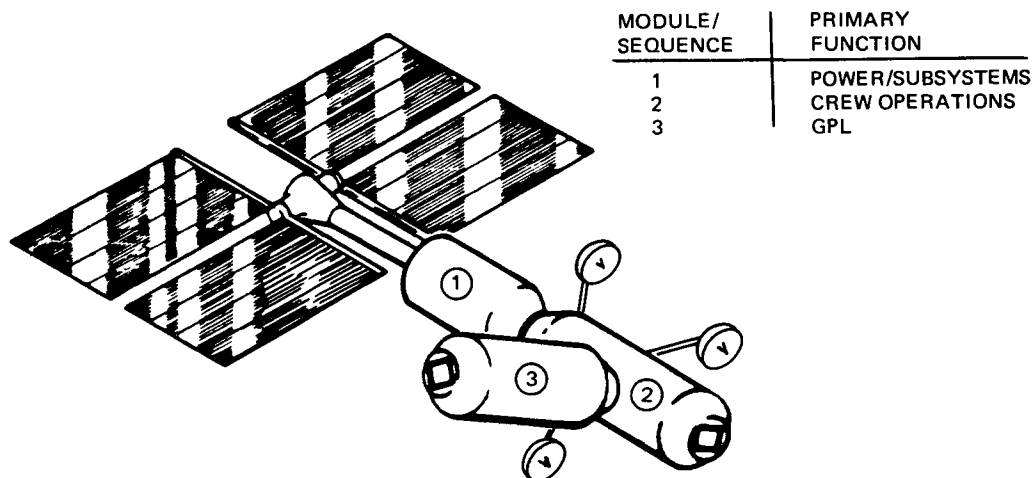


Figure 1. ISS Configuration and Buildup Sequence

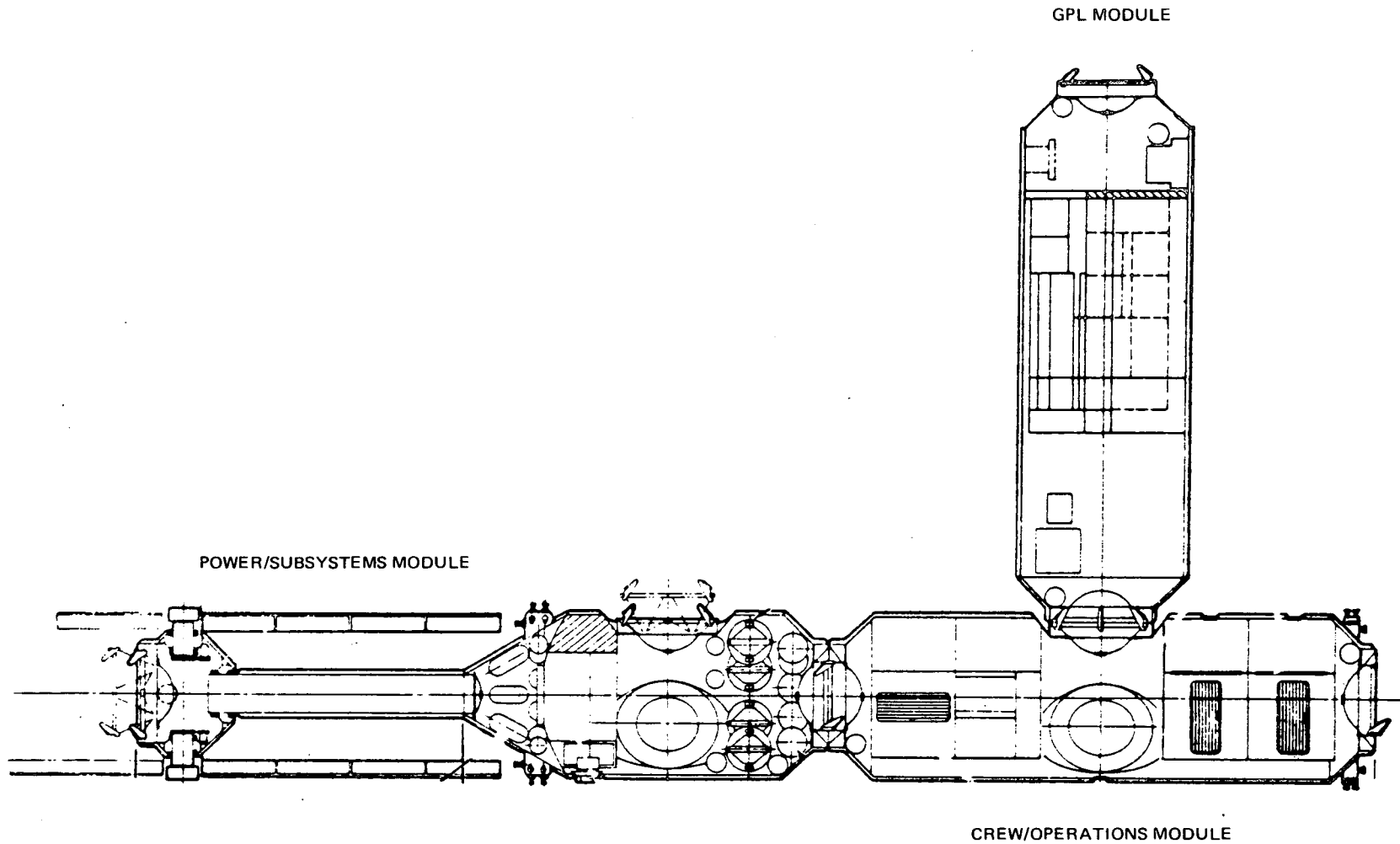


Figure 2. Typical ISS Arrangement Profile

3.1.1.1.1            Power/Subsystems Module  
The Power/Subsystems Module's basic function shall be to provide electrical power to the Modular Space Station. It shall also provide three docking ports and accommodations for most of the subsystem equipment. It will be the first module launched and operate unmanned during buildup. The habitable volumes shall be usually unmanned except for subsystems maintenance and intermodule transfer.

3.1.1.1.2            Crew/Operations Module  
The Crew/Operations Module shall provide accommodations for a crew of six and spacecraft control and operations facilities.

3.1.1.1.3            General Purpose Laboratory (GPL) Module

3.1.1.1.3.1           One complete ISS module designated as the General Purpose Laboratory shall be available for experiment support functions at ISS. Some Space Station equipment, such as EC/LS, CMG's, etc., may be installed in the GPL.

3.1.1.1.3.2           The General Purpose Laboratory Module shall be functionally and physically subdivided into facilities and laboratories combining related technology activities. The facilities shall be permanent throughout the operational mission life but the test, calibration, alignment, etc., equipment contained therein shall be capable of change as the experiment program evolves and changes.

3.1.1.1.3.3           The General Purpose Laboratory Module shall provide support for the Space Station modules, systems and subsystem equipment.

3.1.1.2              Relationship to Interfacing CEI's

3.1.1.2.1              Logistics Module

The primary ISS functions shall be achieved with a docked Logistics Module as shown in Figure 3. The interface involves transport and storage of supplies and use of the volume as a habitable compartment.

- 3.1.1.2.2                   Experiments  
The Initial Space Station shall provide a specific physical interface to the experiment CEI's.
- 3.1.1.2.3                   RAM's  
The ISS shall interface with RAM's in the attached mode, providing control, support and maintenance for the experiment modules and the experiments contained therein. The orbital configuration shall accommodate up to four RAM's simultaneously docked as shown in Figure 4.
- 3.1.1.2.4                   Space Shuttle Orbiter  
Each ISS module shall interface with the Space Shuttle Orbiter for delivery and return from orbit. ISS equipment may be removed to meet orbiter payload requirements. In such a case, this equipment shall be transported to orbit in the logistics module and installed in the appropriate ISS module.
- 3.1.1.2.5                   Mission Operations GSE  
The ISS shall interface with Mission Operations GSE through direct communications and communications via the Data Relay Satellite facilities.
- 3.1.2                        Missions
- 3.1.2.1                    The ISS shall be capable of orbital buildup from modules, each of which can be transported to and from orbit as a Space Shuttle payload.
- 3.1.2.2                    The ISS shall be capable of use in an orbit of 55 degrees inclination at an altitude between 445 and 500 km (240 and 270 nautical miles).
- 3.1.2.3                    The ISS shall be capable of independent operation with full crew of six for periods up to 120 days with the cargo supply and storage capability of one Log M, following the fourth Log M launch. The nominal crew rotation frequency shall be 90 days.

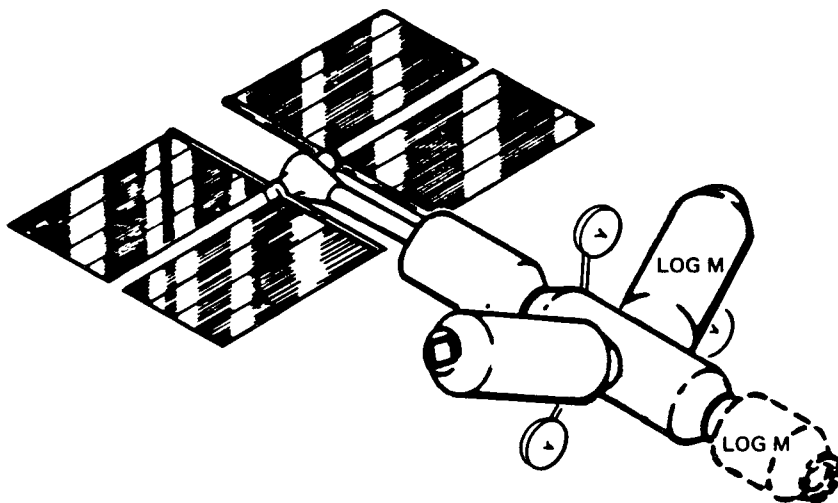


Figure 3. ISS Relationship to Logistics Module

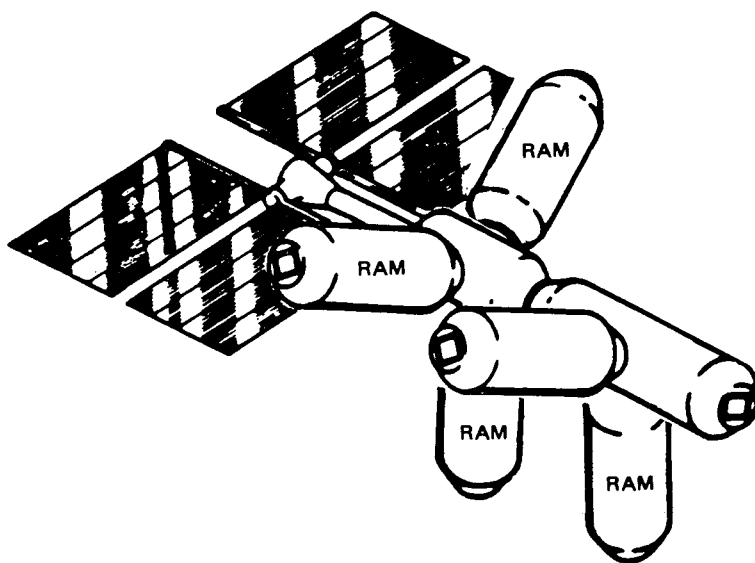


Figure 4. ISS Relationship to RAM's

- 3.1.2.4           The ISS shall be capable of providing adequate resources to support the conduct of a significant and beneficial experiment program for five years.
- 3.1.2.5           The ISS shall be capable of providing checkout, maintenance, and repair of experiment apparatus and equipment, both integral and modular.
- 3.1.2.6           The ISS shall be capable of providing support to RAM modules operating in the attached mode.
- 3.1.3             Operational Concepts
- 3.1.3.1           Prelaunch
- The ISS modules shall be designed to be compatible with prelaunch operations requirements which shall apply to each ISS module, independent of the other modules. These requirements shall apply to operations which start after factory acceptance and terminate at launch.
- 3.1.3.1.1         Logistics Options
- ISS Modules shall be designed to permit removal of selected equipment items after factory acceptance to bring the module within the weight limitation of the Shuttle orbiter. This equipment shall be delivered to orbit by the Logistics Module and is designated "logistics options."
- 3.1.3.1.1.1       Logistics options shall be limited to items which are designed for periodic replacement or are readily removed and installed in orbit.
- 3.1.3.1.1.2       Logistics options shall not include equipment required to meet basic requirements of prelaunch, launch, or buildup operations.
- 3.1.3.1.1.3       Logistics options shall be limited to equipment which may be removed without impairing safe operations.

- 3.1.3.1.2                    Test and Checkout
- 3.1.3.1.2.1                ISS modules shall be designed to require a minimum of test during prelaunch operations. These tests shall not require installation of equipment which is to be delivered to orbit in a Logistics Module.
- 3.1.3.1.2.2                ISS module design shall not preclude prelaunch check-out while installed in the Shuttle cargo bay.
- 3.1.3.1.2.3                As a design goal it shall be possible to determine launch readiness status of ISS module through the combination of Shuttle monitoring and limited transfer of data through the Shuttle to GSE.
- 3.1.3.1.2.4                ISS modules shall be designed for isolation of malfunctions and conduct of maintenance during prelaunch, utilizing onboard subsystems and GSE, independent of the Shuttle orbiter. This capability shall exist both before and after ISS module installation in the Shuttle. Fault isolation shall be generally to the level required for orbital maintenance.
- 3.1.3.1.3                    Access  
Normal prelaunch operations shall not require access to the ISS modules while in the orbiter cargo bay.  
The modules shall be designed for entry, to isolate malfunctions and conduct maintenance at the orbital level or for other prelaunch contingency requirements. This shall be limited to operations during which the module is in a horizontal position. Use of GSE to achieve physical access, provide atmosphere, electrical power, etc. shall be acceptable.
- 3.1.3.1.4                    Shuttle Installation  
The ISS modules shall be designed to be compatible with Shuttle loading facilities, including provisions for direct attachment of hoisting GSE used to install modules in the Shuttle.

3.1.3.2 Launch

The ISS modules shall be designed to be launched by the Shuttle with a minimum of active functions at the interface, to include the capability for redundant monitoring of critical functions by the Shuttle. Critical functions shall be limited to those that are safety related.

3.1.3.3 ISS Buildup Operations

The ISS Modules shall be compatible with buildup concepts which are based on the limitation of 30 days between Shuttle launches. This requires that each module be designed for activation by a two-man crew and that subsystem equipment be designed to operate unmanned during buildup to the extent required to assure a high probability that the buildup sequence will be successfully completed. At each stage of buildup, the ISS shall meet the requirements of the following paragraphs:

3.1.3.3.1 Activation Concepts

3.1.3.3.1.1 The ISS design shall be compatible with the activation concept which limits each of the four activation steps to 48 hours. The 48-hour limitation includes deployment of arrays or antennas, installation of off-loaded equipment, completion of interface connections, checkout, and all other normal activities required to support activation. It does not include fault isolation, repair or other contingency or unplanned activity. The 48-hour limitation in the final activation step includes activation of the first Logistics Module.

3.1.3.3.1.2 The ISS shall be designed to be compatible with a maximum Shuttle on-orbit activation support time of 115 hours.

3.1.3.3.1.3 The ISS shall be designed for shirtsleeve activation. In addition, the design shall provide for the crew to enter in IVA pressure suits, maintaining atmospheric separation from the Shuttle by utilization of the docking port airlock. Equipment shall be designed for achieving and confirming module habitability as early as possible and completing activation in shirtsleeves with free access to the Shuttle.



3.1.3.3.2                   Monitoring

3.1.3.3.2.1               The ISS shall provide the capability for ground monitoring of unmanned operations during buildup. Functions monitored shall—as a minimum—determine whether any failure has occurred which would preclude completion of the next activation operation as planned and determine the need for and nature of a repair flight.

3.1.3.3.2.2               The ISS shall provide the capability for Shuttle monitoring via direct RF link.

3.1.3.3.2.3               The ISS shall provide the capability for Shuttle monitoring of functions critical to activation crew entry. This shall be visual monitoring after docking is completed.

3.1.3.3.3                   Compartmentation

3.1.3.3.3.1               The ISS shall constitute one of the two required separate pressurized habitable compartments while manned, during activation. It shall provide independent life support capability, and other essential services. Implementation of this requirement shall be compatible with the Shuttle, which provides the second compartment during all stages of activation.

3.1.3.4                    Primary Mission Mode

The ISS is operated in the primary mission mode following the first logistics flight when certification for continuous manned operations is completed and the Shuttle departs for return to Earth.

3.1.3.4.1                   Crew Operations

3.1.3.4.1.1               The ISS shall be designed to free the crew from routine operations and shall be capable of being operated and maintained with an average of 1.5 crewmen.

- 3.1.3.4.1.2           The ISS shall provide the capability for the crew to recognize, isolate, and correct malfunctions, independent of ground support.
- 3.1.3.4.1.3           The capability shall be provided to automatically notify the crew of any failure-related automatic switchover. For critical failures the crew shall be automatically notified of conditions requiring crew attention.
- 3.1.3.4.1.4           The ISS shall be designed to allow maximum short-term operational utilization by providing the capability for on-orbit scheduling to integrate and redirect utilization of facilities. This shall be accomplished in a manner which is compatible with long-range over-all mission planning performed on the ground.
- 3.1.3.4.1.5           On-orbit scheduling shall be utilized to integrate all activities, including scheduled maintenance and experiment operations, and shall minimize operational interference between these activities.
- 3.1.3.4.1.6           The ISS shall be designed for operation on a two-shift, 6-day, 60-hour week. The design shall not preclude operation with a single-shift, 6-day, 60-hour week.
- 3.1.3.4.2           Monitoring and Control  
The ISS shall be operationally self-sustaining and shall not require extensive ground-based monitoring. As a minimum, the ISS design shall be compatible with the monitoring and control requirements of the following paragraphs.
- 3.1.3.4.2.1           The ISS shall provide continual communications with the ground, including duplex voice links.

3.1.3.4.2.2           The ISS shall provide the capability of continuously monitoring subsystem, experiment, and mission status information. This shall be primarily automatic, supplemented by manual entry. The status information shall be made available onboard the ISS and to the ground, as required.

3.1.3.4.2.3           The ISS shall provide tracking transponders compatible with the requirement for the ground network to determine orbital position and ephemeris data.

3.1.3.4.2.4           The ISS shall be capable of accepting commands from the ground for conducting selected operations.

3.1.3.4.3           Compartmentation  
The ISS, including one attached Log M and exclusive of the GPL, shall constitute one of the two required pressurized habitable compartments. It shall provide independent life support capability and other essential services. The GPL shall constitute the second compartment with the same capability.

3.1.3.4.4           Contamination  
The ISS shall be designed to minimize local contamination of the immediate environment surrounding the Space Station.

3.1.3.4.4.1           The ISS design shall provide for the return and recovery or suitable passivation and disposal of all expended hardware and waste products related to the ISS and the crew.

3.1.3.4.4.2           Solid wastes shall not be dumped to space.

3.1.3.5           Unmanned Mode

3.1.3.5.1           Each ISS module shall be designed to be placed in a standby, unmanned mode and be activated after a period of one year. It shall be assumed that each module is docked to at least one other module which shall be capable of providing electrical power, limited to TBD kw average. No specific attitude control shall be assumed; however, resupply flights—if required—shall be permissible.

- 3.1.4                    Organization and Management Relationship  
The relationship shall be as specified in Modular Space Station Project Specification RS-02927.
- 3.1.5                    System Engineering Requirements  
System Engineering shall be accomplished in accordance with Modular Space Station Project Specification RS-02927.
- 3.1.5.1                 System Engineering Plan  
Appropriate parts of MIL-STD-499 (Change 1) may be used as a guide in preparing the Contractor's System Engineering Plan (SEP) which describes the Contractor's system of engineering and program.
- 3.1.6                    Government-Furnished Property Lists  
Government-furnished property shall include pressure suits, food, and personal crew items.
- 3.1.7                    Critical Components  
No critical components have been identified.
- 3.2                      Characteristics
- 3.2.1                    Performance  
The ISS performance requirements are grouped according to eleven functional areas:
- Environmental Control and Life Support
  - Structural Mechanical
  - Electrical Power
  - Propulsion and Reaction Control
  - Guidance and Navigation
  - Stabilization and Attitude Control
  - Communications
  - Data Management
  - Crew Habitability and Protection
  - Onboard Checkout and Fault Isolation
  - Experiment Support Equipment

Within each functional area, there are specific functions, each of which is addressed for each applicable mode of ISS operations. All detailed ISS performance requirements have been allocated within this functional organization. The General performance requirements section is reserved for summarizing the fundamental ISS resource requirements relative to the conduct of experiments including RAM's and experiments accommodated integrally and in RAM's.

3.2.1.1                    General Performance

The ISS, with the support of the other project elements specified in Section 3.6, shall meet the requirements of the following paragraphs.

3.2.1.1.1                The ISS shall provide crew resources of 45 hours per day, average, for experiments. The nominal work week shall be six ten-hour days.

3.2.1.1.2                The ISS shall provide 4.8 kw average electrical power for experiments.

3.2.1.1.3                The ISS shall provide four docking ports nominally capable of accommodating attached RAM's.

3.2.1.1.4                Experiment Data

3.2.1.1.4.1             The ISS shall provide the capability of acquiring up to three channels of 10 mbps digital experiment data.

3.2.1.1.4.2             The ISS shall provide the capability of acquiring up to three channels of wide-band video data.

3.2.1.1.4.3             The ISS shall provide the capability of transmitting two channels of experiment data to the ground, via the DRSS. This capability shall be near full-time. Either channel shall be capable of 10 mbps digital data or wide-band video data.

- 3.2.1.1.5            The ISS shall be compatible with the requirement to support the experiment program with up to 4077 kg (9000 lbm) logistics support, every 90 days.
- 3.2.1.1.6            General Purpose Laboratory Resources  
The ISS shall provide the specific experiment support functions specified in 3.2.1.12. In addition, the ISS shall provide general experiment accommodations, in the GPL Module, as specified in the following paragraphs.
- 3.2.1.1.6.1          The ISS shall provide a double barrier for habitable parts of the station for toxic fluids, and for gases present in experiments.
- 3.2.1.1.6.2          The ISS shall provide a double barrier for experiments involving organisms other than man.
- 3.2.1.1.6.3          The ISS shall provide a safety storage for high-pressure gases, fluids, and cryogenics present in experiments.
- 3.2.1.1.6.4          The ISS shall provide a light level adjustment capability in all areas involving viewing, optics, displays, and controls, and manipulative or precision tasks.
- 3.2.1.1.6.5          A central experiment monitoring and control station shall be provided, with the ISS secondary control console.
- 3.2.1.1.6.6          The ISS shall have the capability of monitoring, activating, and deactivating any RAM or RAM experiment.
- 3.2.1.1.7            The ISS shall be designed to provide an environment in which the steady state disturbance level shall not exceed  $10^{-5}g$  with application of operational procedures to reduce the effects of crew motion. During operations with normal crew motion, the ISS shall provide a disturbance level which shall not exceed  $5 \times 10^{-4}g$ . Activation of high thrust propulsion shall not be required during time periods which apply to either of these disturbance level requirements.

## 3.2.1.2

## Environmental Control and Life Support

The environmental control and life support (EC/LS) subsystem shall meet the following overall functional requirements:

- a) The EC/LS subsystem shall provide a continuously habitable, shirt-sleeve environment for the crew and thermal control for the equipment in the ISS. It shall accommodate a normal crew of six men and, during crew rotation, an overlap crew of twelve men for up to five days.
- b) The EC/LS subsystem shall be so designed that in the event one compartment becomes uninhabitable, another compartment with a habitable shirtsleeve environment shall be available to the crew for as long as it takes to restore the Space Station to full habitability.
- c) The ISS shall have capacity for independent operation with the full crew for a period of 120 days. This capacity can be included in the Logistics Module. At least 30 days consumables, including those required for subsystems and experiments, will be available beyond the scheduled resupply mission.
- d) For design purposes, the 24-hour average metabolic level for each crewman shall be 11.8 MJ/day (11,200 Btu/day). The metabolic breakdown shall be as indicated in Table I. The basis is a  $11.7 \times 10^6$  J (2800 kcal) diet.
- e) Crew size dependent EC/LS assemblies shall be designed for six-man capacity.

Within the EC/LS functional area, the detailed requirements are specified for the subfunctional areas shown in Figure 5.

## 3.2.1.2.1

## Atmosphere Supply and Control

The major functions under Atmosphere Supply are as follows:

- a) Maintain atmosphere pressure and composition.
- b) Provide makeup O<sub>2</sub> and N<sub>2</sub>
- c) Provide contingency O<sub>2</sub> and N<sub>2</sub> for emergencies.
- d) Provide for compartment pressurization and depressurization.

Table I  
 CREW METABOLIC BALANCE

Item	Quantity	
	(kg/man-day)	(lb/man-day)
Crew Inputs		
Food	0.69	1.52
Water	2.79	6.17
Oxygen	0.87	1.92
	<u>4.35</u>	<u>9.61</u>
Crew Outputs		
Carbon dioxide	1.04	2.30
Urine water	1.77	3.92
Urine solids	0.07	0.16
Fecal water	0.12	0.26
Fecal Solids	0.04	0.10
Insensible water	1.26	2.78
Other solids	0.04	0.09
	<u>4.34</u>	<u>9.61</u>

- e) Provide for equipment pressurization.
- f) Provide for compartment dump and relief.

Relative to atmosphere supply functions involving storage of high-pressure gases, the EC/LS subsystem shall be designed to meet the requirements utilizing the Log M storage capability, with the exception of the contingency O<sub>2</sub> and N<sub>2</sub> which shall be stored in the ISS.

3.2.1.2.1.1 Primary Mode of Operation

3.2.1.2.1.1.1 Atmosphere Pressure

The ISS atmosphere shall be composed of a mixture of O<sub>2</sub> and N<sub>2</sub> at a total pressure of 101 kN/m<sup>2</sup> (14.7 psia). The partial pressure of oxygen shall be 21.4 kN/m<sup>2</sup> (3.1 psia).



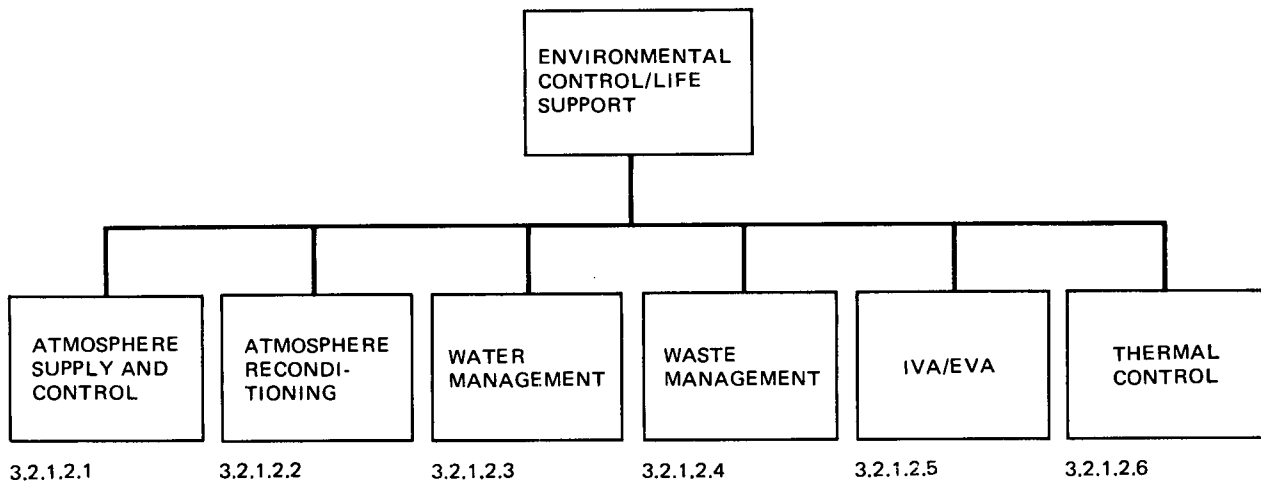


Figure 5. EC/LS Subfunctional Areas

3.2.1.2.1.1.2 Makeup O<sub>2</sub> and N<sub>2</sub>

- a) Crew metabolic O<sub>2</sub> makeup requirements shall be provided in the average amount of 0.87 kg/man day (1.92 lb/man-day).
- b) Nitrogen and oxygen makeup shall be provided for gas loss during air lock and compartment decompression and due to the operation of onboard systems.

The ISS shall accommodate a total airlock and experiment chamber repressurization volume of up to 1,324 m<sup>3</sup>/90 days (46,800 ft<sup>3</sup>/90 days). A portion of this atmosphere may be recovered with a pump system.

3.2.1.2.1.1.3 Contingency O<sub>2</sub> and N<sub>2</sub>

- a) A 30-day contingency supply of crew metabolic O<sub>2</sub> shall be provided for use during emergencies.
- b) O<sub>2</sub> and N<sub>2</sub> shall be provided for repressurization of the largest pressurized habitable volume in the amount of 260 m<sup>3</sup> (9,300 ft<sup>3</sup>). This supply shall be maintained onboard during manned operations and be available to independently supply any pressurized habitable volume. The repressurization supply shall consist of 83 kg (184 lb) oxygen and 230 kg (510 lb) nitrogen.

3.2.1.2.1.1.4 Compartment Pressurization and Depressurization  
A means shall be provided for pressurizing and depressurizing compartments and airlocks.

ISS Module compartments shall be designed for repressurization in 6 hours or less. A means of pressure equalization shall be provided between compartments separated by hatches.

3.2.1.2.1.1.5 Equipment Pressurization

- a) Oxygen and nitrogen shall be provided at a pressure of 410 kN/m<sup>2</sup> (60 psia) for tank pressurization and other equipment needs.
- b) Pressure relief at 520 kN/m<sup>2</sup> (75 psia) shall be provided in O<sub>2</sub> and N<sub>2</sub> lines to protect gaseous supply lines and equipment from overpressure.

- c) O<sub>2</sub> tank recharging capability for Portable Life Support Units shall be provided in the amount of 1.6 kg (3.6 lb) per 30 days. Recharge pressure shall be 5.8 MN/m<sup>2</sup> (850 psia).

3.2.1.2.1.1.6            Compartment Dump and Relief

- a) An ISS Module compartment dump function shall be provided. The dump provision will be electrically actuated and will be backed up with an electrically actuated shutoff valve. The dump provision shall be capable of dumping the largest ISS Module volume of 164 m<sup>3</sup> (5,840 ft<sup>3</sup>) to 6.9 kNm<sup>2</sup> (1 psia) in 3 minutes.
- b) An ISS Module compartment pressure relief function will be provided to protect the compartment from overpressurization. The compartment pressure is limited to 107 ± 1.4 kN/m<sup>2</sup> (15.5 ± 0.2 psia).

3.2.1.2.1.2            ISS Buildup Operations Mode

The ISS shall provide for atmosphere supply and control during the unmanned mode. It shall provide O<sub>2</sub> and N<sub>2</sub> storage, maintain atmosphere pressure and composition, equipment pressurization and compartment dump and relief.

3.2.1.2.2            Atmosphere Reconditioning

The atmosphere reconditioning function shall control levels of humidity, carbon dioxide, and trace contaminants. In addition it shall provide for atmosphere temperature control and compartment ventilation. Levels of contaminants shall be monitored to determine the viability of the atmosphere.

3.2.1.2.2.1            Primary Mode of Operation

3.2.1.2.2.1.1        Atmosphere Temperature and Humidity Control

- a) The shirtsleeve environment shall be achieved by means of an active temperature control system provided with external fluid radiators. The cabin temperature shall be selectively maintained between 18.4 and 29.4°C (65 and 85°F). Sufficient atmosphere cooling capacity shall be provided to remove crew sensible heat, EC/LS sensible heat and 20 percent of the total available electrical power. The design crew sensible heat for six-man crew is given in Table II.

Table II  
 CREW SENSIBLE COOLING LOADS

Case	Crew Size	Heat Load	
		(watts)	(Btu/hr)
Maximum Load [18.4°C (65°F) cabin total]	2 (heavy work)	228	(780)
	4 (medium work)	434	(1,500)
		<u>662</u>	<u>(2,280)</u>
Minimum Load [24.0°C (75°F) cabin total]	6 (sleep)	334	(1,380)

The partial pressure of the cabin atmosphere water vapor will nominally be maintained about 1.1 kN/m<sup>2</sup> (8 mm of Hg) and shall not exceed 1.7 kN/m<sup>2</sup> (13 mm of Hg). Short transients to 0.8 kN/m<sup>2</sup> (6 mm of Hg) will be allowed. Sufficient water vapor removal capacity shall be provided to remove the latent loads given in Table III.

Table III  
 HUMIDITY CONTROL DESIGN LOADS

Case	Item	Latent Load	
		(watts)	(Btu/hr)
Maximum Load [24.0°C (75°F) cabin]	2 crew (heavy work)	310	1,060
	4 crew (medium work)	327	1,120
	Experiments	305	1,040
	Crew equipment	<u>383</u>	<u>1,310</u>
Total		1,325	4,530
Minimum Load [18.4°C (65°F) cabin total]	6 crew (sleeping)	307	1,050

3.2.1.2.2.1.2 Trace Contaminant Control and Monitoring  
Harmful airborne trace contaminants and odors shall be monitored and controlled in each pressurized habitable volume.

3.2.1.2.2.1.3 CO<sub>2</sub> Control

- a) Carbon dioxide partial pressures shall be maintained below 0.4 kN/m<sup>2</sup> (3 mm Hg) in all habitable areas. The maximum sustained design removal capacity shall be 0.1 g/sec (0.78 lb/hr) for a six-man crew.
- b) Carbon dioxide partial pressures of 1.0 kN/m<sup>2</sup> shall be allowed for up to seven days during emergency.
- c) Carbon dioxide shall be provided to the propulsion subsystem in the average amount of 6.25 kg/day (13.8 lb/day) and a pressure of 210 to 290 kN/m<sup>2</sup> (31 to 42 psia).

3.2.1.2.2.1.4 Ventilation

- a) Atmosphere ventilation shall provide an atmosphere velocity of 0.1 to 0.25 m/sec (20 to 50 fpm) in occupied areas.
- b) Conditioned air shall be distributed within the occupied areas to prevent composition and temperature stratification.
- c) 640 cm<sup>3</sup>/sec (136 cfm) conditioned air shall be provided to the RAM's, which shall provide their own distribution and ventilation.

3.2.1.2.2.2 ISS Buildup Operations Module

The ISS shall provide atmosphere temperature control in the ISS Buildup unmanned mode.

3.2.1.2.3 Water Management

- a) The ISS shall provide for water management, which includes collection, treatment, monitoring, storage and supply of water from urine, condensate, and wash water.

3.2.1.2.3.1 Primary Mission Mode of Operation

3.2.1.2.3.1.1 Water Collection and Treatment

Waste water shall be collected from the various water sources and treated to render inert for storage, or to pretreat prior to water recovery. The sources and quantities collected and treated are listed in Table IV.

Table IV  
 WATER COLLECTION AND TREATMENT DATA

Source	kg/day	Quantity*(lbs/day)
Urine	10.6	23.4
Urine Flush	1.06	2.35
Humidity Condensate	7.61	16.7
Wash Water	132	293

\*Values are average for six-man crew.

3.2.1.2.3.1.2 Water Monitoring

Water potability shall be monitored on a daily basis on an individual tank basis.

3.2.1.2.3.1.3 Water Storage

- a) Shall be capable of separately storing waste water and potable water.
- b) Shall be capable of simultaneously supplying, storing, and testing the potable water supply.
- c) Shall be capable of being decontaminated.
- d) Shall have the capacity to store 2.34 kg/man-day (5.15 lb/man-day) of crew potable water. Food water shall provide another 0.462 kg/man-day (1.02 lb/man-day) of potable water, which brings the total crew water intake to 2.79 kg/man-day.

3.2.1.2.3.1.4 Water Supply

Water shall be supplied for crew and equipment needs as given in Table V.

Table V  
REQUIREMENTS FOR WATER SUPPLY

---

Wash-water rate, average	22.2 kg/man-day (48.9 lb/man-day)
Wash-water rate, peak	30 g/sec (240 lb/hr) for 600 seconds
Wash-water temperature	40°C (105°F)
Potable-water temperature, hot	71°C (160°F)
Potable-water temperature, cold	7°C (45°F)
Potable-water delivery rate	0.9 kg/sec (120 lb/min) for 3 seconds
EVA water-use rate, average	1.5 kg/day (3.3 lb/day)

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3.2.1.2.3.2           ISS Buildup Operations Mode  
The ISS shall not provide water management functions in the ISS buildup unmanned mode. No condensate will exist in the unmanned mode.

3.2.1.2.4            Waste Management  
The ISS shall provide for waste management by providing for fecal collection, treatment and storage for Earth return and for urine collection, and treatment and storage if returned to Earth.

3.2.1.2.4.1         Primary Mission Mode of Operation

3.2.1.2.4.1.1       Urine Collection, Treatment and Storage

- a) Urine collection shall be provided which is capable of collecting and transferring a 1,000 cc micturation to urine storage or urine water recovery. Flush water shall be provided from water storage and shall be limited to 10 percent of the micturation flow.
- b) Urine collection shall be provided which can be performed while the crewman is defecating in a sitting position or independently in the standing position.

- b) Collected urine shall be treated to prevent bacteria growth or chemical activity. This treatment shall be compatible with urine storage and processing functions.
- c) Collected urine shall not be dumped overboard as a matter of planned operation.
- d) Frequency of micturations shall be six-man-day and duration of micturation shall be one minute/event.

3.2.1.2.4.1.2

Fecal Collection, Treatment and Storage

- a) Fecal collection shall be performed with the crewman in a sitting position.
- b) Fecal treatment shall be provided to render the feces inactive for long-term storage and Earth return.
- c) Fecal water or evolved gasses shall not be dumped overboard.
- d) No odors or bacteria shall escape into the cabin atmosphere.
- e) Frequency of defecation shall be one/man-day and duration of defecation shall be five minutes/event.

3.2.1.2.4.2

ISS Buildup Operations Mode

The ISS shall not provide for waste management in the ISS buildup unmanned mode.

3.2.1.2.5

IVA/EVA

Support shall be provided for crewmen during suited EVA and during both suited and unsuited IVA operation. Prebreathing capability shall also be provided to ensure denitrogenation of the crew prior to entering suits at reduced pressure.



3.2.1.2.5.1 Primary Mission Mode of Operation

3.2.1.2.5.1.1 EVA

Life support shall be provided for suited crewmen during EVA. The detailed functions which shall be provided, follow:

- a) Shall provide life support, for up to 4 hours of extravehicular tasks.
- b) Shall provide a cooling capacity of 5.1 MJ (4,800 Btu) and support metabolic loads ranging from 120 watts (400 Btu/hr) to short-term peaks of 590 watts (2,000 Btu/hr).
- c) Shall provide capacity for removing 3.0 g CO<sub>2</sub>/sec (0.39 lb CO<sub>2</sub>/hr) maximum and shall provide 2.5 g O<sub>2</sub>/sec (0.32 lb O<sub>2</sub>/hr) maximum for astronaut consumption.
- d) Shall supply oxygen to the pressure garment assembly (PGS) ventilation loop at a nominal temperature range of 18 to 20°C; 30°C maximum (65 to 68°F; 85°F maximum).
- e) Shall reduce the PGS oxygen inlet dewpoint to a maximum of 10°C (50°F).
- f) Shall regulate and maintain suit pressure from 22 to 28 kN/m<sup>2</sup> (3.5 to 4.0 psid).
- g) Shall provide warning indicator should a malfunction occur. These indicators are:

Low suit pressure  
Low ventilation flow  
High oxygen flow  
Low feedwater pressure  
CO<sub>2</sub> level

- h) Shall provide, in case of a malfunction, oxygen for a minimum of 30 seconds, at 1 g/sec (8 lb/hr) for respiration, forced convective cooling of the astronaut, and visor defogging.

3.2.1.2.5.1.2 IVA

Life support shall be provided for crewmen during IVA by providing the following functions.

- a) Shall provide 30 g/sec (240 lb/hr) circulating water at 12°C (54°F) for each suited crewman.

- b) Shall provide an average flow of 0.63 g/sec (240 lb/hr) of O<sub>2</sub> at a pressure of 210 kN/m<sup>2</sup> (30 psia).

3.2.1.2.5.1.3 Crew Oxygen Prebreathing

- a) A means of crew oxygen prebreathing shall be provided. An average O<sub>2</sub> flow of 0.63 g/sec (5.0 lb/hr) shall be provided to each crewman for the 2 hours required for preconditioning.
- b) During the prebreathing function, the crewman shall not be unduly restricted so that he may continue his normal work functions at a reduced rate.

3.2.1.2.5.1.4 Portable Crew O<sub>2</sub> Source

Portable O<sub>2</sub> sources shall be provided for crew breathing use. Six individual sources shall be provided, each having a 900-sec (15-minute) O<sub>2</sub> supply.

3.2.1.2.5.2 ISS Buildup Operations Mode

The ISS shall be required to provide for IVA/EVA during the ISS buildup unmanned mode. Orbiter resources may be utilized.

3.2.1.2.6 Thermal Control

Thermal control shall provide for the collection, transport, distribution, and rejection of Space Station heat so that the crew and equipment are maintained within required temperature limitations.

3.2.1.2.6.1 Primary Mission Mode of Operation

3.2.1.2.6.1.1 General

- a) An active thermal control system shall be provided with external fluid radiators.
- b) The mean radiant wall temperature, referenced to the crew, shall be maintained between 16 and 26°C (60 and 80°F).

- c) The maximum surface temperature of surfaces that may be contacted by the crew shall not exceed 40°C (105°F).
- d) No condensation shall form on internal surfaces.
- e) Heat transport fluids located within pressurized crew compartments shall be nontoxic and nonflammable at ambient atmosphere pressure and composition.
- f) Redundant equipment and electrical or fluid paths shall be physically separated, where possible, to minimize the probability of damage to one when the other is damaged.

3.2.1.2.6.1.2 Heat Collection

- a) Battery cooling shall be provided at a nominal temperature of 3°C (38°F), with excursions allowed to 16°C (60°F) for short durations of a few days.
- b) Electrical and electronic cooling shall be provided for 80 percent of the total electrical power load. This heat collection shall be performed at temperatures of between 18 and 43°C (65 and 110°F).

Design heat loads for electrical and electronic cooling shall be as follows:

Power/subsystems module:	5,250 watts
Crew/operations module:	3,240 watts
GPL module:	4,100 watts

The crew and EC/LS loads are shown in Table III.

- c) Fluid cooling shall be provided for electrical and electro-mechanical equipment.
- d) EC/LS heat shall be collected as required for the EC/LS to satisfy its performance requirements.

3.2.1.2.6.1.3 Heat Transport

- a) The heat transport function shall be accomplished in such a way that in conjunction with passive thermal control techniques, no condensation of atmosphere water occurs on plumbing and coolant service components.
- b) The heat transport function shall transport collected heat to the external radiator for heat rejection.

- 3.2.1.2.6.1.4            Heat Rejection
- a) A means shall be provided for modulating radiator temperature level to reject variable Space Station heat loads and prevent radiator fluid from freezing.
  - b) The probability of not losing the heat rejection function in a module due to meteoroid damage shall be 0.99 or greater during the initial 10 years of Space Station operation.

3.2.1.2.6.2            ISS Buildup Operations Mode

The ISS shall provide thermal control during all phases of unmanned buildup, to the degree required to permit operation of electrical and electronic equipment during the buildup.

- 3.2.1.2.6.3            Prelaunch and Launch Operations Mode
- a) Provide means to reject prelaunch Space Station heat loads to ground cooling equipment.
  - b) Provide means of providing thermal control of operating Space Station equipment during launch rendezvous, docking and startup.

3.2.1.3                Structure/Mechanical

The structure/mechanical subsystem for the ISS provides the habitability enclosures, operable mechanical mechanisms, and the primary/secondary structural elements upon which other subsystems are integrated and the payload is carried and serviced. It shall include, but not be limited to:

- a) Pressure shells
- b) Floors
- c) Walls
- d) Access and viewing provisions
- e) Support and transfer equipment
- f) Docking equipment
- g) Deployment mechanisms
- h) Meteoroid Protection and Space Radiator System
- i) Experiment equipment accommodations
- j) Solar Array Orientation Assembly

3.2.1.3.1 Configuration

The Initial Space Station shall consist of three modules, designated Power/Subsystem, Crew/Operations, and General Purpose Laboratory. The structure/mechanical subsystem shall provide the primary structure for these modules and shall provide installation accommodations for the subsystem functions/equipments allocated to the individual modules as defined in the subsections of 3.1.1 and as required by the individual subsystem operational and performance requirements. The physical requirements specified in the subsections of 3.2.2 shall be foremost in establishing the structure/mechanical configuration design of the individual modules and buildup of the module cluster.

3.2.1.3.2 Commonality

The design goal shall be to provide maximum commonality in the structure/mechanical subsystem within the bounds of acceptable design and cost effectiveness to the program.

3.2.1.3.3 Strength and Rigidity

3.2.1.3.3.1 Yield Load

The structural/mechanical subsystem shall have sufficient strength and rigidity to sustain yield load without failure, and without deformation which would prevent any portion of the vehicle from performing its intended function without deleterious permanent set. The simultaneous application of accompanying environmental effect (temperature, pressure, and vibration) shall be applied to determine the critical loading conditions.

3.2.1.3.3.2 Ultimate Load

The structural/mechanical subsystem shall have sufficient strength and rigidity to withstand the ultimate design load without failure and without deformation which would result in premature failure of any safety critical function. Environmental effects shall be applied as specified in 3.2.1.3.3.1.

3.2.1.3.3.3            Dynamic Magnification, Shock and Surge  
The structural/mechanical subsystem shall have sufficient strength and rigidity to withstand the effects of dynamic magnification, shock factors and surge phenomena, as applicable.

3.2.1.3.3.4            Shuttle Induced Environment  
Design and analysis of the subsystem for strength and rigidity shall reflect the mass and resultant loading conditions of the evolved configuration design and the physical, thermal and other induced environment conditions specified for Shuttle. Payloads in the Program Interface and Support Requirement Specification No. PS-02926.

3.2.1.3.4              Design Criteria

3.2.1.3.4.1            Design Safety Factors  
The structural/mechanical subsystem shall be designed in conformance with the general design safety factors specified in paragraph 3.3.6.1 and the following paragraphs.

3.2.1.3.4.1.1         Cabin, Internal Pressure Only  
Proof pressure:            1.50 x limit pressure  
Yield pressure:            1.10 x proof pressure  
Ultimate pressure:        2.00 x limit pressure

3.2.1.3.4.1.2         Window, Internal Pressure Only  
Proof pressure:            2.00 x limit pressure  
Ultimate pressure        3.00 x limit pressure  
Windows must be checked for crack growth under sustained pressure loadings.

3.2.1.3.4.1.3         Astronaut Restraints  
Tether ultimate factor of safety: 2.0  
Tether attachment ultimate factor of safety: 2.0

3.2.1.3.4.2 Radiation Limits

The structural/mechanical subsystem combined with other mass aboard the station shall be compatible with the following allowable quarterly radiation limits:

<u>Organ</u>	<u>Limit Dose</u> (rem)
Skin (0.0 mm)	105
Eye (3.0 mm)	52
Marrow (5.0 cm)	35

3.2.1.3.4.3 Fatigue

Fatigue criteria shall be based on a load history profile showing usage cycles, load intensities, and environments. Structural members shall be designed to the following factors times that of the maximum expected load history profile.

Low-cycle fatigue:	4.0
High-cycle fatigue:	10.0

3.2.1.3.4.4 Safe Life

All major load-carrying structures of the structural/mechanical subsystem shall be designed to a safe life of 10 years in orbit.

3.2.1.3.4.5 Meteoroid Protection

Meteoroid protection shall be provided by the ISS design so that when exposed to the meteoroid flux given in TM X-53865, Second Edition, dated August 1970, the following properties are met:

- a. The probability of no loss of pressure in the habitable volumes of the ISS shall be 0.90 or greater for the initial 10 years of space station operation.
- b. The probability of not sustaining unrepairable (in orbit) damage to a module shall be at least 0.990 per year for any configuration assembled in orbit.

3.2.1.3.4.6 Fail-Safe Design

Fail-safe design concepts shall be applied to all critical structure so that failure of a single structural member shall not degrade the strength or stiffness of the structure to the extent that the crew is in immediate jeopardy.

The structural shall also be designed to resist damage resulting from accidental impact during normal crew activities.

3.2.1.3.5 Design Requirements

3.2.1.3.5.1 Operating Pressure

The ISS structure subsystem shall be designed for an oxygen-nitrogen mixture at a normal operating pressure of  $101 \text{ kN/m}^2$  (14.7 psia), and a partial pressure of oxygen at reduced pressures with a minimum operating pressure of  $69 \text{ kN/m}^2$  (10 psia).

3.2.1.3.5.2 Differential Pressure

The differential pressures across the pressurized compartment shell, for the conditions noted, shall not exceed:

a) Collapse:	$0 \text{ kN/m}^2$	(0 psi)
b) Proof:	$151 \text{ kN/m}^2$	(22 psi)
c) Leak check:	$101 \text{ kN/m}^2$	(14.7 psi)
d) Burst:	$202 \text{ kN/m}^2$	(29.4 psi)

3.2.1.3.5.3 Leakage Rate

The total leak rate of the ISS three module cluster shall not exceed  $0.0022 \text{ kg/day}$  ( $0.005 \text{ lb/day}$ ).

3.2.1.3.5.4 Venting

Vents shall be capable of maintaining a positive pressure differential relative to all bulkheads during the worst case combination of three-sigma deviation to the ascent trajectory,



during ground conditioning and associated venting, and during orbital pressurization of pressurizable compartments. Venting shall be controlled so that modules returning to earth shall be maintained at a pressure level of 0.5 lbs/in.<sup>2</sup> (34.5 kN/m<sup>2</sup>) above ambient.

3.2.1.3.5.5                    Separate Volumes

The structure/mechanical subsystem design shall provide the capability for separate pressurized habitable compartments with independent life support capability at each manned stage of cluster buildup and operation, compatible with basic compartmentation requirements of paragraphs 3.1.3.3.3 and 3.1.3.4.3. This capability shall recognize and be compatible with the dual path ingress and egress considerations in paragraph 3.2.2.5.

3.2.1.3.5.6                    Docking Ports

The three modules of the ISS shall contain a total of twelve docking ports. The modules shall have docking ports at each end and the Power/Subsystems and Crew/Operations modules shall have three radial docking ports, 120 degrees apart, in a single plane. These radial docking ports shall be indexed to a +Z orientation in the nominal horizontal flight mode. Longitudinal location of the radial docking plane shall be at the approximate midpoint of the module constant section to provide adequate separation between laterally adjacent docked modules.

Allocation of the docking ports shall be per the ISS buildup specified in Section 3.1.1, logistic module placement of 3.1.1.1.2.1, and the RAM placement per e.1.1.2.3. One end port on the Power/Subsystems Module and one on the General Purpose Laboratory Module have a primary allocation for orbiter dock; however, these ports shall be capable of other module contingency use.

The docking port design shall meet the criteria specified in the following paragraphs.

3.2.1.3.5.6.1                    All docking ports shall be structurally identical to permit docking with any other docking port.

3.2.1.3.5.6. With a module attached, a pressurized section of sufficient volume shall be provided to maintain or repair the docking mechanism (less the seal) in a shirtsleeve environment. All utility interfaces between modules shall be within this pressurized section.

3.2.1.3.5.6.3 The docking mechanisms and supporting structure shall be designed to meet the following design criteria:

Axial closing velocity:	0.3 m/sec	(1.0 ft/sec)
Lateral velocity:	7.6 cm/sec	(0.25 ft/sec)
Pitch, yaw, and roll rates:	0.5 deg/sec	
Angular misalignment:	±5.0 deg	
Lateral displacement:	±0.3 m	(±1.0 ft)

3.2.1.3.5.7 Doors and Hatches

All pressure doors and hatches shall be designed for pressure in either direction. The exception is the outer door of the two scientific airlocks in the GPL module which shall be designed for internal pressure only. The pressure door and hatch operating mechanism design shall include features as specified in the following paragraphs.

3.2.1.3.5.7.1 Hatches at intermodule interfaces shall provide the capability of an IVA airlock. Sufficient volume shall be included between the two hatches for two suited crewmen.

3.2.1.3.5.7.2 All hatches shall be capable of operation by one crewman and with the exception of the GPL scientific airlock doors shall be operable from either side.

3.2.1.3.5.7.3 The outer door of the two scientific airlocks shall be remotely operable.

3.2.1.3.5.7.4           The capability for equalization of pressure across the hatches shall be provided and appropriate indicators of conditions in adjacent compartments shall be displayed near the doors and hatches.

3.2.1.3.5.7.5           Each manually operated pressure hatch and door mechanism design shall include a secondary safety latch to contain the door if opened under a differential pressure condition.

3.2.1.3.5.7.6           Pressure hatch design shall provide a means of visual verification that proper closure has been accomplished.

3.2.1.3.5.8           Viewports  
Viewports of both viewing and optical quality shall be incorporated in the ISS modules to provide diametric viewing areas. Viewport installations shall provide a 90-degree unobstructed view cone from a focal point equal to one-half the window diameter.

The viewports shall be designed to protect the modules interior from meteoroid penetration. The window design shall permit on orbit removal/replacement (with supplemental aids) for maintenance in a shirtsleeve environment. Viewports with optical quality requirements shall be protected from scratches, pits, etc. , except when optical usage is required.

3.2.1.3.5.9           Scientific Airlocks  
The ISS shall provide two scientific airlocks for support of a varied experiment program. Locating the two airlocks in diametrically opposite positions shall be a design goal. The structure and door design of chambers shall be capable of withstanding an internal pressure of TBD N/m<sup>2</sup> (TBD psi).

3.2.1.3.5.10           Antenna Deployment Booms  
The structure/mechanical subsystem shall provide three antenna mounting booms on the Crew/Operations Module for deployment of the high-gain antennas. The booms shall provide the capability specified in the following paragraphs.

3.2.1.3.5.10.1        Provide structural support for the antenna in a stowed position within the envelope limits specified for orbiter payloads (ref. Specification No. PS-02926, Appendix A, Section 3.1.2.2.4). Structural integrity shall be maintained in the stowed position when exposed to the orbiter induced environments specified in Section 3.2.1, Specification No. PS-02926.

3.2.1.3.5.10.2        The booms shall be capable of retracting to the locked stowage position for potential earth return of the crew module or to accommodate radial module docking.

3.2.1.3.5.11        Cargo Transfer Equipment  
Equipment and provisions shall be provided to facilitate the movement of cargo and replacement items within the ISS modules. Transfer equipment shall be designed to:

- a) Interface with logistic module transfer provisions.
- b) Minimize crew involvement and time.
- c) Be operational in a shirtsleeve environment.
- d) Provide methods for guidance and a means of restraining the generated inertia.

3.2.1.4                Electrical Power  
The function of the electrical power subsystem shall be to collect and convert solar energy to electrical power; to store and release electrical energy for solar eclipse periods and for load peaks; to regulate, transmit, control, and distribute electrical power to the Space Station power-consuming subsystems, the docked Research and Applications Modules (RAM's), integral experiments and logistics vehicles required. It shall provide:

- a) A 24-hour average power level of 16.7 kw at the load buses for normal operation.
- b) TBD kw during the worst credible single power failure event (excluding total loss or separation of the Power/Subsystems Module) for a duration of TBD hours.

- c) TBD kw for TBD hours to preserve experiments and subsystems required for return to full operational capability.
- d) 1.6 kw for a minimum of one hour during an emergency to permit fault identification and correction or station abandonment.
- e) Emergency power capability that is not compromised by the worst possible single mode of failure. Emergency operation modes shall be controllable from two independent inhabitable compartments.
- f) Control, monitoring, and display capability in each independent inhabitable region for both emergency operation and full-power operation modes. All electrical power subsystem assemblies will be supplied by two or more alternate power-supply feeders or sources.

Within the electrical power functional area, the detailed requirements are specified for the sub-functional areas shown in Figure 6.

#### 3.2.1.4.1 Solar Energy Collection

The solar energy collection and conversion function shall be provided by flexible solar arrays, a two-axis gimbaled array orientation system, sun sensors, and appropriate instrumentation. The equipment shall be designed to be launched integrally with the Power/Subsystems Module in a retracted configuration, and to be deployed by remote control. The array shall be capable of being retracted for return to earth in the Shuttle (after which a capability for use shall not be a requirement, except after extensive refurbishment). Individual panels shall be capable of independent operation.

##### 3.2.1.4.1.1 Primary Mission Mode of Operation

###### 3.2.1.4.1.1.1 Solar Array Orientation

The solar array shall be capable of full solar orientation without restrictions upon or constraints from the station flight attitude and orientation.

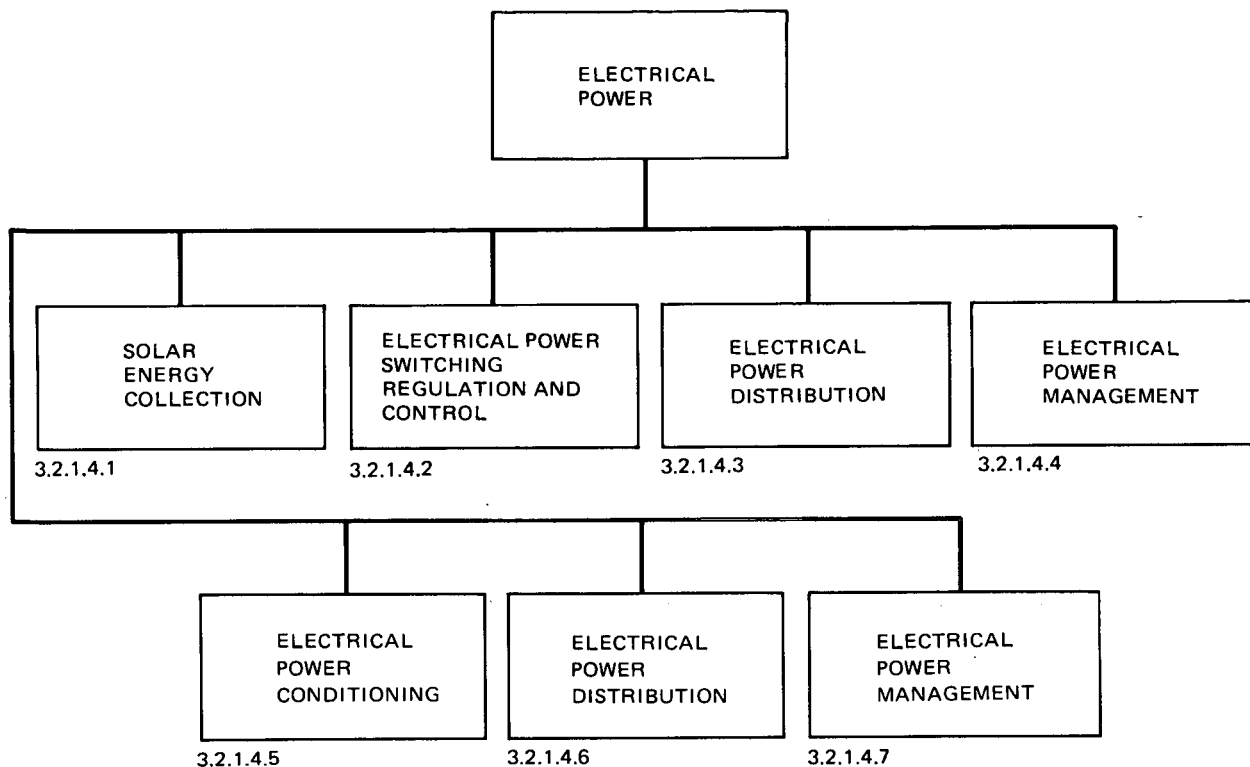


Figure 6. Electrical Power Subfunctional Areas

3.2.1.4.1.1.2. Solar Array Wing Orientation  
The solar array wings shall be capable of either independent or common orientation drive in the alpha (orbital-rate) axis and of common orientation drive in the Beta (orbit-plane to ecliptic-plane declination) axis.

3.2.1.4.3.1.3 Solar Tracking  
The sun sensors shall be capable of sensing the position of each solar array wing independently, relative to the sun-line. The orientation drive systems shall position the wings normal to the sun-line within  $\pm 8$  degrees during sunlight operation, and prior to entering the sunlit position of the orbit. Redundancy shall be provided in sun sensors and drives and the capability for mechanically joining array mast axes for common drive in both axes shall be provided.

The solar tracking system shall normally operate in an automatic, closed-loop mode. A capability for remotely-controlled positioning shall also be provided. Monitoring provisions shall be incorporated for position and positional error information.

3.2.1.4.1.1.4 Solar Panel Degradation

The solar panels shall be sized to allow for a total accumulated degradation of 30 percent in 5 years on orbit and 40 percent in 10 years on orbit.

3.2.1.4.1.1.5 Magnetic Compatibility

The electrical current collection system on the arrays shall be designed to minimize resultant magnetic fields to assure compatibility with onboard experiments and docked RAM's.

3.2.1.4.1.1.6 Shadowing

Shadowing shall be accommodated by electrical load management during the short periods in which illuminated area may be limited by shadowing. Solar modules and panels shall be electrically designed to preclude shadow-induced damage due to "hot-spot" effects or to current overloading.

3.2.1.4.1.1.7 Instrumentation

Instrumentation shall be provided to determine panel temperatures, voltages, currents, and illumination intensities for each independent solar power source (panel strip) and also for major subelements (panels or modules) necessary to evaluate basic performance, degradation, and potential failure modes.

3.2.1.4.1.2 ISS Buildup Operations Mode

3.2.1.4.1.2.1 Solar Array Activation

The solar array shall be designed to be deployed in 2 hours by a two-man activation crew after the Power/ Subsystems Module reaches orbit and before separation from the Space

Shuttle. Provisions shall be made for monitoring solar array voltage to verify basic capability, solar energy shall be supplied to the Power/Subsystems Module loads and batteries, and compatibility shall be verified.

3.2.1.4.1.2.2 Premanning Solar Array Orientation

The solar arrays shall be capable of being placed in the minimum drag "trailing" position, with the plane of the solar array coincident with the velocity vector.

3.2.1.4.1.3 Unmanned, Contingency Operations Mode

3.2.1.4.1.3.1 Remotely-Controlled Operation

Instrumentation shall be provided to supply telemetry data for ground monitoring to permit status evaluation and command/control of the solar energy collection system.

3.2.1.4.1.3.2 Solar Array Recovery

The complete solar array shall be retractable for recovery of the array and orientation assemblies intact with the Power/Subsystems Module. Solar cell integrity is not required to be retained for subsequent reuse of the panels.

3.2.1.4.1.3.3 Solar Panel Replacement

Solar panels shall be designed for replacement on orbit by EVA as a contingency operational capability. This shall be accomplished by individual panel strip retraction, replacement, and redeployment.

3.2.1.4.2 Electrical Power Switching Primary Regulation and Control

The electrical power switching, primary regulation and control functions shall be provided by a system of remotely controlled circuit breakers, manually operated disconnect switches, and automatic regulation equipment. The regulation equipment included in this functional group shall be used to regulate the voltage delivered to the system. This equipment shall be located in the Power/Subsystem Module,



with the primary power switching equipment and sufficient control equipment to control all functions of solar energy collection regulation, and electrical system configuration.

3.2.1.4.2.1 Primary Mission Mode of Operation

3.2.1.4.2.1.1 Normal Operation

The electrical power switching, primary regulation, and control functional group shall normally operate in an electrically parallel mode. A source bus shall receive voltage-regulated power from all solar array panel strips and shall supply power to two full-capacity transmission lines. Power shall be divided approximately equally between the lines. Normal operation shall also be possible with any degree of division of the sources and/or loads between the two transmission lines.

3.2.1.4.2.1.2 Maintenance

The switches, regulators, and control elements shall be arranged for electrical isolation to permit deenergized maintenance or replacements without interference with normal full-capacity station operations.

3.2.1.4.2.1.3 Regulator Assignments

Individual solar panel strips shall be regulated by individual regulators. Switching shall be provided to reassign regulators to different solar panels and to allow maximum flexibility of configuration and to improve reliability.

3.2.1.4.2.1.4 Automatic and Remote Control

The power switches shall be designed to permit basic circuit configuration changes by remote control from either of the operations centers. Sufficient manual switches or lock-out circuits on the power switches shall be provided to assure safety interlocking for maintenance. The regulators shall operate in a self-regulating control mode with override and set-point bias control from either of the Operations Centers. Position sensors for switches and parameter sensors for regulators shall be provided for remote monitoring.

3.2.1.4.2.1.5            Instrumentation  
Instrumentation shall be provided to determine switch position and control status, and for regulator voltages, currents, and operating temperatures.

3.2.1.4.2.2            Unmanned, Contingency Operations Mode  
Instrumentation shall be provided to supply telemetry data for ground monitoring to permit status evaluation and command/control of the Electrical Power Switching, Primary Regulation and Control functional group.

3.2.1.4.2.3            Prelaunch Operations Mode  
The Electrical Power Switching, Primary Regulation and Control functional group shall be capable of test before launch; energized by ground power at appropriate buses instead of solar array power. It shall provide normal internal switching and control for the electrical power subsystem elements needed for prelaunch checkout of other subsystems.

3.2.1.4.2.4            Launch Operations Mode  
During launch, the Electrical Power Switching and Control functional assemblies shall be capable of operation, using internal batteries and/or regulated Space Shuttle power. The battery line regulators shall be utilized for voltage regulation when internal batteries are used.

3.2.1.4.3            Electrical Energy Storage  
The Electrical Energy Storage functional group shall provide:

- a) Electrical power during Earth eclipse of the Space Station
- b) Storage of energy during solar illumination
- c) Power for extraordinary peaks during partial reduction of normal solar power
- d) Supplemental power during short periods of partial solar array shadowing
- e) Emergency station power in the event of loss of normal solar array power

- f) Primary launch and ascent power for the power module (supplemented by Space Shuttle power if required)
- g) End-of-mission power when solar arrays are retracted for recovery

3.2.1.4.3.1 Primary Mission Mode of Operation

3.2.1.4.3.1.1 Normal Operation

The batteries in the Energy Storage Assembly shall be charged and discharged within their normal operating range under automatic control, at an efficient rate compatible with the charging source, the electrical loads and the power available. The charging rate shall be reduced to a rate consistent with continuous overcharge or charging shall be interrupted if the thermal input to the cooling system exceeds the design value. The battery shall provide the signal near the end of charge to reduce the charge rate or to terminate charge. Charge termination shall be preferred operating mode.

3.2.1.4.3.1.2 Depth of Discharge

Average depth of discharge over a 24 hour period shall be 15 percent (Max normal is 35 percent peak). This is compatible with a 2.5-year nominal battery lifetime (approximately 14,500 cycles). The charging equipment shall accommodate an average depth of discharge of up to 30 percent (70 percent peak) compatible with a 1.0-year nominal life (approximately 5,800 cycles).

3.2.1.4.3.1.3 Lifetime

The batteries shall have a minimum normal design life of 2.5 years (reference paragraph 3.2.1.4.3.1.2). The provisions for greater depth of discharge during buildup, emergency, or contingency operation (array shadowing, for example) shall result in not less than a 1.0-year projected lifetime.

3.2.1.4.3.1.4 Emergency Power

The Energy Storage assembly for ISS shall provide a nominal emergency energy source of 72 kw-hr when discharged from full charge. The minimum available energy shall be 46.5 KW-hr when discharged from the nominal maximum depth of discharge (35 percent).

3.2.1.4.3.1.5 Discharge Voltage

The discharge voltage to the regulated Main Distributor Bus in each module shall be 112 to 118 volts dc under all specified load conditions.

3.2.1.4.3.1.6 Location

As a minimum two series strings of four batteries each shall be located in each Space Station Module when the ISS is fully implemented for manning. The battery modules shall be accessible for periodic inspection, maintenance and replacement.

3.2.1.4.3.1.7 Electrolyte Containment

The battery assemblies shall be designed to prevent leakage of electrolyte due to any single failure into any pressurized or unpressurized compartment of the ISS. Leakage of electrolyte from hermetically-sealed cells shall be collected in the hermetically-sealed module container. Such loss of electrolyte shall result in an indication of cell performance change which will discontinue the charging or discharging of the cells, and will, thus, prevent further release of either gas or electrolyte. The collected electrolyte shall not be vented overboard or otherwise exposed in the space station due to its toxic and corrosive nature.

3.2.1.4.3.1.8 Instrumentation

Sufficient instrumentation and sensors shall be provided to determine cell pressure in each battery module, third electrode voltage in each module, internal temperature of each module, coolant inlet and outlet temperature for each battery, input and output voltage and current for each battery charger, input and output voltage and current for each battery line regulator, and battery state-of-charge.

3.2.1.4.3.1.9 Replacement

The batteries shall be replaceable. New modules shall be delivered in a fully charged, conditioned state. Sufficient installed redundancy shall provide for continuity of service during replacement of failed units.

3.2.1.4.3.2 ISS Buildup Operations Mode

3.2.1.4.3.2.1 Energy Storage Assembly Hardware

The Power/Subsystems Module shall be designed for launch with an initial battery complement, battery charges and regulators adequate to provide adequate reliability for the activation phase. The Crew/Operations Module and the General Purpose Laboratory shall be designed to be launched initially without batteries, but with provisions for addition of the batteries, battery chargers, and battery line regulators prior to and/or concurrent with initial manning. The design shall accommodate supply of this equipment by early Logistics Module missions and installation by the station activation crew-men. Power for the unmanned station modules shall be derived from initial batteries, charged by the solar arrays operated in the trailing (minimum-drag) unoriented position.

3.2.1.4.3.3 Unmanned, Contingency Operations Mode

3.2.1.4.3.3.1 Remotely-Controlled Operation

The instrumentation shall be provided to supply telemetry data for ground monitoring to permit energy storage status evaluation and remote command/control of the solar energy collection system.

3.2.1.4.3.3.2 Emergency Operation

The reserve capacity of the batteries shall be available to satisfy unmanned "emergency" periods of at least TBD hours, during which remotely-controlled power restoration procedures may be undertaken.

3.2.1.4.3.4 Prelaunch Operations Mode

3.2.1.4.3.4.1 Energy Storage Assembly Activation

The energy storage assembly shall be designed to be activated before Space Shuttle launch. Capability shall exist for essential charge and discharge functions to be tested on the ground, using ground power supply to simulate solar array power, followed by bringing the batteries to full charge before launch on the Space Shuttle.

- 3.2.1.4.3.5           Launch Operations Mode
- 3.2.1.4.3.5.1        Power/Subsystems Module  
Batteries shall provide power to the Power/Subsystems Module from Space Shuttle launch to solar array deployment.
- 3.2.1.4.3.5.2        Crew/Operations Module and General Purpose Laboratory  
The Crew/Operations Module and the General Purpose Laboratory shall be designed to operate on Space Shuttle power until electrical power transmission line connections are made to the solar array/battery power source in the Power/Subsystems Module.
- 3.2.1.4.4            Electrical Power Transmission  
The electrical power transmission assembly for the ISS electrical power subsystem shall include cabling, primary buses, junction units, and primary protection. Primary switching functions are included in the Electrical Power switching, Primary Regulation, and Control Functional group (reference paragraph 3.2.1.4.8).
- 3.2.1.4.4.1          Primary Mission Mode of Operation
- 3.2.1.4.4.1.1        Function  
The transmission assembly shall transmit bulk power from the source buses located in the power turret to the main distributors located in each station module.
- 3.2.1.4.4.1.2        Protection  
Individual electrical differential protection zones shall be provided for all transmission circuits. Ample mechanical protection shall be provided for primary cables and buses. Circuit protection shall be provided in all circuits supplied from the transmission assembly. The protection devices shall be coordinated with the primary bus protection, within a differential protection format.

3.2.1.4.4.1.3           Single Point Ground

A single point ground shall be established for each isolated power source (solar array, transformer-rectifier, or inverter).

3.2.1.4.4.1.4           Location

The transmission assembly shall originate in the pressurized turret and shall terminate in the main distributors located in each station module. The solar array power conductors shall be routed from the solar arrays to the two source buses located in the pressurized turret on the power tunnel. The transmission circuit conductors shall then be routed through the tunnel to primary buses installed in the main distributors within each station module.

3.2.1.4.4.2           ISS Buildup Operations Mode

The electrical power transmission assembly shall be extendible from module to module, with full power capacity, by means of the common connector interfaces provided for all modules. These shall include four power transmission cable connections and the two control cable connections. Only these manually secured interconnections shall be required for station buildup, with respect to the transmission assembly.

3.2.1.4.4.3           Unmanned, Contingency Operations Mode

3.2.1.4.4.3.1       Unmanned Control and Protection

The electrical power transmission assembly, after ISS buildup as described in paragraph 3.2.1.4.4.2, shall be capable of operation up to full power while the station is unmanned. All self-protective functions shall be automatic, and the design shall provide that necessary switching operations for system reconfiguration be performed by remote command/control.

3.2.1.4.4.3.2       Contingency Operations

The electrical power transmission assembly shall be dual redundant, therefore, normal quality of power shall be retained with the loss of either cable set. The loss of one cable of

one set shall not degrade the power system performance. Dependence upon a single cable of one set remaining shall be possible with degraded quality at full power.

3.2.1.4.4.4 Prelaunch Operations Mode

3.2.1.4.4.4.1 Ground Testing

The electrical power transmission assembly shall be capable of prelaunch checkout, to consist of testing all functions and power quality using the ground power system. Such tests shall include checkout of current limits and tripping set points for circuit-breakers and relays.

3.2.1.4.4.5 Launch Operations Mode

The Crew/Operations and GPL Module design shall be compatible with the transfer of power from the Space Shuttle through the transmission assembly to these station modules.

3.2.1.4.5 Electrical Power Conditioning

The electrical power conditioning assembly for the ISS electrical power subsystem shall include sine and square wave inverters, battery charger-regulators, and battery discharge PWM series (buck) regulators.

3.2.1.4.5.1 Primary Mission Mode of Operation

3.2.1.4.5.1.1 Function

The conditioning assembly shall provide regulated power for the electrical power subsystem buses, and controlled power for battery charging.

3.2.1.4.5.1.2 Protection

Subassemblies of the conditioning assembly shall be designed for self protection. Static units shall have the capability to limit and withstand short-circuit currents for a protective device coordination period, followed by self-tripping before internal damage



occurs. Circuit breakers shall be provided on the power input side. Contractors shall be used to switch the outputs. Reverse current relays shall be used in the battery discharge regulator outputs to prevent the solar array source from discharging into an internal fault.

3.2.1.4.5.1.3 Replacement

All subassemblies shall be capable of replacement. Selected (TBD) components of subassemblies shall also be capable of replacement.

3.2.1.4.5.2 ISS Buildup Operations Mode

The electrical power conditioning assembly for each station module shall be normally isolated from each other station module, except for the common transmission assembly. Therefore, the ISS buildup operations mode shall not require any changes in the assembly except for the average power increase from the fully dormant (quiescent) operating state to the fully manned ISS operating state.

3.2.1.4.5.3 Unmanned, Contingency Operations Mode

The electrical power conditioning assembly shall be capable of accommodating either unmanned or contingency operations of the station without modifications.

3.2.1.4.5.4 Prelaunch Operations Mode

3.2.1.4.5.4.1 Ground Testing

The electrical power conditioning assembly shall be capable of prelaunch checkout, to consist of testing all functions, power quality, and efficiency from minimum to maximum electrical load, using the ground power system. Such testing shall include the self-protection feature during overloads or short circuits.

3.2.1.4.5.4.2 Ground Operation

All conditioning subassemblies except the battery discharge PWM series (buck) regulators shall be operable when the Space Station is supplied with ground power simulating solar array source power. Ground power shall also be provided to simulate each

electrical power subsystem battery. The battery discharge PWM series (buck) regulators shall be operable when the station module is supplied with power from the battery simulators.

3.2.1.4.5.5            Launch Operations Mode

The launch operations of the electrical power conditioning assembly shall be essentially the same as the normal on-orbit operations, except for the low power level requirements.

3.2.1.4.6            Electrical Power Distribution

The electrical power distribution assembly for the ISS electrical power subsystem shall include cabling, load buses, load-bus switching, load-bus protection, distribution circuit protection, battery switching, and distribution panels for final distribution to the loads.

3.2.1.4.6.1           Primary Mission Mode of Operation

3.2.1.4.6.1.1        Function

The distribution assembly shall distribute bulk power from the transmission assembly and energy storage assembly (batteries) to the conditioning assembly, and shall distribute both bulk power and conditioned power to distribution panels within all station modules.

3.2.1.4.6.1.2        Input

Input power to the distribution assembly shall be 112 to 116 vdc bulk power from the transmission assembly and from the batteries.

3.2.1.4.6.1.3        Output

Output power from the distribution assembly (i. e., power delivered to the distribution panels) shall include the following types:

- a) 115  $\pm$  3.0 vdc
- b) 400 Hz  $\pm$  1 percent, three-phase 115/200 vac  $\pm$  2-1/2 percent, sine wave

- c) 400 Hz  $\pm 1$  percent, three-phase 115/200 vac  $\pm 2-1/2$  percent, quasi-square wave
- d) 60 Hz  $\pm 1$  percent, one-phase 115 vac  $\pm 5$  percent, sine wave (GPL instrument power)

Essential and nonessential bus sections shall be provided in each distribution panel for the various power types as established by the electrical load analysis.

3.2.1.4.6.1.4 Control

The distribution assembly shall be controlled automatically through the power management assembly or by internal closed-loop functions. Manual backup or override capability shall be provided.

3.2.1.4.6.1.5 Protection

Electrical protection shall be provided for all distribution circuits. The primary function of the protectors shall be to protect the wire, not the load. Protectors shall be coordinated with protective functions in the transmission assembly. The installation shall provide maximum mechanical protection against faults in cables and buses and other critical elements in the distribution assembly.

3.2.1.4.6.1.6 Single-Point Ground

A single point ground shall be established for each independent system. Neutral, common, or return conductors shall be provided for all circuits. Structure shall not be used as a conducting medium except to return ground fault current for the purpose of tripping the circuit breaker which supplies a faulty circuit.

3.2.1.4.6.2 ISS Buildup Operations Mode

The electrical power distribution assembly for each station module shall be normally isolated from each other module, except through the common transmission assembly. Therefore, the ISS buildup operations shall not require any changes in the assembly except for the switching necessary to accommodate electrical load changes from the fully dormant (quiescent) to the fully manned ISS operating state.

3.2.1.4.6.3 Unmanned, Contingency Operation Mode  
The electrical power distribution assembly shall be capable of accommodating either unmanned or contingency operations of the station without modifications.

3.2.1.4.6.4 Prelaunch Operations Mode

3.2.1.4.6.4.1 Ground Testing  
The electrical power distribution assembly shall be capable of prelaunch checkout, to consist of testing all functions and power quality using the ground power system and either dummy loads or vehicle loads. Such tests shall include checkout of current limits and tripping-set-points for circuit-breakers and relays, using dummy loads.

3.2.1.4.6.5 Launch Operations Mode  
The use of the electrical power distribution assembly during the launch operations mode shall include the supply of operating power to all active subsystem electrical loads.

3.2.1.4.7 Electrical Power Management  
The electrical power management assembly shall provide control of:

- a) The sequential partial shunt regulators for voltage control
- b) Solar array orientation
- c) Sun-sensing and drive control
- d) Batteries and associated electronics
- e) Integrated displays and controls

In addition it shall operate in conjunction with onboard checkout and fault isolation and the data management functional areas.

3.2.1.4.7.1 Primary Mission Mode of Operation

3.2.1.4.7.1.1 Function

The power management assembly shall control subsystem loads according to established priorities; it shall control system configuration in event of malfunction; and it shall control the charging and discharging of the batteries.

- 3.2.1.4.7.1.2            Automatic and Manual Control  
The power management functions shall be performed automatically, with manual backup or override capability.
- 3.2.1.4.7.1.3            Sensors  
Sensors shall be provided for monitoring all critical operational parameters.
- 3.2.1.4.7.2            ISS Buildup Operations Mode  
The power management assembly shall provide all necessary functions for monitoring, display, control, and onboard checkout of the electrical power subsystem, and for self-test of the power management assembly during all stages of buildup to the ISS.
- 3.2.1.4.7.3            Unmanned, Contingency Operations  
The power management assembly shall provide remotely-controlled monitoring and control of the electrical power subsystem either:
- a) From the ground command/control facilities through the telemetry system for unmanned periods or for last-resort contingency operation
  - b) From the secondary operations/control center located in the GPL Module as a contingency mode
  - c) From the rudimentary control equipment located in the Power/ Subsystems Module which was initially used when only this module was on orbit.
- 3.2.1.4.7.4            Prelaunch Operations Mode  
The power management assembly shall be utilized to the maximum extent practical for the prelaunch test operations. It shall provide the built-in test functions, self-check functions, analytic functions, display functions, and control functions necessary to verify flight-readiness of the electrical power subsystem.

3.2.1.4.7.5. Launch Operations Mode

The power management assembly shall provide the necessary display and control functions and interfaces of the electrical power subsystem with other subsystems and with the Space Shuttle during launch, rendezvous and docking.

3.2.1.5 Propulsion and Reaction Control

The ISS propulsion subsystem shall supply the impulsive forces in accord with the needs determined by the stabilization and attitude control subsystem specified in paragraph 3.2.1.6. The subsystem shall provide low thrust using biowaste fluids as propellant and high thrust utilizing monopropellant hydrazine. Within the propulsion functional area, the detailed requirements are specified for the subfunctional areas shown in Figure 7. The propulsion subsystem shall be designed for orbital maintenance and repair without EVA.

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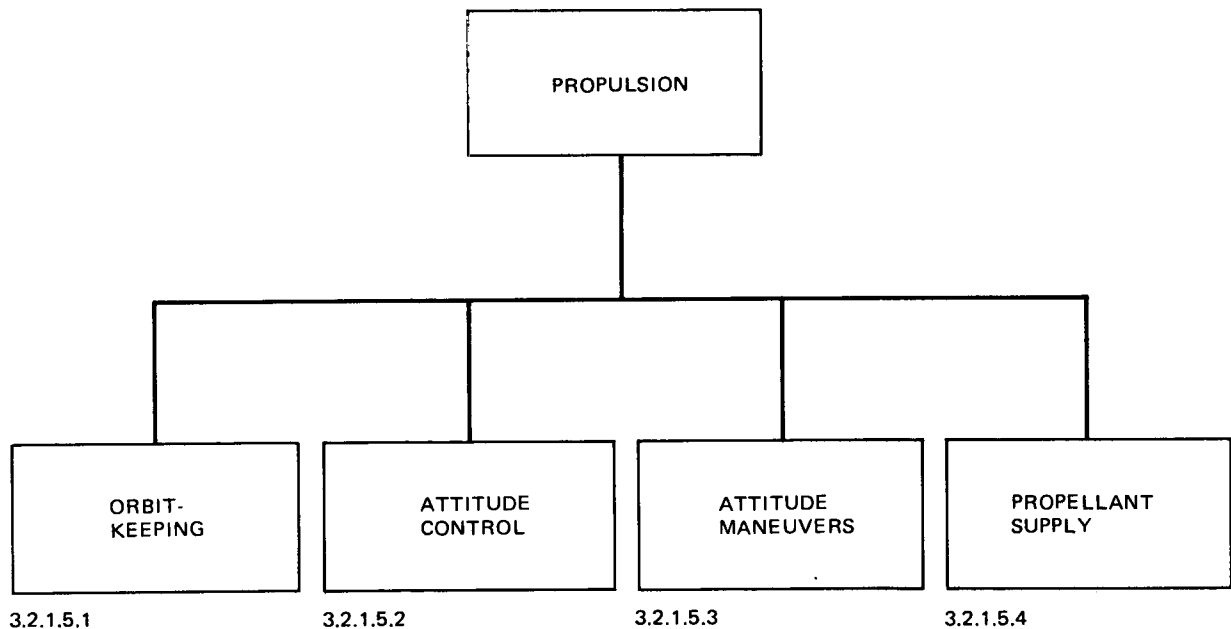


Figure 7. Propulsion Subfunctional Areas

3.2.1.5.1 Orbit-Keeping

Orbit-keeping impulse shall be applied to compensate for velocity losses due to atmospheric drag at the required orbital altitude of 445 to 500 km (240 to 270 nmi).

3.2.1.5.1.1 Primary Mission Mode of Operation

The primary operational mode shall be to provide periodic thrusting to cancel the accumulated effects of atmospheric drag. The impulse shall be provided by heating and ejecting waste CO<sub>2</sub> obtained from the EC/LS system. System operation shall be automatic with regard to propellant collection, storage and conditioning and shall be designed to minimize constraints upon vehicle attitude while in operation.

3.2.1.5.1.2 ISS Buildup Operations Mode

Orbit keeping shall not be required during the ISS buildup period. The initial module (Power/Subsystems Module) shall be launched into a higher orbit than desired for long term operation and allowed to decay during buildup. Orbit-keeping shall be initiated after the station is manned.

3.2.1.5.2 Attitude Control

The propulsion subsystem shall provide sufficient thrust and impulse to counteract attitude disturbances that are beyond the capability of the control moment gyros (CMG's).

3.2.1.5.2.1 Primary Mission Mode of Operation

3.2.1.5.2.1.1 Under normal operating conditions, the CMGs will control the vehicle attitude and desaturation will be accomplished by the use of gravity-gradient torques. The propulsion system shall have the capability to provide desaturation torque when the attitude constraints of the gravity-gradient desaturation method are not acceptable.

3.2.1.5.2.1.2 The propulsion subsystem shall be capable of controlling the attitude disturbance caused by the docking or dedocking of free-flying modules, the dedocking of the Space Shuttle, or the impact from a Space Shuttle docking attempt when latching does not occur.

- 3.2.1.5.2.2 ISS Buildup Operations Mode
- 3.2.1.5.2.2.1 During the ISS buildup period, the station attitude shall be controlled solely by the propulsion subsystem. The ISS attitude shall be limited to local horizontal with the solar panels trailing and feathered in order to reduce the attitude control requirements. An attitude deadband shall be  $\pm 10$  degrees, except during docking or orbital assembly.
- 3.2.1.5.2.2.2 During periods of docking and/or orbital assembly, the attitude control deadband shall be reduced to  $\pm$ TBD degrees for the docking operation.
- 3.2.1.5.2.3 Backup Attitude Control  
The propulsion subsystem shall be capable of providing attitude control to the extent of available propellant in the event of CMG failure.
- 3.2.1.5.3 Attitude Maneuvers  
The propulsion subsystem shall be capable of providing attitude maneuvers.
- 3.2.1.5.3.1 The propulsion subsystem shall be sized to allow for TBD maneuvers per month during the operational phase. These maneuvers shall consist of a 90-degree attitude change in each axis. Alignment for docking is not considered a maneuver.
- 3.2.1.5.3.2 Buildup Operations Mode  
There will be no requirement for attitude maneuvers during this period.
- 3.2.1.5.3.3 Backup Attitude Maneuvers  
There will be no provision for backup attitude maneuvers.



3.2.1.5.4

Propellant Supply

The propulsion subsystem shall contain provisions to be supplied from the Log M.

3.2.1.5.4.1

The primary transfer mode will be by bulk transfer through umbilicals at the docking ports. Propellant supply pressures shall be no greater than 2,400 kN/m<sup>2</sup> (350 psia). Flow rates will not exceed 630 cm<sup>3</sup>/sec (10 GPM). Propellant transfer provisions shall be incorporated at all docking ports intended for use by Logistics Modules.

3.2.1.6

Guidance and Navigation

(Combined with 3.2.1.7, Stabilization and Attitude Control)

3.2.1.7

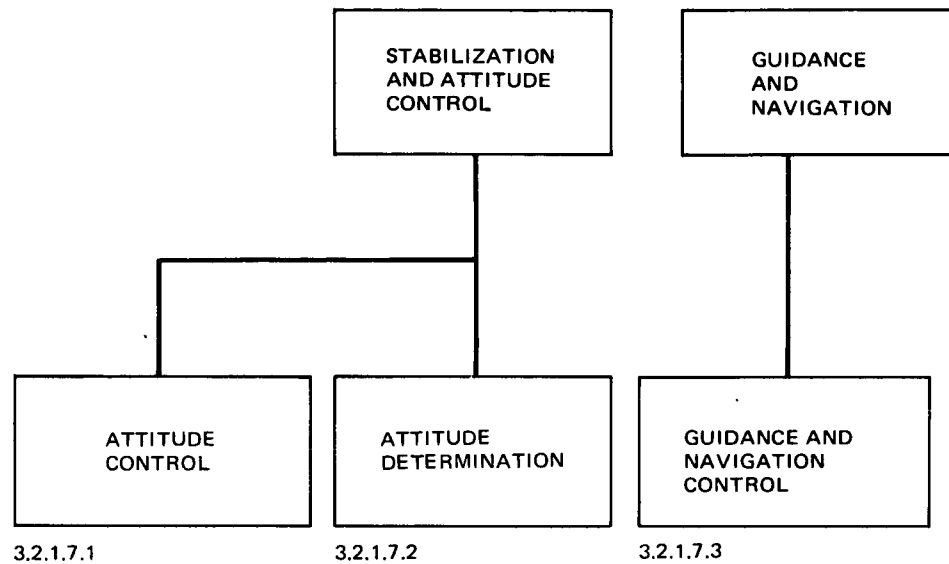
Stabilization and Attitude Control

The function of the guidance, navigation and control (GNC) subsystem is to control the orientation of the Space Station during all orbital operations. This capability shall be provided for any combination of RAMs and logistics modules not exceeding a total of five modules docked to the ISS. The GNC subsystem shall also provide vehicle attitude and navigation information to support experiments. The GNC subsystem shall utilize elements of the ISS data management functional area such as computations, data processing, data acquisition and data distribution. Within the guidance, navigation and control functional area, the detailed requirements are specified for the subfunctional areas shown in Figure 8.

3.2.1.7.1

Attitude Control

The GNC subsystem shall provide the capability of controlling the Space Station's attitude in several orientations utilizing either Control Moment Gyros (CMG) or reaction control thrusters. The CMG shall be used as the primary control actuator. The ISS body axes are shown in Figure 9 and are defined by the GNC attitude reference bench mark.



**Figure 8. Stabilization and Attitude Control/Guidance, Navigation and Control Subfunctional Areas**

3.2.1.7.1.1 Primary Mission Mode of Operation

3.2.1.7.1.1.1 Orientations

The Guidance and Navigation (G&N) and Stabilization and Attitude control subsystems shall have the capability of controlling the station attitude in any of the four orientations defined below:

- a) Horizontal – The Z-axis is aligned with the vertical and the negative Y-axis is parallel to the orbital rate vector.
- b) Perpendicular to Orbit Plane (POP) – The X-axis is parallel to the orbital rate vector and angular rate about X-axis is maintained at nominally zero degree/sec.
- c) Perpendicular to Orbit Plane/Orbit Rate (POP/OR) – The X-axis is parallel to the orbit rate vector and the Z-axis is aligned with the vertical. The vehicle rotates about the X-axis at orbit rate.

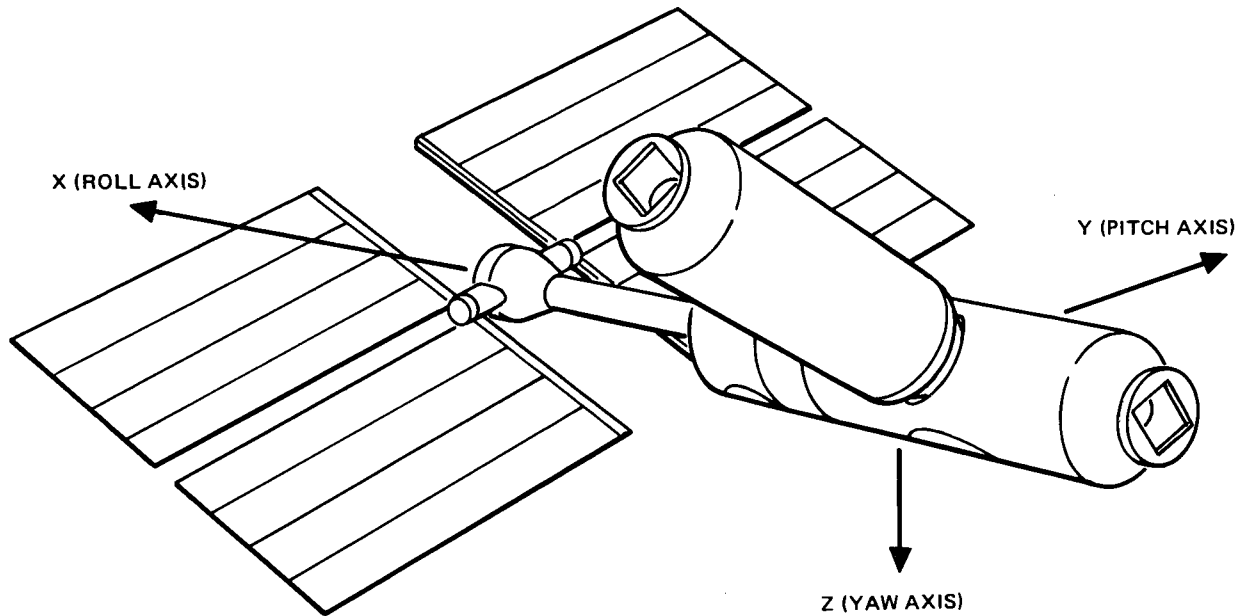


Figure 9. ISS Body Axes

- d) Inertial – Fixed vehicle attitude with respect to the celestial sphere.
- e) Trimmed horizontal – This orientation is obtained from the horizontal orientation by a pitch attitude displacement which aligns the principal x-axis in the horizontal plane and the pitch axis is aligned with the normal to the orbit plane.

Trimmed horizontal orientation is the primary vehicle orientation. These subsystems shall provide the capability to automatically acquire and hold the horizontal orientation from any random orientation upon command. They shall also provide the capability to automatically acquire and hold any of the defined orientations from the primary (trimmed horizontal) orientation.

3.2.1.7.1.1.2 Pointing and Stability

In all defined orientations these subsystems shall provide pointing of the body axes to within 0.25 degree and stability of the body axes to within 0.005 degree per second relative to the reference coordinates of the selected orientation.

3.2.1.7.1.1.3 CMG Momentum Storage Capacity

The control moment gyros for the ISS shall be capable of providing a total momentum storage capacity of (10,800 Nm·sec). The CMGs shall be configured to provide the following momentum envelope:

Pitch:	$\pm 10,800 \text{ Nm}\cdot\text{sec}$ ( $\pm 8000 \text{ ft}\cdot\text{lb}\cdot\text{sec}$ )
Yaw:	$\pm 10,800 \text{ Nm}\cdot\text{sec}$ ( $\pm 8000 \text{ ft}\cdot\text{lb}\cdot\text{sec}$ )
Roll:	$\pm 5,400 \text{ Nm}\cdot\text{sec}$ ( $\pm 4000 \text{ ft}\cdot\text{lb}\cdot\text{sec}$ )

3.2.1.7.1.1.4 Attitude Trim Capability

While in the horizontal orientation, the G&N and S and AC subsystems shall have the capability to determine and maintain the roll and yaw axis in a trimmed attitude which minimizes control propellant consumption. This orientation is called trimmed horizontal and it is the long-term orientation of the Space Station.

In the POP/OR orientation these subsystems shall have the capability to determine and maintain the pitch and yaw axis in a trimmed attitude which minimizes the attitude control propellant requirement.

3.2.1.7.1.1.5 Shuttle Docking Operations

These subsystems shall be capable of providing attitude control with reduced capability with the shuttle docked to it. The actuators shall nominally be inhibited while the Shuttle is docked to the ISS.

3.2.1.7.1.2           ISS Buildup Operations Mode  
The G&N and S and AC subsystems shall provide attitude control throughout the buildup phase utilizing the reaction control thrusters which are part of the propulsion subsystem. The equipment required to provide the capability shall be located in the power module. The GNC subsystem is not required to provide separate attitude control capability for each ISS module.

3.2.1.7.1.2.1        Orientation  
They shall provide control of the ISS in the horizontal orientation as described in 3.2.1.7.1.1.1 and shall be capable of automatically acquiring this orientation from any random orientation of the Space Station.

3.2.1.7.1.2.2        Rate Stabilization  
These subsystems shall provide a rate stabilization capability in which the body rates are maintained below 0.005 degree per second.

3.2.1.7.2            Attitude Determination  
The G&N and S and AC subsystems shall determine the attitude and rate of the ISS with respect to both inertial and Earth-centered coordinates. This information will be used to control the attitude of the vehicle and to support experiments.

3.2.1.7.2.1         Primary Mission Mode of Operation

3.2.1.7.2.1.1       Inertial Reference  
The G&N and S and AC subsystems shall determine the attitude of the ISS body axes with respect to an inertial reference frame to within  $\pm 0.10$  degree in each axis.

3.2.1.7.2.1.2       Earth Centered Reference  
The G&N and S and AC subsystems shall determine the attitude of the ISS body axes with respect to a rotating, Earth-centered reference frame to within  $\pm 0.1$  degree in each axis.

3.2.1.7.3 Guidance and Navigation

The Guidance and Navigation subsystem shall maintain a continuous knowledge of the orbital parameters through an onboard ephemeris, program using periodic updates from the NASA tracking network and provide the capability to maintain or change the orbital parameters, through use of the capability of the propulsion function area.

3.2.1.7.3.1 Primary Mission Mode of Operation

3.2.1.7.3.1.1 Position Information

The G&N subsystem shall provide downrange, cross-range, and altitude information accurate to  $\pm 1.8$  km ( $\pm 1.0$  nmi).

3.2.1.7.3.1.2 Orbit-Keeping

The G&N subsystem shall determine the change in velocity ( $\Delta V$ ) requirements for orbital transfers. The GNC shall have the capability of commanding the required  $\Delta V$  through use of the propulsion subsystem functions operating on either an intermittent (high-thrust) basis or on a continuous (low-thrust) basis.

3.2.1.8 Communications

The ISS communications subsystem shall provide RF communications between the ISS and the ground either directly or via a data relay satellite system (DRSS), the Shuttle Orbiter and crew members engaged in EVA. The ISS shall provide for the transmission and reception of the following types of data:

a) Direct to ground

Command, voice, and ranging reception.

Telemetry, voice, and ranging transmission.

b) Ground via DRSS

Television, multiple-voice, entertainment audio, digital data, and ranging reception.

Television, experiment data, multiple voice, digital data, and ranging transmission.

- c) Shuttle Orbiter
  - Voice, command, and ranging reception.
  - Voice, telemetry, and ranging transmission.
- d) EVA
  - Voice and biomedical telemetry reception.
  - Voice transmission.
- e) IVA
  - Voice and telemetry

The communications subsystem shall also provide normal and emergency voice communications between modules, crew duty and living stations, and docked modules utilizing the data bus provided in the data management functional area. Within the communications functional area, the detailed requirements are specified for the subfunctional areas shown in Figure 10.

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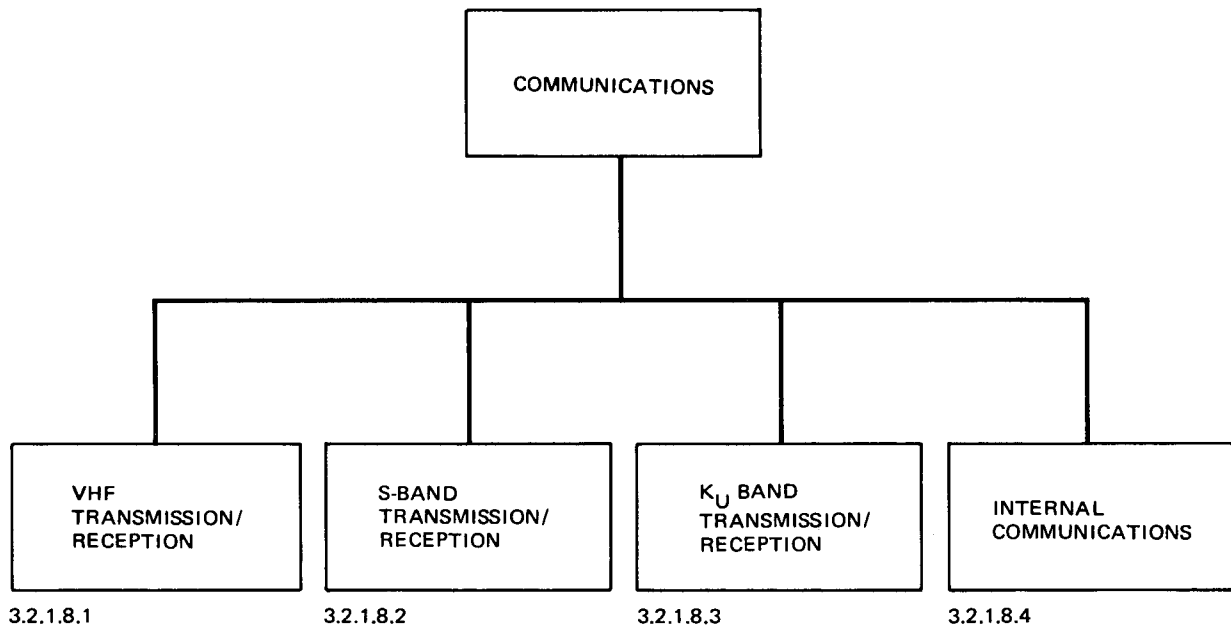


Figure 10. Communications Subfunctional Areas

3.2.1.8.1 VHF Transmission/Reception

The communications subsystem shall provide for the transmission and reception of information between the ISS and DRSS and between the ISS and EVA crewmen.

3.2.1.8.1.1 Primary Mission Mode of Operation

3.2.1.8.1.1.1 The ISS shall be capable of receiving a VHF signal at a fixed frequency in the aviation services VHF low band and demodulating voice signals modulated on the carrier. The detected voice shall be provided as an output to the internal communications system.

3.2.1.8.1.1.2 The ISS shall be capable of receiving a VHF signal at a fixed frequency in the aviation services VHF low band and demodulating pulse-code-modulation (PCM) signals modulating the carrier at rates up to 10 Kbps. The detected data signals shall be provided as an output to a data terminal.

3.2.1.8.1.1.3 The ISS shall be capable of transmitting a VHF signal at a fixed frequency in the aviation services VHF low band, and modulating the carrier with a voice signal having a bandwidth of 300 to 3,000 Hz.

3.2.1.8.1.1.4 The ISS shall be capable of transmitting a VHF signal at a fixed frequency in the aviation services VHF low band, and modulating the carrier at rates up to 10 Kbps with PCM signals received by the subsystem from a data terminal.

3.2.1.8.1.1.5 The ISS shall be capable of simultaneously transmitting two VHF signals at fixed frequencies in aviation services VHF high band. The carrier of each shall be frequency modulated (FM) in parallel by a voice signal from the control console and by the detected voice signals from the receiver which is not associated with that transmitter's duplex channel receiver described in 3.2.1.8.1.1.6.



3.2.1.8.1.1.6           The ISS shall be capable of simultaneously receiving two VHF signals at fixed frequencies in the range of 250 MHz to 300 MHz. Reception on these frequencies shall be provided at the same time that the signals described in 3.2.1.8.1.1.5 are being transmitted. One receiver shall operate in conjunction with one transmitter described in 3.2.1.8.1.1.5, providing two sets of transmitter-receivers which shall each have full-duplex channel capability. Data subcarriers on each of the two channels shall be demodulated and the output provided to a Remote Data Acquisition Unit. The voice outputs from the two receivers shall be provided to the control console.

3.2.1.8.1.2           ISS Buildup Operations Mode

3.2.1.8.1.2.1        During ISS buildup operations, the VHF data links defined in paragraphs 3.2.1.8.1.1.2 and 3.2.1.8.1.1.4 shall be capable of providing for the transmission of module status information and reception of command and control information.

3.2.1.8.1.2.2        While docked to the Shuttle Orbiter during buildup operations, the VHF voice links defined in paragraphs 3.2.1.8.1.1.1 and 3.2.1.8.1.1.2 shall be capable of being utilized.

3.2.1.8.1.3           Unmanned, Contingency Operations Mode  
During unmanned, contingency operations, the capability defined in paragraph 3.2.1.8.1.2.1 shall be provided.

3.2.1.8.2           S-Band Transmission/Reception

The communications subsystem shall provide for the transmission and reception of information between the ISS and the Shuttle Orbiter and between the ISS and the NASA ground stations.

3.2.1.8.2.1           Primary Mission Mode of Operation

3.2.1.8.2.1.1        The ISS shall be capable of receiving and demodulating a signal in the S-Band at a fixed frequency consisting of

a PRN ranging signal, a voice modulated on subcarrier and 1 Kbps of data modulated on a subcarrier. The voice and data signals on the subcarriers shall be detected and provided as outputs to the appropriate telephone terminals or to data terminal. The receiver shall phase-lock to the received carrier signal and it shall be possible to drive a coherent transmitter from the receiver to enable the two units to be used as a transponder.

3.2.1.8.2.1.2            The ISS shall be capable of transmitting a signal at a fixed frequency in the S-Band. The carrier frequency shall be capable of being referenced to either the received S-Band signal described in 3.2.1.8.2.1.3, or to a non-coherent auxiliary oscillator. When referenced to the received frequency, the ratio of transmitted frequency to received frequency shall be 204/221. The transmitter shall be modulated by the detected PRN signal, a voice signal modulating a subcarrier, a 10 Kbps digital data signal modulating a subcarrier, or combinations of the three signals. The voice signal source will be a digital data terminal.

3.2.1.8.2.1.3            The ISS shall be capable of utilizing the S-Band transmitter and receivers required by paragraph 3.2.1.8.2.1.1 and 3.2.1.8.2.1.2 in conjunction with a cooperative ranging system in another vehicle. It shall be capable of providing information on the range and range rate between the two vehicles to a digital data terminal. It shall be capable of generating ranging signals locally for transmission and range determination by comparison with the signals received back from the other vehicle.

3.2.1.8.2.1.4            The ISS shall be capable of transmitting a signal at a fixed frequency in the S-Band modulated by a video signal containing frequencies up to 3 MHz maximum or a one (1) Mbps digital data stream.

3.2.1.8.2.2            ISS Buildup Operations Mode

3.2.1.8.2.2.1            During ISS buildup operations, the S-Band links defined in paragraphs 3.2.1.8.2.1.1 and 3.2.1.8.2.1.2 shall

provide telemetry, command, and ranging capability between the ISS and Shuttle Orbiter during rendezvous and docking operations.

3.2.1.8.2.2 While docked to the Shuttle Orbiter, the S-Band links defined in paragraph 3.2.1.8.2.1.1 and 3.2.1.8.2.1.2 shall provide backup two-way voice and data communications.

3.2.1.8.2.3 Unmanned, Contingency Operations Mode  
During unmanned contingency operations the S-Band system shall provide for the transmission and reception of telemetry, commands, and ranging data direct to the ground stations.

3.2.1.8.3  $K_u$ -Band Transmission/Reception  
The communications subsystem shall provide for the transmission and reception of information between the ISS and the ground via the DRSS.

3.2.1.8.3.1 Primary Mission Mode of Operations

3.2.1.8.3.1.1 The ISS shall be capable of simultaneously receiving a  $K_u$ -Band signal, demodulating ranging data, multiple voice on a subcarrier and up to 100 Kbps on a subcarrier, and providing one of the data streams as an output to a data terminal.

3.2.1.8.3.1.2 The ISS shall be capable of receiving a  $K_u$ -Band signal at a fixed frequency, demodulating the frequency multiplexed video and voice or wideband audio and voice frequency modulating the carrier and providing the outputs to the appropriate storage, display, and telephone terminals. The capability to simultaneously receive this signal and the signal described in 3.2.1.8.3.1.1 shall be provided.

3.2.1.8.3.1.3 The ISS shall be capable of transmitting a  $K_u$ -Band signal at a fixed frequency, modulating the carrier with a subcarrier which is modulated by up to 100 Kbps of digital data being received by the subsystem from a data terminal, turned around ranging data, and multiple voice channels modulated on a second subcarrier. This carrier shall also be capable of being modulated by the signals described in 3.2.1.8.3.1.3.

3.2.1.8.3.1.4           The ISS shall be capable of transmitting a  $K_u$ -Band signal at a fixed frequency, and modulating the carrier with a signal consisting of a video channel and voice or high rate digital data up to 10 Mbps maximum. The capability to simultaneously transmit these signals and the signals described in 3.2.1.8.3.1.3 shall be provided.

3.2.1.8.3.2           ISS Buildup Operations Mode  
Operation of the  $K_u$ -Band RF system is not required during ISS buildup operations.

3.2.1.8.3.3           Unmanned, Contingency Operations Mode  
Operation of the  $K_u$ -Band RF system is not required during unmanned, contingency operations.

3.2.1.8.4           Internal Communications  
The communications subsystem shall provide normal and emergency voice communications within the ISS and docked modules.

3.2.1.8.4.1           Primary Mission Mode of Operation

3.2.1.8.4.1.1         An onboard telephone system which shall be provided has a compatible interface with the Earth-based Bell Telephone system.

3.2.1.8.3.1.2         Individual and simultaneous module paging capability shall be provided.

3.2.1.8.4.1.3         Emergency voice and alert time capability shall be provided.

3.2.1.8.4.1.4         The generation of all reference signals required for proper operation of the onboard telephone equipment shall be provided.

3.2.1.8.4.1.5         The communications subsystem shall provide for the reception of entertainment audio signals.

3.2.1.8.4.2           ISS Buildup Operations Mode  
During ISS buildup operations voice communications shall be provided between the module activation crew and the Shuttle Orbiter.

3.2.1.9 Data Management

The ISS data management shall meet the following overall functional requirements.

- a) Acquisition, conditioning, processing, display, storage and/or distribution of experiment data, subsystems sensors/circuits outputs, checkout and fault isolation data and other data.
- b) Data formatting, timing, short-term activity scheduling, inventory control, maintenance information control, training and display generation under software control.
- c) Automated and manual control of subsystems and experiments.
- d) Internal and external surveillance of ISS station for crew and ground personnel.
- e) Audio and visual crew entertainment.
- f) Support the onboard checkout and fault isolation functional area through use of data management capabilities.

Within the data management functional area, the detailed requirements are specified for the subfunctional areas shown in Figure 11. These subfunctional areas are grouped by related functional requirements.

3.2.1.9.1 Data Acquisition and Distribution

Data acquisition and distribution shall provide the capability for signal conditioning, conversion, message formatting, controlling and transferring all subsystem and experiment command and control data and experiment electronic scientific data throughout the ISS modules via a data bus. The data bus will also interface with docked RAM's and logistic modules data management at ISS docking ports.

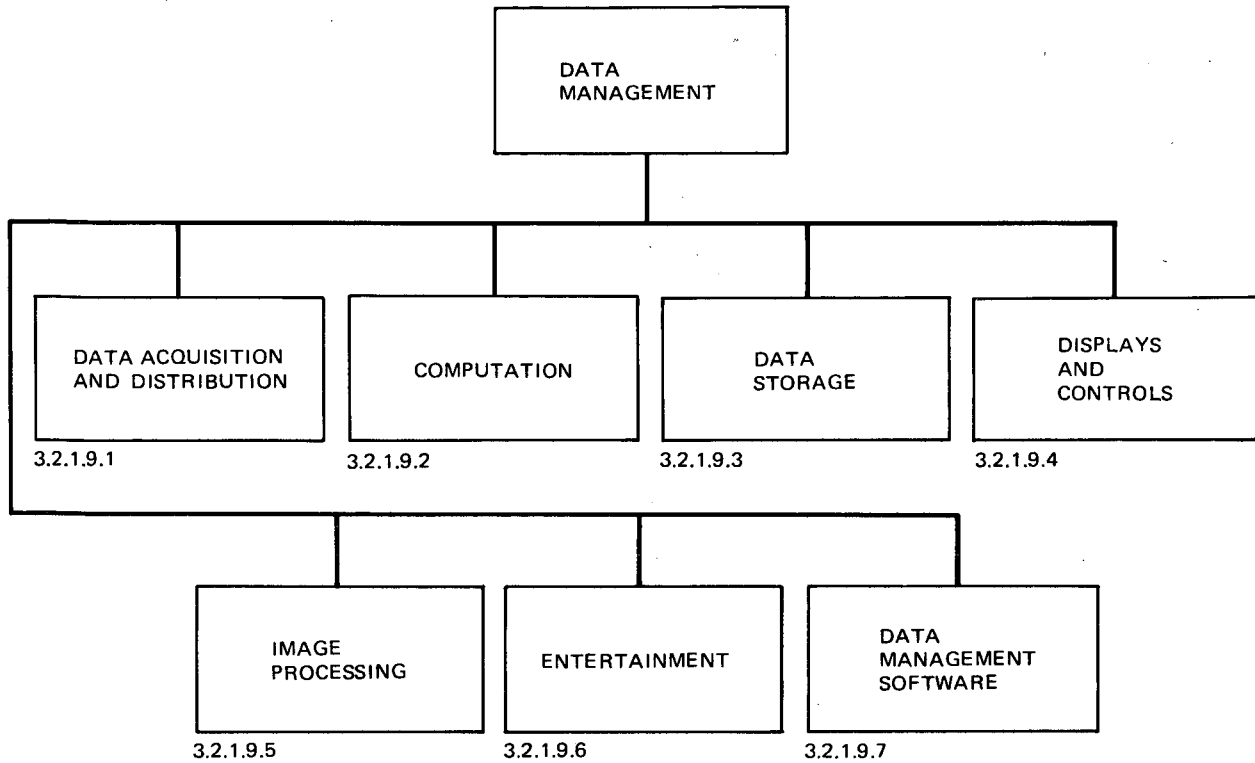


Figure 11. Data Management Subfunctional Areas

- 3.2.1.9.1.1 Primary Mission Mode of Operation
- 3.2.1.9.1.1.1 Multiplexing  
 Data acquisition units shall include the capability for time and frequency multiplexing groups of data sources. Sequential and random access of all channel inputs under program control shall be provided.
- 3.2.1.9.1.1.2 Formatting  
 Message formatting shall be controllable by data management computer software.
- 3.2.1.9.1.1.3 Data Sources  
 The data acquisition capability shall provide for up to the following:
- a) Number of Sources: 2,790 analog, 1,480 discrete, 160 digital serial (data sources and commands).

- b) Digital Rate: 1 megabit/second serial bit stream
- c) Analog Source Bandwidth: 10 KHz

3.2.1.9.1.1.4 Analog-to-Digital Conversion

Analog-to-digital conversion shall provide 8-bit resolution. Analog-to-digital conversion shall be capable of sampling rates up to 250 samples per second.

3.2.1.9.1.1.5 Limit Checking

The capability shall be provided to perform a bit-by-bit comparison of 7-bit digital words against stored, program selectable limits. Out-of-limit conditions shall be flagged upon any noncomparison of any given word.

3.2.1.9.1.1.6 Data Distribution

Data distribution shall be by a centrally controlled bus concept using a hybrid Time Division Multiplex (TDM) Frequency Division Multiplex (FDM) technique for the digital bus and an FDM technique for the analog bus. The capability shall be provided for up to 8 digital channels, 8 television and video channels, 48 telephone channels, 3 entertainment channels, 1 public address channel, and other channels as necessary for reference signals and tones. The bus rate of each digital channel will be 10 MBPS. Redundant data bus elements and means for switching shall be provided to the extent necessary to ensure continuous capability to transfer critical mission operations data.

3.2.1.9.1.1.7 Addressing

Data distribution addressing capability shall be provided for selecting up to 1,024 unique devices.

- 3.2.1.9.1.1.8            Decoding
- The capability shall be provided to decode data terminal and acquisition unit addresses, output channels, control words, and response words.
- 3.2.1.9.1.1.9            Error Detection
- The data distribution concept shall provide a bit error rate less than  $10^{-6}$  and an undetected error probability less than  $1.2 \times 10^{-10}$ .
- 3.2.1.9.1.1.10          Buffering
- Modularly expandable buffering capability shall be provided to allow queueing commensurate with source data rates and data bus polling rates. Storage time shall exceed bus polling time; i.e., capacity divided by the data rate times storage period shall be greater than one.
- 3.2.1.9.1.1.11          Transfer Modes
- Provision shall be included for data transfer under central control in the following modes:
- a) Between computer and data terminals.
  - b) Between two different data terminals.
- 3.2.1.9.1.1.12          Television
- Closed circuit television capability shall be provided in each ISS module for internal surveillance and on the external surface of each ISS module to supplement windows for observation of the surface of the ISS.
- 3.2.1.9.1.1.13          Commands
- The capability shall be provided for up to 1,480 discrete commands. Digital word command capability is included in 3.2.1.9.1.1.3.



3.2.1.9.1.2 ISS Buildup Operations Mode

The ISS shall provide data acquisition and distribution capability within each module for module control and checkout during all phases of ISS buildup. Data bus control capability will be provided only in the Power/Subsystems and GPS modules.

The data acquisition and distribution elements in the Crew/Operations Module shall be capable of operation only after the data bus has been mated between the Power/Subsystems and Crew/Operations Modules.

3.2.1.9.2 Computation

The computation capability will be primarily provided by two computing complexes located in separate ISS modules. The functions associated with ISS operations shall normally be performed by the computing complex in the Power/Subsystems Module. The functions associated with experiment operations shall be performed by the computing complex in the GPL module. The latter computing complex shall also provide the backup ISS operations capability. The computation elements shall interface with other ISS elements via the data bus.

3.2.1.9.2.1 Primary Mission Mode of Operations

3.2.1.9.2.1.1 Processing Rate

Each computing complex shall be a composite of general purpose processing units with a total capability of at least 1,213,000 operations per second.

3.2.1.9.2.1.2 Main Memory Capacity

The main memory of each computing complex shall consist of 16,000 word modules with a total capacity of at least 192,000 words.

- 3.2.1.9.2.1.3            Auxiliary Memory Capacity  
Auxiliary storage shall be provided for each computing complex for volatile memory load and reload of programs with a total capacity of at least 1,376,000 words.
- 3.2.1.9.2.1.4            Input/Output Control  
Input/Output control shall provide the capability to initiate and terminate all data bus information flow, the acquisition of data for onboard data processing, and the transmission of data from processing units and main memory to other ISS elements, all under the supervision of one of the processing complexes.
- 3.2.1.9.2.1.5            Modularity  
Computation units such as processors, memories, etc., shall be modular to permit growth and shall be interchangeable among the program element equipments.
- 3.2.1.9.2.1.6            Crew Access  
Provisions shall be made for crew access of computation operations from the primary, experiment, and portable display and control consoles/units.
- 3.2.1.9.2.1.7            Self Test  
A self-test capability shall be provided to allow fault detection and automatic switching of selected computation elements. Critical malfunctions detected by self-test shall be capable of being displayed.
- 3.2.1.9.2.1.8            Computer Program Changes  
Provisions shall be made for replacement or revision of onboard computer programs. These changes may be received uplink via the communications subsystem or carried aboard a Shuttle flight.

3.2.1.9.2.2 ISS Buildup Operations Mode

The ISS shall provide computation capability during all phases of ISS buildup. There are no computation elements in the crew/Operations Module. Computation capability for the Crew/Operations Module shall be provided only after the data bus has been mated between the Power/Subsystems and Crew/Operations Modules. The ISS shall be designed for offloading selected memory modules for the first launch and installation of the offloaded memory modules after ISS manning, while maintaining computation capability.

3.2.1.9.3 Data Storage

Data storage shall provide the capability to store and retrieve bulk data for onboard processing, transmission via the communications functional area and return via the log M.

3.2.1.9.3.1 Primary Mission Mode of Operation

3.2.1.9.3.1.1 Control

Data storage and retrieval operations shall be computer controlled via the data bus. The capability shall be provided for decoding and executing control messages containing operation mode, storage unit, record address and record length. Control, access time and bit density capabilities shall be compatible with the requirements of digital, image video, converted analog and personnel video data.

3.2.1.9.3.1.2 Digital Data Recording

The digital tape recording rate shall be at least  $2.5 \times 10^7$  bits/second. The tape bit packing density shall be at least  $10^6$  bits per square inch. Both continuous and periodic recording of data shall be provided with a minimum storage capacity of  $1 \times 10^{10}$  bits per tape reel.

3.2.1.9.3.1.3 Video Data Recording

The video tape recording frequency response shall be 4.5 MHz at 3 db. The recording time shall be 3 hours minimum.

3.2.1.9.3.2 ISS Buildup Operations Mode

The ISS shall provide data storage capability during all phases of the ISS buildup. The data storage elements in the Crew/Operations Module shall be capable of operation only after the data bus has been mated between the Power/Subsystems and Crew/Operations Modules.

3.2.1.9.4 Displays and Controls

Displays and controls shall provide ISS operational capability to the crew in at least two separate and independent EC/LS habitable compartments during manned phases of operation. The primary command and control center in the Crew/Operations Module shall be the central command post for monitor and control of all ISS subsystems operations and checkout, vehicle surveillance, and personnel/activities scheduling. The experiment/backup command and control center in the GPL Module shall be a centralized operation center for monitoring and checkout (management) of the experiment program both onboard and contained in attached RAM's. In addition, this center shall provide emergency/backup subsystem control capability in the event the crew is forced to evacuate the primary command and control center.

3.2.1.9.4.1 Primary Mission Mode of Operation

3.2.1.9.4.1.1 Prime Display

The prime display shall be capable of presenting computer-generated alphanumeric/graphic information and dynamic real-world TV imagery provided by vidicon cameras and other

analog sensors. These two sources of data can be shown independently, adjacent to each other, or superimposed to provide complete flexibility and visibility of computer processing and data control operations.

3.2.1.9.4.1.2            Display Response

The prime display and associated electronics shall provide the requested information within 1.0 second from time manual command is initiated.

3.2.1.9.4.1.3            Display Refresh

The prime display shall appear flicker-free when viewed under an ambient lighting of 215 lumens/m<sup>2</sup> (20 foot-candles) or approximately 3.4 candela/m<sup>2</sup> (1 foot-lambert) at the display surface.

3.2.1.9.4.1.4            Special Features

The prime display in conjunction with the controls, data bus, and computers shall be capable of providing special features of variable blinking, vector flashing, and split-screening.

3.2.1.9.4.1.5            Prime Control

The prime control shall be a computer keyboard unit. The keyboard and associated function select switches will provide access to and control of computer operations, modification or correction of existing software routines, or changes of computer functions to accommodate real-time requirements.

3.2.1.9.4.1.6            Auxiliary Control

Secondary means of achieving control shall be provided by means of auxiliary computer input devices consisting of a programmable function keyboard and/or a light-pen device used in conjunction with the prime display device. These auxiliary control devices

shall permit the operator to sequentially select from a computer displayed listing of category selection, function selection, and parameter selection items to effect the required control input.

3.2.1.9.4.1.7           Dedicated Control

Selected ISS critical and high usage functions shall be activated by dedicated controls.

3.2.1.9.4.1.8           Manual Steering

Hand controller capability shall be provided for manual steering operation inputs, operate attitude and translation thrusters, aim sensors/cameras, and control capability of a dynamic crosshair marker on the display for providing location of X-Y coordinates to the computer for specific purposes.

3.2.1.9.4.1.9           Reference Data Display

A display capability for a minimum of 128 pages of addressable reference data shall be provided at each control center.

3.2.1.9.4.1.10          Caution and Warning Annunciation

A matrix of light annunciators shall be provided for display of caution and warning alerting conditions.

Warning functions shall consist of dedicated redundant annunciators arraigned into a matrix. Caution functions may be an alphanumeric readout device which has capability of displaying up to 10 alert messages simultaneously and providing recall capability to determine status at any given time.

3.2.1.9.4.1.11          Voice Message Generation

A voice message generator shall be provided which will permit a spoken voice message to be generated via one of the computers. This unit shall supplement the caution and warning

function as well as provide operational and experiment information through an internal vocabulary. The unit shall be capable of composing phrases of up to four discrete words from code words supplied by the computer.

3.2.1.9.4.1.12            Portable Display and Control

Portable display and control units will be provided for use at remote locations where control and display of specific data is required on a part-time basis. These units will be capable of assisting in ISS and RAM onboard checkout and fault isolation and experiment equipment calibration and adjustment. They will interface with the data bus through plug-in connections at terminal units located at strategic locations in each ISS module.

3.2.1.9.4.2            ISS Buildup Operations Mode

Portable display and control units will provide the display and control capability whenever a crewman enters the Power/Subsystems module prior to mating with the Crew/Operations module. The display and control elements in the Crew/Operations Module shall be capable of operation only after the data bus has been mated between the Power/Subsystems and Crew/Operations Modules.

3.2.1.9.5            Image Processing

An image processing capability shall be provided in the GPL module for a quick look at experimental results, experiment instruments calibration and experiment monitoring and control. Image processing functions shall include film development, image transformation, image storage and image retrieval.

- 3.2.1.9.5.1 Primary Mission Mode of Operation
- 3.2.1.9.5.1.1 Control  
Image control shall provide for selection of images for viewing and/or processing, processing modes, computer programming routines, optical processor parameters, and for film-recording operations.
- 3.2.1.9.5.1.2 Image Display  
Image display shall provide for video presentation of images being processed or edited.
- 3.2.1.9.5.1.3 Video Storage  
Video storage shall provide for:
- a) Working Storage: 4 images
  - b) Temporary Storage: 1 hour of data
- 3.2.1.9.6 Entertainment  
Entertainment provisions shall include equipment and material for audio and video entertainment for the crew.
- 3.2.1.9.6.1 Primary Mission Mode of Operation
- 3.2.1.9.6.1.1 Entertainment Provisions  
Entertainment provisions shall include TV monitors, film library, tape storage, audio units, and video units necessary to provide both group and individual entertainment. Audio and video units shall have the capability to interface with appropriate data distribution units.
- 3.2.1.9.6.1.2 Commercial TV Compatibility  
The TV monitor shall be compatible with U.S. national television distribution standards.



3.2.1.9.7                    Software  
Software shall be provided which consists of executive programs and applications programs for the operations and experiment support computing facilities. The applications programs shall include: flight support, flight operations, onboard checkout, data management maintenance and experiment supervisor programs. (Software requirements for those computer programs will be identified in the modular space station computer program contract end item (CPCEI), Part I).

3.2.1.9.7.1                Primary Mission Mode of Operation

3.2.1.9.7.1.1            Executive Programs  
Executive programs shall provide for: interrupt handling and input/output control, computer monitoring, testing and reconfiguration, applications programs scheduling, clock and internal timer services, and internal communications control.

3.2.1.9.7.1.2            Flight Support Programs  
Flight support program functions shall include: activity scheduling, inventory management, maintenance/operational procedures, and utility routines.

3.2.1.9.7.1.3            Flight Operations Programs  
Flight operations programs shall support: displays and controls, communications, guidance, navigation and control, environmental control/life support, electrical power, and propulsion functional areas.

3.2.1.9.7.1.4            Onboard Checkout and Fault Isolation Programs  
Onboard checkout and fault isolation programs shall provide for continuous monitoring, periodic testing, fault isolation, operational interfaces, and reconfiguration. (These special application programs are part of the onboard checkout and fault isolation functional area and are specified in Section 3.2.1.11.5.)

3.2.1.9.7 Software

Software shall be provided which consists of executive programs and applications programs for the operations and experiment support computing facilities. The applications programs shall include: flight support, flight operations, onboard checkout, data management maintenance and experiment supervisor programs.

3.2.1.9.7.1 Primary Mission Mode of Operation

3.2.1.9.7.1.1 Executive Programs

Executive programs shall provide for: interrupt handling and input/output control, computer monitoring, testing and reconfiguration, applications programs scheduling, clock and internal timer services, and internal communications control.

3.2.1.9.7.1.2 Flight Support Programs

Flight support program functions shall include: activity scheduling, inventory management, maintenance/operational procedures, and utility routines.

3.2.1.9.7.1.3 Flight Operations Programs

Flight operations programs shall support: displays and controls, communications, guidance, navigation and control, environmental control/life support, electrical power, and propulsion functional areas.

3.2.1.9.7.1.4 Onboard Checkout and Fault Isolation Programs

Onboard checkout and fault isolation programs shall provide for continuous monitoring, periodic testing, fault isolation, operational interfaces, and reconfiguration. (These special application programs are part of the onboard checkout and fault isolation functional area and are specified in Section 3.2.1.11.5.)

3.2.1.9.7.1.5 Data Management Maintenance Programs

Data management maintenance programs shall provide for central processor unit testing, main and auxiliary memory testing, data management subsystem unit testing, reconfiguration and data handling and processing services testing.

3.2.1.9.7.1.6 Experiment Supervisor Programs

Experiment supervisor programs shall provide for experiment scheduling and monitoring, crew/remote interfaces, and data-handling and -processing services.

3.2.1.9.7.1.7 Higher-Level Language Capability

Higher-level language capability shall be provided to include the following as a minimum:

- a) High-level programming language(s) for producing computer program changes.
- b) High-level language(s) to provide an interactive command and control interface with ISS subsystems.
- c) High-level language(s) oriented toward the command and control of experiments.

3.2.1.10 Crew Habitability and Protection

The ISS crew habitability and protection subsystem shall provide the crew with living quarters, work stations and provisions to sustain a six-man crew for 90 days (nominal). It shall provide also the tools, aids, provisions and facilities which are necessary to enhance effective crew performance. Within the crew habitability and protection functional area, the detailed requirements are specified for the subfunctional areas shown in Figure 12.

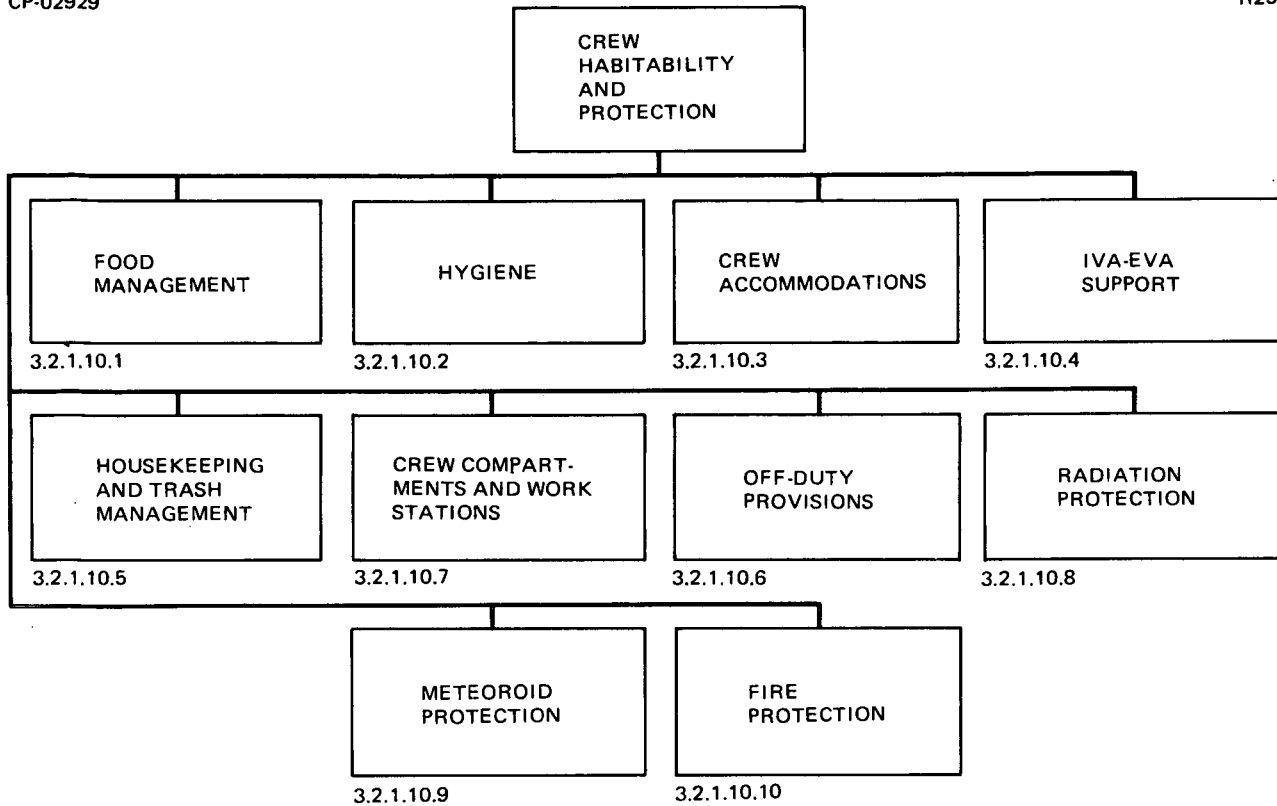


Figure 12. Crew Habitability and Protection Subfunctional Areas

3.2.1.10.1 Food Management  
 Food management shall provide the food stores (both ambient and controlled temperatures), equipment, facilities and supplies required for the storage, preservation, preparation, service and consumption for six crewmen.

3.2.1.10.1.1 Onboard Food Storage  
 The ISS shall provide a 30-day supply of food in the Crew/Operations Module for routine use of the crew and in addition a 30-day contingency supply shall be stored aboard the ISS.

3.2.1.10.1.1.1 Food storage capability of the ISS shall be compatible with the log M for convenient replenishment of food on the ISS on an as-needed basis.

- 3.2.1.10.1.1.2 ISS provisions for food storage shall accommodate dried, freeze-dried, dehydrofrozen, wet-pack, and perishable foods.
- 3.2.1.10.1.2 Crew Diet  
The crew diet shall provide adequate quantities of proteins, fats, carbohydrates, minerals, and vitamins based upon anticipated crew body weight, age, height, and activity levels.
- 3.2.1.10.1.2.1 Food management design shall be based on a 30-day supply of food for six crewmen.
- 3.2.1.10.1.2.2 Food management shall be designed to be compatible with food which has water requirements of 2.8 kg (6.2 lb) per man per day.
- 3.2.1.10.1.2.3 The ISS design shall be capable of providing a crew diet of 11.7 MJ (2,800 kcal) diet per man per day. Each crewman shall be provided with three meals and an optional snack for each 24-hour period.
- 3.2.1.10.1.3 Food Preparation and Cleanup  
A food preparation and cleanup center shall be provided as well as an area designated for consumption of meals. It shall include equipment and provisions for hot and cold rehydration, cooking, and warming of foods. Zero-g restraints shall be provided where needed. Serving- and eating-utensils, housekeeping, and trash-disposal devices shall also be included.
- 3.2.1.10.1.3.1 Packaging Requirements  
Packaging design shall facilitate the identification and instructions for preparation, inventory control, and disposal of food waste products.

3.2.1.10.1.3.2

Oven

A combination resistance and microwave oven shall provide for the cooking or heating of fresh and dehydrofrozen, and reconstituted foods. The oven shall be capable of heating foods to a specified internal temperature and holding food at specified lower temperatures. The oven shall be to accommodate a six-man meal or to prepare individual snack items with maximum efficiency and a minimum of crew time in interaction. Automatic controls, timers, and situation lights shall be provided as required. The interior configuration of the oven will be designed to avoid entrapment of food particles and to permit ease of cleaning.

3.2.1.10.1.3.3

Preparation, Eating and Cleanup Provisions

Food management shall provide preparation, eating, and cleanup utensils to accommodate six-man meal preparation services and cleanup. Nominally, three meals and an optional snack shall be available. Additional service shall be provided for two crewmen during crew overlap, as required. Food-preparation, eating-, and cleanup-utensils shall be designed to be compatible with zero-g operations and with other related food-management assemblies.

3.2.1.10.1.3.4

Freezer

The freezer shall be capable of storing fresh and dehydrofrozen food at a temperature of  $-23^{\circ}\text{C}$  to  $-15^{\circ}\text{C}$  ( $-10^{\circ}\text{F}$  to  $+5^{\circ}\text{F}$ ).

3.2.1.10.1.3.4.1

The freezer shall be designed for effective utilization of superinsulation to reduce heat loss to a minimum.

The front-to-back interior dimensions shall not exceed the 95th percentile of functional arm reach. Automatic controls and situation lights shall be designed and located for operator efficiency. An automatic audiovisual warning system shall be incorporated to indicate system failure or a temperature

rise above TBD limits; alternatively the freezer system shall interface with the master caution-alarm system. Freezer interiors shall be illuminated automatically when the door is open.

3.2.1.10.1.3.4.2 The freezer shall be capable of transferring heat from within the compartments and dumping it directly or indirectly into the EC/LS subsystem.

3.2.1.10.1.3.5 Refrigerator

A refrigerator shall be provided for storing food requiring controlled temperature. Additionally, it shall serve as a storage compartment for use in defrosting frozen foods, storing unconsumed prepared foods, and a maximum of a 2-week supply of perishable food.

3.2.1.10.1.3.5.1 The refrigerator shall maintain stored food at temperatures ranging from 4°C to 10°C (40°F to 50°F).

3.2.1.10.1.3.5.2 The refrigerator assembly consists of four insulated compartments at preselected temperature levels.

3.2.1.10.1.3.6 Dishwasher

Food management shall provide for the automatic washing and drying of food preparation, serving, and eating devices. The operating system shall be free of oscillations which could cause perturbations in stabilization and control. The duty cycle shall consist of an automatic washing and drying sequence suitable for zero-g. Any cleaning agent, disinfectant, or drying agent required shall be metered automatically; only nontoxic agents shall be used.

3.2.1.10.1.3.7 Water Dispensers

Food management assembly shall provide for the dispensing of hot water at 71°C (160°F) and cold water at 4 to 10°C (40 to 50°F) for the reconstitution of food and beverages and for drinking water purposes. The dispensers shall be conveniently located in the food preparation center. The dispensers shall be designed to accommodate food-packaging concepts for hydratable foods and beverages and with drinking water concept.

3.2.1.10.2 Hygiene

The hygiene function shall provide the crew with the equipment and supplies necessary to maintain health and grooming standards.

3.2.1.10.2.1 Shower

A shower shall be provided in hygiene compartment to provide a whole-body wash capability with high crew acceptability. The shower shall consist of a cylindrical enclosure equipped with the provisions for wetting, washing, rinsing, and drying the body. A water collection and blower shall be used to remove the local accumulations of water to aid in drying. Temperature and flow rate shall be controllable by the crewman.

3.2.1.10.2.2 Chamber Sink

Provisions for hand and face wash shall be provided by an enclosed chamber sink similar to a glove box. The sink shall provide for the entrapment of water and cleaning agent. A mixture of hot and ambient temperature water shall be provided along with metered dispensing of the cleaning agent. The sink shall be compatible with oral hygiene provisions (pressurized water cleaning device, brush and dentifrice).



3.2.1.10.2.3            Personal Hygiene Kit

Each crewman shall be supplied with a personal hygiene kit containing the small equipment items and supplies needed for routine personal hygiene and grooming. These items shall be selected on an individual crewman basis to assure that personal requirements are met and that unnecessary items are deleted.

3.2.1.10.2.4            Laundry

The laundry shall be capable of handling a minimum of 0.45 kg (10 lb) of dry clothing per cycle. Both wash and dry cycles shall be completed in 30 min or less.

3.2.1.10.3              Crew Accommodations

The crew habitability and protection subsystem shall provide crew accommodations throughout the ISS as required to assure adequate crew performance and safe operations. Crew accommodations shall consist of the following:

- a) Crew Quarters -- Bunk, bed roll, desk, individual light fixture, personal communications, clothing module, personal items, and expendables.
- b) Crew Aids -- Restraints and locomotion devices, tool kit, portable lighting (IVA and EVA), and cargo-handling equipment.
- c) Medical Support -- Diagnostic, therapeutic, urinalysis, hematology, and microbiology equipment.

3.2.1.10.3.1            Crew Quarters

Each crewman shall be provided with private quarters for sleeping, study, rest and relaxation, and as a source of personal isolation. The private quarters shall be capable of

accommodating two or more crewmen to work or socialize together without interference from other activities.

3.2.1.10.3.1.1        A sleep restraint, or bunk, shall be provided which accommodates an individual bed roll which is either washable or disposable. The sleep restraint shall be located not to interfere with other activities when not in use.

3.2.1.10.3.1.2        A desk, or the equivalent, shall be provided with a writing surface, storage facilities, adequate lighting, and restraints.

3.2.1.10.3.1.3        Storage of a personal clothing module and an area for soiled clothing shall be provided. The clothing module shall be sized for one crewman for 30 days.

3.2.1.10.3.1.4        An emergency oxygen mask with a portable, rechargeable oxygen bottle (see Section 3.2.1.10.4) shall be stored in the private quarters.

3.2.1.10.3.1.5        Restraints and locomotion aids shall be strategically located as necessary to permit efficient use of the quarters area.

3.2.1.10.3.2        Crew Aids

The crew accommodations assembly shall provide restraints and locomotion aids throughout the ISS to assure safe and convenient crew operations. Fixed restraints and locomotion aids shall be at specific locations as required by the tasks to be performed at that location. Portable restraints and locomotion aids shall be provided as required for infrequent or unplanned tasks.

3.2.1.10.3.2.1 Fixed restraints shall be provided in the galley at the food preparation console. These restraints shall be suitable for the standing position and shall be adequate for single or two-man operations. Fixed (seat) restraints for six men shall be provided at the dining table. Seat restraints shall be stowable as will the table to provide an open area as required for other activities. Fixed foot restraints shall be provided at each console (or unit such as urinal, laundry, handwash, WMS).

3.2.1.10.3.2.2 Sleep restraints shall be provided in each of the private quarters. These restraints shall be stowable and the body restraint shall be washable. Fixed seat restraints shall be provided at each desk in the private quarters. These restraints shall be stowable in the desk area.

3.2.1.10.3.2.3 Fixed restraints shall be provided in the wardroom as required for exercise and recreation equipment. These restraints shall be stowable or otherwise not interfere with other activities. Fixed foot restraints shall be provided also at each work station in the GPL.

3.2.1.10.3.2.4 Fixed foot restraints shall be provided at the Command-Control Console for two operators working concurrently or separately. These shall be provided at the TV monitor, the electronic equipment consoles, and for maintenance tasks, as required.

3.2.1.10.3.2.5 Portable foot restraints shall be provided throughout the station as required for infrequent or unplanned tasks.

3.2.1.10.3.2.6 Tool kits, containing standard and a limited quantity of special tools, shall be provided for spares replacement and general maintenance. These tools shall be applicable also for minor emergency and repair operations. The kit shall be compact and easily transported from one work station to another.

3.2.1.10.3.2.7 Additional aids shall include portable lighting (flash light), portable fan (to provide air circulation in remote work areas), and portable (high-intensity) lighting for use in remote work areas.

3.2.1.10.3.3 Medical Support Assembly

The onboard medical support assembly shall provide first aid, resuscitation, and supportive measures for Earth-return of crewmen in the event of illness or injury. The medical support assembly shall include equipment for diagnosis, therapeutics, urinalysis, hematology and microbiology. The equipment shall be designed for operation by a specially trained astronaut and shall not require a physician. The equipment shall be designed for stowage in standard modules for ease of installation and in-flight use.

3.2.1.10.3.3.1 Diagnostic equipment shall be provided for the routine evaluation of crew health status and in the event of illness or injury. Diagnostic equipment shall include at least the following items: thermometer, stethoscope, ophthalmoscope/otoscope set, aneroid sphygmomanometer, light source (head mounted), nasal speculum, binocular magnifying glasses, neurological examination kit, tongue depressors (metal), politzer bag, and batteries.

3.2.1.10.3.3.2 Therapeutic equipment shall be provided for the treatment of illness or injury. The equipment shall include at least the following items: catherization kit, emergency kit, dental kit, minor surgery kit, bandage set, and drugs.

3.2.1.10.3.3.3 Laboratory equipment shall be provided for onboard urinalysis, hematology, and microbiology. The urinalysis equipment shall include at least a microscope, reagent strips,

and a specific gravity meter. The hematology equipment shall include at least a hemocytometer, unipettes, hemoglobinometer, lances, and pipettes.

3.2.1.10.3.3.4 The microbiology equipment shall include at least swabs, needles and loops; incubator; slide staining kits, plates and tubes of media and antibiotic discs and strips.

3.2.1.10.4 IVA-EVA Support

The intravehicular activities (IVA) and the extravehicular activities (EVA) support shall provide protective garments, emergency oxygen masks and portable oxygen supply, maintenance devices, communications, tethers, and restraints for all emergency and any planned hazardous operations requiring special support equipment. In addition, special lighting as required to assure safe and efficient operation during IVA and EVA shall be provided. Crew status monitoring shall be provided at the command-control center and at the EVA hatch.

3.2.1.10.4.1 IVA/EVA Operations

The design of all IVA/EVA support equipment shall be compatible with the following operational requirements:

- a) A minimum of two crewmen shall participate in EVA. The two crewmen shall be suited and pressurized so that one can assist the other as required. Both crewmen shall normally participate in performing the actual tasks to reduce the risk involved and to minimize the crew time required to complete the tasks.
- b) EVA duration shall be restricted to 3 hours.
- c) Crewmen shall be tethered to the spacecraft.
- d) Crewmen shall remain within visual range of each other at all times.
- e) Continuous monitoring of EVA crewmen shall be maintained onboard through direct or TV surveillance, voice communication and telemetry readouts of critical life support and physiological functions.

- f) PSA's (pressure suit assemblies) and PLSS's (portable life support systems) shall be stored in the airlock.
- g) Prebreathing of oxygen shall be provided for 2 hours prior to EVA.
- h) Continuous communication shall be maintained between IVA crewmen and the command-control center.

3.2.1.10.4.2 Protective Garments

3.2.1.10.4.2.1 Two EVA suits shall be accommodated. These shall be individually fitted and shall be located in the GPL Module.

Portable backpacks for life support (as opposed to umbilicals) shall be provided.

3.2.1.10.4.2.2 A pressure suit shall be available for each crewman and located in a readily accessible area.

3.2.1.10.4.2.3 Four grossly fitted IVA suits shall be provided for research personnel; two suits shall be located in the Power/Subsystems Module and two in the Crew/Operations Module. Life support will be provided by umbilicals.

3.2.1.10.4.3 Emergency Oxygen Supply

Emergency oxygen shall be provided throughout the station to protect the crew against environmental hazards as fire and toxicity. The oxygen supply shall be available through portable bottles or the 96-hour emergency pallet. Six masks and portable supply bottles shall be located in private quarters (Crew/Operations Module). Three masks shall be located in the Power/Subsystems Module. Six masks shall be located in the GPL with supply from the two pallets located in that module. The portable bottles shall supply a minimum of 15-min supply and the emergency pallets a minimum of 96 hours.

The emergency masks shall also be usable for pre-breathing of oxygen prior to EVA. In this case, oxygen shall be supplied by EC/LS.

3.2.1.10.4.4 EVA Tethers and Lighting

Specially designed handholds and restraints shall be provided as required for specific EVA tasks. They shall be compatible with two-man operations (suited and pressurized), and with the special tools and work aids to be used. Additionally, special lighting (high intensity, if necessary, shall be provided also to assure safe and efficient crew performance and to permit close observation of the EVA from the station.

3.2.1.10.5 Housekeeping and Trash-Handling

Housekeeping and trash-handling shall provide for (a) the collection, containment, decontamination, and transport of all forms of loose debris, trash and particulate material generated by the crew and equipment throughout the station and other attached modules; (b) cleaning and disinfection of all microbiological contamination of equipment and surface exposed to the crewmen; (c) collection, temporary storage, and pretreatment of all trash and waste discarded in various compartments throughout the station; (d) deactivation of all bacteria in the collected trash and debris; (e) reduction of the volume of processed and unprocessed trash prior to stowage; (f) stowage of processed trash that ensures deactivated bacterial remains in the deactivation state.

Housekeeping and trash-handling shall be designed to prevent the release of odors, aerosols, gasses and particulate matter into the atmosphere. Trash containers and packages shall be clearly labeled indicating the contents and any special handling instructions.

3.2.1.10.5.1           Cleaning and Disinfecting Equipment

3.2.1.10.5.1.1        Compact (hand-held) vacuum cleaners shall be provided for the collection and containing of loose debris and particulate matter in the crew quarters, hygiene compartment, galley and wardroom.

3.2.1.10.5.1.2        Retrieval nets shall be provided for the collection of loose debris and particulate matter.

3.2.1.10.5.1.3        Disposable wet and dry wipes and cleaning solutions shall be provided for cleaning and disinfecting, contaminated surfaces and equipment. Solutions used for cleaning and disinfecting surfaces and equipment shall be capable of hygienic control of any anticipated microbiological contaminants.

3.2.1.10.5.2           Trash Collection and Containment

Color-coded trash receptacles with removable liners and pretreated self-contained trash bags shall be provided for the temporary collection and storage of trash. Storage provisions for trash liners and bags shall be available in appropriate compartments throughout the station.

Bags and liners shall be capable of being sealed at the opening. Trash bags shall be designed to retain liquids and solids. Provisions shall be incorporated in the bag design to permit gases and water vapor to escape through a sealable port.

3.2.1.10.5.3           Trash Compaction

A trash compactor shall be provided to reduce the volume of collected trash. The compactor shall collect trash bags in a collection hopper. The compactor shall provide for



compressing trash to 25% or less of the uncompacted volume. The trash shall be deposited as a compacted slug in a receptacle, compatible with return cargo containers.

3.2.1.10.5.4           Trash Storage

Trash shall be stored and sealed in containers which have two pneumatic ports -- one for withdrawing the container air to remove the oxygen and water vapor through the cabin vacuum facility, and the second for pressurizing the container with gaseous nitrogen to provide a dry inert atmosphere surrounding the trash.

3.2.1.10.6           Off-Duty Provisions

Off-Duty equipment shall be provided to reduce monotony, muscular tension and stress, and maintain morale in order to assure crew work performance. Individual selection shall be provided insofar as practical, and shall include reading materials (microfilm and viewer, books, magazines and journals), writing materials (paper, plus pencils, log books, and workbooks, games and hobbies (group and individual), and exercise (group and individual). These items shall be located in the wardroom or private quarters as appropriate. A television display monitor for display of uplink broadcast and prerecorded movies from video tape shall be provided. A stereo receiver and recorder and tape storage with preprogrammed games. Individual headsets in the private quarters shall be used to monitor tapes.

3.2.1.10.7           Crew Compartments and Work Stations

Crew accommodations shall be provided in the Crew/Operations Module, the GPL and the Power/Subsystems Module. The accommodations shall generally be integrated within defined compartments, work stations or open functional areas. The following

general requirements and design goals shall be used to guide the overall habitability design effort:

- a) All compartments shall be designed to maximum habitability.
- b) Interiors shall be optimized with due consideration to ground checkout and evaluation requirements and constraints.
- c) Volume allocation, equipment location, and interior arrangement shall be designed to minimize "casual" interference, i.e., to avoid crowding while performing tasks.
- d) The opportunity for freedom of choice in facility usage shall be maximized.
- e) The common use of free space shall be applied where appropriate.

These general requirements shall be applied to specific modules and work stations as specified in the following paragraphs.

3.2.1.10.7.1 Crew/Operations Module

3.2.1.10.7.1.1 Private Quarters

3.2.1.10.7.1.1.1 The private quarters shall be provided with adequate light and sound attenuation to assure privacy and isolation, as desired.

3.2.1.10.7.1.1.2 The quarters shall be capable of easy conversion to two- or three-man staterooms and the design shall accommodate either male or female crew members.

3.2.1.10.7.1.2 Wardroom/Galley/Gymnasium

The wardroom, galley and gymnasium area shall provide for multiple usage for a variety of simultaneous on- and off-duty activities without interference.

3.2.1.10.7.1.2.1 The galley shall accommodate the equipment necessary for food preparation, serving, storage and cleanup.

The eating area shall be provided with a removable table and six "seat" restraints. The eating area shall be capable of quick conversion to an exercise or recreation area or to a meeting room.

3.2.1.10.7.1.3 Hygiene/Waste Management  
Duplicate hygiene facilities shall be provided to reduce interference during periods of high usage and to provide suitable accommodations for mixed crews. One hygiene facility shall be located on either side of the galley/wardroom area.

3.2.1.10.7.1.3.1 Two complete enclosed facilities with appropriate accommodations for male and female crew members shall be provided.

3.2.1.10.7.1.3.2 The hygiene compartments shall be provided with appropriate noise, odor, and contamination control.

3.2.1.10.7.1.3.3 Hygiene compartments shall be located adjacent to the private quarters.

3.2.1.10.7.1.3.4 Hygiene compartments shall be easily accessed from other modules, particularly the GPL.

3.2.1.10.7.1.3.5 The waste management compartment (within the total hygiene compartment) shall accommodate the urine collector, fecal collector, and appropriate expendibles. It shall be provided with appropriate odor, liquids, and contamination control.

3.2.1.10.7.1.3.6 A second urinal shall be accommodated outside the waste management system compartment. It shall share a "console" space with hygiene equipment.

subsystems equipment without crowding and without blocking the operator's view from one end of the module to the other.

3.2.1.10.8                      Radiation Protection

Radiation protection shall provide the crew with protection against adverse radiation exposure by monitoring and measuring the extent and kind of radiation exposure to assure crew safety and for further analytic investigations. This shall include onboard and extravehicular dosimetry which will be operated in conjunction with the caution and warning functions. Protective goggles will be provided for the crew during times of solar flare activity.

3.2.1.10.9                      Meteoroid Protection

Meteoroid protection shall provide for detection and location in the event a penetration does occur. Leak detection sensors are required at strategic locations throughout the modules to alert the crew of a hazardous condition. Sensor outputs shall be relayed to the warning and alarm function.

3.2.1.10.9.1                    Meteoroid Damage Repair

Repair techniques (TBD) shall be provided for damage to the main wall.

3.2.1.10.10                    Fire Protection

Fire protection shall be provided by the location of fire extinguishers throughout the station to suppress any fire after it has been isolated. Emergency oxygen masks and protective clothing shall be provided to protect the crew against related hazards. An automatically (heat sensing) extinguishing system shall be located in experiment or other areas where a fire hazard exists.

3.2.1.10.7.1.4 Command-Control Center

The command-control center shall be located adjacent to the wardroom/docking port area. This location shall allow an off-duty crewman to respond quickly to any warning signals from the center and the command-control operator to view docking operations while monitoring all other functions.

3.2.1.10.7.2 Power Module

A crew work station shall be accommodated in the Power/Subsystems Module, providing the controls and displays necessary to operate, monitor, service, and maintain equipment such as communications, data management, and onboard checkout.

3.2.1.10.7.2.1 The crew work station shall be designed to be normally manned on an intermittent basis only.

3.2.1.10.7.2.2 The pressurized compartment shall be capable of providing a retreat from environmental hazards. Two EVA suits and two PLSS's, three oxygen masks, and a 96-hour emergency pallet shall be installed in the compartment.

3.2.1.10.7.3 General Purpose Laboratory

The grouped facilities shall be arranged along the longitudinal axis of the module. Maximum advantage of zero-g operations shall be taken by locating one bank of equipment over the other, yielding a near-equivalent second "floor." The equipment arrangement shall avoid locating one operator directly over the other. The two banks of equipment shall be separated by a center divider located on the "floor" of the module. This arrangement shall accommodate the experiment support and

3.2.1.11 Onboard Checkout and Fault Isolation

The ISS shall provide onboard checkout and fault isolation support for integral subsystems and experiments as well as limited support of subsystems and experiments within docked modules. The onboard checkout and fault isolation capabilities shall meet the following overall functional requirements:

- a) Determine the acceptable operating status of subsystems and experiments.
- b) Indicate out-of-tolerance conditions that require crew attention.
- c) Provide visual and audible warning indications in all habitable compartments for functions presenting an immediate threat to life.
- d) Isolate faults to the replaceable unit level primarily with the equipment under test in an in-place configuration.
- e) Provide a trend analysis capability for specified long-life parameters where its use is appropriate for malfunction prediction.
- f) Utilize automation techniques to the greatest practical extent to free the crew from routine operations.
- g) Operate primarily in an automatic mode, but maintain a capability for crew cognizance and control of all checkout operations.
- h) Provide a capability for making subsystem and experiment status information available onboard, to the ground, or both, as required.
- i) Support subsystem checkout and fault isolation from a backup location in the event evacuation from any single ISS compartment is required due to its being damaged or rendered untenable.

Within this functional area, detailed requirements are specified for the subfunctions shown in Figure 13.

Implementation of these subfunctions shall take advantage of ISS data management capabilities in the areas of data acquisition and distribution, computation, data storage, displays and controls, command generation, and software. Special processing and stimuli-generation capabilities that are integral to other subsystem and experiment equipments shall also be utilized.

3.2.1.11.1 Checkout Data Acquisition

Capability shall be provided to access checkout information directly from subsystem and experiment data sources; or indirectly in cases where a test and digital formatting

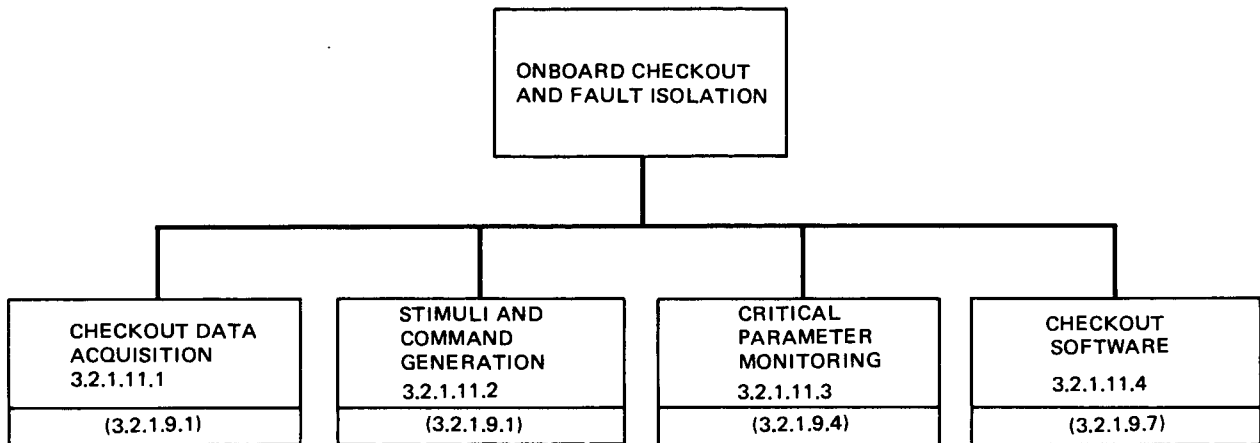


Figure 13. Onboard Checkout and Fault-Isolation Subfunctional Areas

capability is integral to the subsystem or experiment, or where data is provided normally as part of the ISS data-management function.

3.2.1.11.1.1 Primary Mission Mode of Operation

3.2.1.11.1.1.1 Checkout Data Sources

The ISS shall be capable of accepting the sources specified in 3.2.1.9.1.1.3 for purposes of checkout and fault isolation.

3.2.1.11.1.1.2 Direct Checkout Data Acquisition

Capability shall be provided for operating in one of three modes when accessing checkout information directly from subsystem and experiment data sources. Mode selection shall be under computer control.

a) Limit-Checking Mode—Analog and discrete input channels shall be sequentially scanned, and each input shall be compared against stored upper and lower limit check information. Out-of-limit conditions shall

be made available to the controlling computer. Individual limits shall be capable of being changed at any time by the computer. A capability shall also exist for selectively inhibiting individual channels from generating error messages. Analog signals shall be processed with at least a 7-bit accuracy.

- b) Sequential Sampling Mode—Analog and discrete input channels shall be scanned and, without limit-checking, the data shall be formatted and made available to the controlling computer.
- c) Random Sampling Mode—Data from an individual analog or discrete input channel, without limit-checking, shall be formatted and made available to the controlling computer.

3.2.1.11.1.1.3 Indirect Checkout Data Acquisition

Capability shall be provided to access checkout data indirectly in cases where a test and digital formatting capability is integral to the subsystem or experiment, or where data is provided as a normal function of ISS data management. Checkout data shall be accepted in the form of serial digital streams and sampled, under computer control, in a sequential or random manner.

3.2.1.11.1.2 ISS Buildup Operations Mode

A capability shall be provided for checkout data acquisition during all phases of buildup to permit both manned and unmanned control and checkout of ISS subsystems. Special provisions shall be made to access the required data for monitoring and control of a limited number of Crew/Operations module functions prior to mating this module with the Power/Subsystems module.

3.2.1.11.1.3 Contingency Mode

A capability shall be provided for checkout data acquisition during quiescent unmanned operations to permit required monitoring and control of ISS subsystems.

3.2.1.11.2 Stimuli and Command Generation

A stimuli and command generation capability shall be provided to permit checkout and fault isolation of ISS



subsystems and integral experiments. Commands shall be as specified in 3.2.1.9.1.1.13.

3.2.1.11.2.1 Primary Mission Mode of Operation

3.2.1.11.2.1.1 General Purpose Stimuli

The ISS shall be capable of generating the specified computer-controlled, general-purpose stimuli to the following:

a) Subsystems

37 channels of serial digital data at a maximum rate of  $1 \times 10^6$  bits/sec/channel.

384 analog signals from 0 to 115 VDC.

b) Integral Experiments

8 channels of serial digital data at a maximum rate of  $1 \times 10^6$  bits/sec/channel.

128 analog signals from 0 to 115 VDC.

3.2.1.11.2.1.2 Special Purpose Stimuli

A capability shall be provided for controlling special purpose stimuli which are unique to checkout and fault isolation of certain ISS subsystems and integral experiments. These stimuli may be either integral to the subsystems and experiments, or provided separately.

3.2.1.11.2.2 ISS Buildup Operations Mode

A stimuli generation capability shall be provided to permit both manned and unmanned control and checkout of ISS subsystems during all phases of buildup. Special provisions shall be made to supply the required stimuli for control of a limited number of Crew/Operations Module functions prior to mating this module with the Power/Subsystems Module.

3.2.1.11.2.3 Contingency Mode

A capability shall be provided for stimuli generation during quiescent unmanned operations to permit required control of ISS subsystems.

## 3.2.1.11.3

## Critical Parameter Monitoring

A capability shall be provided for monitoring ISS caution and warning functions and for indicating immediately any out-of-tolerance conditions. Warning functions are those which, if out-of-tolerance, could present an immediate threat to crew life. Caution functions are those which, if out-of-tolerance, could result in major degradation of ISS performance unless specific crew action is taken.

## 3.2.1.11.3.1

## Primary Mission Mode of Operation

## 3.2.1.11.3.1.1

## Critical Data Sources

The ISS shall be capable of monitoring up to a sampling rate of five times per second the following critical data:

18 discrete warning signals of either 0 or 5 VDC

40 discrete caution signals of either 0 or 5 VDC

68 analog warning signals preconditioned to one of two ranges:

0 to 40 MV or 0 to 5 VDC

292 analog caution signals preconditioned to one of two ranges:

0 to 40 MV or 0 to 5 VDC

## 3.2.1.11.3.1.2

## Warning Functions

The ISS shall conform to the following requirements for warning functions as specified in the following paragraphs:

## 3.2.1.11.3.1.2.1

Monitoring of warning functions shall be by independent redundant sensors incorporated within subsystems or experiments, and wired directly to the ISS caution/warning equipment.

## 3.2.1.11.3.1.2.2

Status of all warning functions shall be provided at both the primary and secondary ISS control centers through the use of the displays specified in 3.2.1.9.4.1.10.

- 3.2.1.11.3.1.2.3      Detection of out-of-tolerance warning functions shall result in the activation of visual and aural alarms in each ISS habitable compartment.
- 3.2.1.11.3.1.2.4      Monitoring and alarm activation for warning functions shall be capable of operation independent of other ISS subsystem elements.
- 3.2.1.11.3.1.2.5      A capability shall be provided for changing stored warning parameter limits only by manual means and consistent with ISS safety guidelines.
- 3.2.1.11.3.1.2.6      A capability shall be provided for manually inhibiting individual alarm functions in a manner that is consistent with safety requirements.
- 3.2.1.11.3.1.2.7      A capability shall be provided for automatic generation of commands for initiating corrective action which cannot wait for crew intervention.
- 3.2.1.11.3.1.2.8      Indications shall be provided to ISS control centers for cases where critical corrective action has been automatically taken by either the caution/warning system or within other ISS subsystems.
- 3.2.1.11.3.1.2.9      A capability shall be provided for digitizing and formatting all critical function data for transmission to the ISS data management function.
- 3.2.1.11.3.1.3          Caution Functions  
The ISS shall conform to the requirements of 3.2.1.11.3.1.2.2 and 3.2.1.11.3.1.2.6 through 3.2.1.11.3.1.2.9, as well as the following, for caution functions.

- 3.2.1.11.3.1.3.1      Monitoring of caution functions shall be by direct wiring from sensors within subsystems and integral experiments to the ISS caution/warning system.
- 3.2.1.11.3.1.3.2      Detection of out-of-tolerance caution functions shall result in the activation of alarm indications in affected compartments and in the primary and secondary control centers.
- 3.2.1.11.3.1.3.3      Transmission of caution data within the ISS shall be through the data management function.
- 3.2.1.11.3.1.3.4      A capability shall be provided for changing stored caution parameter limits by remote control.
- 3.2.1.11.3.2            ISS Buildup Operations Mode  
The capability for monitoring ISS warning functions and for indicating any out-of-tolerance conditions of these functions shall be provided whenever one or more crewmen are within any of the ISS modules. The corresponding capability associated with caution functions shall be provided whenever the ISS data management function is operating.
- 3.2.1.11.3.3            Contingency Mode  
A capability shall be provided for monitoring critical ISS parameters during quiescent unmanned operations.
- 3.2.1.11.4              Checkout Software  
Software used for onboard checkout and fault isolation shall be compatible with and utilize the operating system software provided by the data management function as specified in 3.2.1.9.7.  
(Software requirements for these computer programs will be identified in the modular space station computer program contract end item (CPCEI), Part I)

- 3.2.1.11.4.1            Primary Mission Mode of Operation  
The software capability for ISS checkout and fault isolation shall comply with the requirements of the following paragraphs.
- 3.2.1.11.4.1.1        A capability shall be provided for real-time structuring of new or revised special application software routines.
- 3.2.1.11.4.1.2        Fault isolation routines required following detection of a life critical failure shall be automatically initiated.
- 3.2.1.11.4.1.3        A capability shall be provided for both time- and event-oriented checkout program initiation.
- 3.2.1.11.4.1.4        A high-level language shall be utilized to facilitate the man-machine interface in all phases of ISS preparation and operation.
- 3.2.1.11.4.1.5        A capability shall be provided for specifying options to control the sequence of program operation.
- 3.2.1.11.4.1.6        A capability shall be provided for supplying checkout status information and for executing specific programs on request of the operator.
- 3.2.1.11.4.2            ISS Buildup Operations Mode  
With the data management function operating, a capability for remote selection and control of special application checkout programs shall be provided to permit ground or shuttle support of ISS subsystems during unmanned buildup activities.
- 3.2.1.11.4.3            Contingency Mode  
A capability shall be provided for remote selection and control of special application software programs during quiescent unmanned operations to permit checkout support of ISS subsystems.

3.2.1.12 Experiment Support Equipment

Experiment support equipment shall provide the capability to perform and support experiments. In addition it shall support operations and maintenance of ISS subsystems when required. This function shall also provide the facilities required to support, service and maintain RAMs. The experiment support equipment functions shall be accommodated in the General Purpose Laboratory Module. The GPL shall be functionally and physically subdivided into facilities and laboratories combining related technology activities. The facilities shall be permanent throughout the operational mission life but the test, calibration, alignment, etc., equipment contained therein shall be designed to facilitate change as the experiment program evolves and changes.

The GPL shall be physically divided into the facilities in Figure 14 which correspond to the subfunctional capabilities described in this specification.

The nature of experiment and subsystem support provided in the General Purpose Laboratory Module shall be as follows:

- a) Analytical or test
- b) Checkout
- c) Experiment control
- d) Assembly, disassembly
- e) Contingency repair
- f) Storage of parts, experiment and experiment support equipment, experiment consumables and experiment spare parts.
- g) Component replacement
- h) Subsystem and assembly fault isolation
- i) Experiment, experiment support equipment and subsystem calibration
- j) Work areas for testing, research, repair, calibration and other like functions
- k) Physical accommodation for the performance of integral experiments

3.2.1.12.1 Special Provisions  
 Special provisions shall be provided within the General Purpose Laboratory as specified in the following paragraphs:

3.2.1.12.1.1 The Hard Data Processing Facility, Optical Sciences Laboratory, and the Data Evaluation Facility shall have light-suppressing movable partitions for film handling, analysis operations, and operator comfort. All areas shall have vacuum devices to keep air contamination at a minimum.

3.2.1.12.1.2 Storage cabinets shall be provided for storage of replacement parts. Design of cabinets will take zero-g environment into account for best utilization.

3.2.1.12.1.3 Attachments for emergency suit pressurization, and breathing; and an emergency air station, as well as communication facilities, shall be strategically located in work areas. All work areas shall have fire-fighting equipment.

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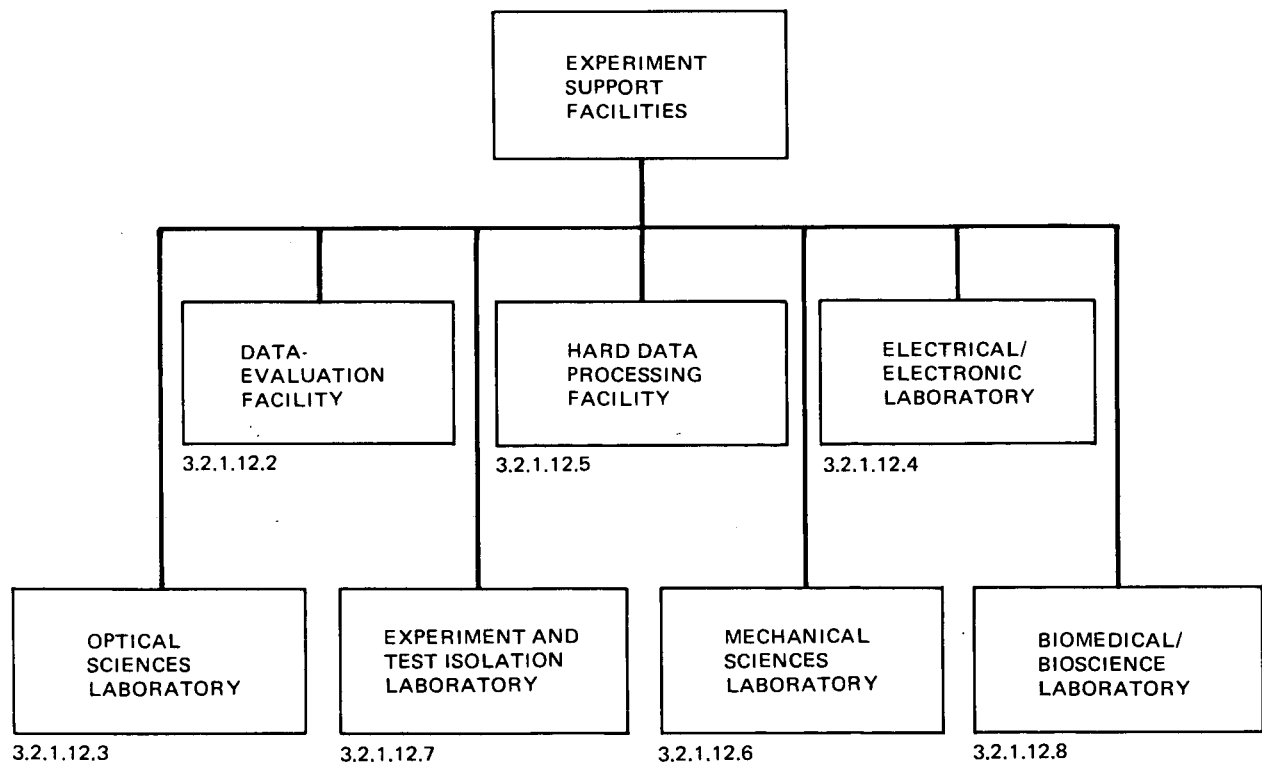


Figure 14. Experiment Support Facilities and Laboratories

- 3.2.1.12.1.4 All areas shall have mobility aids and motion constraints.
- 3.2.1.12.1.5 Areas producing waste fluids shall provide portable storage for experiment waste fluids for return to Earth aboard a logistics vehicle.
- 3.2.1.12.1.6 Areas producing solid waste material shall provide portable storage for solid waste for return to Earth aboard a logistics vehicle.
- 3.2.1.12.2 Data Evaluation  
The data evaluation facility shall have the capability to analyze, reconstruct, mensurate, store, condition, prepare, evaluate, and retrieve experimental and operational data. The data evaluation facility shall work in conjunction with the ISS data management subsystem to make up a complete complement of hardware and software for ISS data-handling capability.
- 3.2.1.12.2.1 The data evaluation facility shall include those functions or capabilities that are logically related or associated with the availability of film, video, analog and digital data; and the handling, processing, and evaluation of such data.
- 3.2.1.12.2.2 The data evaluation facility shall support both experiments and operations and shall provide services to all experiments and subsystems.
- 3.2.1.12.2.3 In addition to the functions supplied by the data management subsystem, the data evaluation facility shall supply a multiformat viewer/editor, microfilm retrieval, automatic film reader, copy machine, and stereo viewer.
- 3.2.1.12.3 Optical Sciences  
The optical sciences laboratory shall contain optical test, calibration, and alignment equipment. It shall



support a wide range of experiment and operational equipment such as: contamination, telescopes, cameras, scanners, navigation equipment, stabilization equipment, electronic imagers, rendezvous and tracking equipment and any other equipment requiring optical or spectral alignment, calibration, trouble shooting or setup.

3.2.1.12.3.1           The optical sciences laboratory shall accommodate a scientific airlock chamber for performance and deployment of experiments. The scientific airlock chamber shall accept an 46-cm (18-in.) diameter experiment package.

3.2.1.12.3.2           The optical sciences laboratory shall accommodate an optically flat broad spectrum transmission window associated with the airlock chamber. It shall allow viewing and photography of deployed experiments and external phenomena.

3.2.1.12.3.3           An experiment and airlock display and control unit adjacent to the airlock, with the appropriate interfaces provided shall be provided.

3.2.1.12.3.4           An airlock chamber extension is provided which allows the chamber to accommodate experiment packages up to 2.1-m (7-ft) long.

3.2.1.12.3.5           The following equipment comprises the Optical Sciences Laboratory: In addition to the scientific airlock chamber and precision optical window provided by the structural/mechanical subsystem, the optical science laboratory shall contain an optical work station, optical bench, precision work fixtures, microdensitometer, monochromator spectrometer, modulation transfer function measurement system, and an optical spectrum analyzer.

3.2.1.12.4           Electronic/Electrical Support  
The electronic/electrical laboratory provides all the instrumentation, test gear, stimuli, controls, and displays necessary for testing, electronic calibration, and maintenance of experiments and ISS subsystems.

- 3.2.1.12.4.1           The main service facility in the electronic/electrical laboratory shall be a multi-instrument test bench. This test bench and console shall provide the capability for bench checkout, calibration and contingency repair of electronics and electrical equipment. The instruments in the multi-instrument test bench shall be designed to be unplugged and utilized in a remote location as portable test equipment. A miniature laminar flow glove box for cleaning, assembling, disassembling, and soldering shall be provided.
- 3.2.1.12.4.2           In addition to the multi-instrument test bench, the electronic/electrical laboratory shall provide a battery charger, high-voltage/source, and high-energy counter calibration equipment.
- 3.2.1.12.5             Hard Data Processing  
The hard data processing facility shall include the capabilities and all the equipment related to film availability, film handling and processing, preliminary film calibration and "quick-look" film data evaluation. The hard data processing facility provides basic services and as such supports all experiments and operations utilizing film.
- 3.2.1.12.5.1           Film storage shall be provided. Predictable, consistent and satisfactory film quality shall be maintained through the use of a storage cabinet. The film storage cabinet shall provide radiation protection as well as temperature stabilization.
- 3.2.1.12.5.2           A light table with integral densitometer and a spectral color analyzer shall be provided to take film test strip data.
- 3.2.1.12.5.3           A black and white film processor, color film and plate processor, and a rapid film processor shall be provided. Processed film shall be archival quality. As such it shall either be stored, microfilmed (with either the microfilm or original copy sent to Earth), copied, or scanned and sent to Earth electronically.

3.2.1.12.5.4 Additional equipment shall include a microfilmer, light table, spectro photometer and densitometer.

This shall be compatible with the video data display and control console and experiment display and control provided by the data management function.

3.2.1.12.6 Mechanical Sciences

The mechanical sciences laboratory shall be capable of supporting a wide range of experimental and operational functions. Many types of mechanical electromechanical, and chemical functions shall be accommodated by the equipment in this laboratory.

3.2.1.12.6.1 The mechanical sciences laboratory shall provide laminar flow glove boxes with chemical and gas capabilities for heavy duty, light duty, and specialized functions. The glove boxes shall be designed for assembly, disassembly, repair, replacement, purging, cleaning, lubrication, and calibration of items of subassembly size. These glove boxes shall provide zero-g hold down for items subject to disassembly, and for the removal of elements and replacement of spares or consumables involved under the lighting and clean room conditions necessary for the protection of flight crews and reliability of items receiving maintenance attention.

3.2.1.12.6.2 Work benches shall provide the stowage for hand tools and maintenance consumables used frequently. Stowage is provided in this facility for shop tools and specialized spares.

3.2.1.12.6.3 The glove boxes shall provide laminar flow and vacuum removal of contaminants.

3.2.1.12.6.4 Provisions for a precision work fixture shall be included in the mechanical lab. This precision work fixture shall have a working relationship with the optical bench and can be utilized in the optics facility.

- 3.2.1.12.6.5           The mechanical sciences laboratory shall contain equipment such as the metallograph tester, thermostructural tester, X-Ray diffraction unit, X-Ray generator, and a specimen structural tester for performance and an analysis of materials science experiments.
- 3.2.1.12.7            Experiment and Test Isolation  
The experiment and test isolation laboratory includes the facilities to do experiments, maintenance and operations isolated from the ISS environment. It provides the capability to isolate toxic liquids, gases, molten solid materials and high pressures.
- 3.2.1.12.7.1           An airlock chamber shall be provided for experiments involving exposure to environment other than that in the ISS.
- 3.2.1.12.7.2           A chemistry and physics glove box and a storage and analysis console shall be located in the laboratory to provide enclosed work stations for experiments and operations involving chemical-handling and other, similar-type functions.
- 3.2.1.12.7.3           A heat exchanger is provided as part of the airlock chamber for heat transfer to the ISS radiator from high temperature experiments.
- 3.2.1.12.7.4           Temporary storage and utilization capability shall be provided for high-pressure gases, gases, cryogenics, toxic fluids, and similar materials for use during experiments.
- 3.2.1.12.7.5           Capability shall be provided for operating experiments remotely from a monitor and display console after they have been set up and the experiment and test isolation laboratory has been sealed.

3.2.1.12.7.6            The laboratory shall be designed to function as a separate test cell and to provide manned EVA capability. It shall be capable of withstanding two atmospheres of reverse or positive pressure and will have the capability of relief blowout to vacuum.

3.2.1.12.7.7            The equipment in the experiment and test isolation laboratory shall include a hazard detection system, electrical and vacuum power center, hydraulic/pneumatic work station, cryogenic and fluid storage, high-pressure gas storage, airlock/environmental chamber, chemistry and physics glove box, and a chemistry and physics analysis and storage unit.

3.2.1.12.8              Biomedical/Bioscience

The biomedical/bioscience laboratory is a rudimentary facility for monitoring of astronaut well-being, microbiological research, plant physiology, and invertebrate research.

3.2.1.12.8.1            The biomedical equipment shall have the capability to measure such things as heart functions with an electrocardiogram and a vectorcardiogram, work performance with a bicycle ergometer, body mass with a body mass measurement device and effects on the physiology of using a lower-body negative pressure device.

3.2.1.12.8.2            Equipment shall also be available in a biochemical and biophysical analysis unit for zero-g blood and urine analysis.

3.2.1.12.8.3            A biological glove box is provided for biological work requiring isolation or separation from the Space Station environment due either to toxicity or contamination.

3.2.2 Physical

3.2.2.1 Weight Limitation

3.2.2.1.1 The weight (mass) of each ISS module shall not exceed 9,072 kg (20,000 lbm) at launch.

3.2.2.1.2 The total of all launched weight necessary for initial manning for 30 days plus a 30-day contingency supply is 33,300 kg (73,500 lbm). This limitation shall apply to total of the Power/Subsystems, Crew/Operations and GPL Modules and the cargo capability of the first launch of a Logistics Module.

3.2.2.1.3 ISS subsystem equipment transported by the Logistics Module to achieve initial manning capability shall be limited to the first three launches.

3.2.2.1.4 The weight of required ISS cargo support shall not exceed 6,074 kg (13,382 lbm) for each logistics launch. This shall provide expendables, crew accommodation equipment, and off-loaded subsystem equipment to support operations with a 30-day contingency, as follows:

<u>Logistics Launch</u>	<u>Operation Period</u>	<u>Crew Size</u>
1	30 days	2
2	30 days	4
3	30 days	6
4	90 days	6

3.2.2.1.5 After launch four, the weight of required ISS cargo support, providing steady state supplies and supporting operations with a crew of six, shall not exceed:

<u>Operation Period</u>	<u>Cargo Support</u>
30 days	1,000 kg (2,200 lbm)
60 days	2,000 kg (4,400 lbm)
90 days	3,000 kg (6,600 lbm)

3.2.2.1.6 ISS cargo support weight shall include any unique packaging or fastening devices or equipment required to interface with the standard provisions of the Logistics Module.

3.2.2.1.7 The ISS design shall not preclude off-loading modules for return from orbit for repair or replacement. Module return limitation is 9,072 kg (20,000 lbm).

3.2.2.1.8 During an EVA the Life Support Equipment shall provide the following expendables (per 4 man-hours of EVA):

Feedwater:	4.9 Kg	(11 lb)
Oxygen:	0.72 Kg	(1.6 lb)
LiOH:	2.2 Kg	(5.0 lb)
Power supply:	2.5 Kg	(5.5 lb)

3.2.2.1.9 High thrust propellant tankage shall be at least 453 kg (1,000 lb).

3.2.2.1.10 Low thrust propellant tankage shall be at least 12.5 kg (27.6 lb).

3.2.2.2 Center of Gravity

3.2.2.2.1 Longitudinal center of gravity shall be limited to the envelope shown in Figure 15 below (the orbiter payload envelope is shown in reference).

3.2.2.2.2 Lateral and vertical axis limits are  $\pm 0.30\text{m}$  (12 in.).

3.2.2.3 External Dimensions

3.2.2.3.1 Each ISS module shall have maximum external dimensions of 4.3m (14 ft) diameter and 17.7m (58 ft) length.

3.2.2.3.2 Mechanisms that are attached to the module during launch but are external to the pressure shell, such as handling rings, attachments for deployment, docking mechanisms, thrusters,

antenna deployment booms, etc., shall be contained, at launch, within an envelope of 4.6m (15 ft) diameter and 18.3m (60 ft) length. Exceptions are the structural support fittings at the Shuttle payload interface support points which are outside of the 4.6m (15 ft) envelope.

3.2.2.3.3 The booms when deployed and locked shall provide an antenna standoff between the antenna center and module shell of approximately 6.0 meters.

3.2.2.4 Internal Dimensions

3.2.2.4.1 The private quarters shall be approximately 2.1 m (7 ft) x 2.1 m (7 ft) x 1.2 m (4 ft), a volume of approximately 5.3 m<sup>3</sup> (196 ft<sup>3</sup>).

3.2.2.4.2 Freedom for maneuverability in two planes shall be provided in terms of free volume measuring 2 m (6.5 ft) x 2 m (6.5 ft) x 1 m (3.5 ft), a volume of approximately 4.0 m<sup>3</sup> (148 ft<sup>3</sup>).

3.2.2.4.3 Furnishings (in place) and personal equipment volume of 0.93 m<sup>3</sup> (33 ft<sup>3</sup>) shall be provided.

3.2.2.4.4 The total volume of the wardroom, galley and gymnasium shall be approximately 40 m<sup>3</sup> (1,420 ft<sup>3</sup>).

3.2.2.4.5 The following volumes shall be allocated for each hygiene compartment:

Shower:	1.7 m <sup>3</sup>	(60 ft <sup>3</sup> )
Waste management:	1.8 m <sup>3</sup>	(65 ft <sup>3</sup> )
Urinal/handwash:	0.85 m <sup>3</sup>	(30 ft <sup>3</sup> )
Laundry:	0.56 m <sup>3</sup>	(20 ft <sup>3</sup> )
Free space:	1.8 m <sup>3</sup>	(65 ft <sup>3</sup> )
Total	6.7 m <sup>3</sup>	(240 ft <sup>3</sup> )



3.2.2.4.6 The following volumes shall be allocated for the command control center:

Equipment:	3.1 m <sup>3</sup>	(110 ft <sup>3</sup> )
Operating space:	3.0 m <sup>3</sup>	(105 ft <sup>3</sup> )
Total	6.1 m <sup>3</sup>	(215 ft <sup>3</sup> )

3.2.2.4.7 The docking port and latches shall provide a nominal clear diameter of 1.7 m (5 feet).

3.2.2.4.8 The following viewing requirements shall be provided:

<u>Type</u>	<u>Quantity</u>	<u>Diameter</u>	<u>Location</u>
Viewing	14	15 cm (6 in.)	One per pressure hatch
Viewing	3	30 cm (12 in.)	Wardroom
Viewing	6	30 cm (12 in.)	One per crew quarter
Viewing	2	30 cm (12 in.)	One per control station (primary and secondary)
Optical	2	30 cm (12 in.)	One per scientific airlock

3.2.2.4.9 Two scientific airlocks shall be provided. One airlock with a diameter of 1.25 meters shall be located in the test and isolation section of the GPL module. A smaller, 0.75-meter airlock shall be located in the main section of the GPL. Each airlock shall have a constant diameter clear length of approximately 1.0 meter.

3.2.2.5 Cargo Transfer

3.2.2.5.1 Docking port hatches in the ISS shall provide a cargo transfer opening of 1.5 m (5 ft) minimum.

3.2.2.5.2 Each ISS module shall provide passageway for transport of cargo from any module into any other module.

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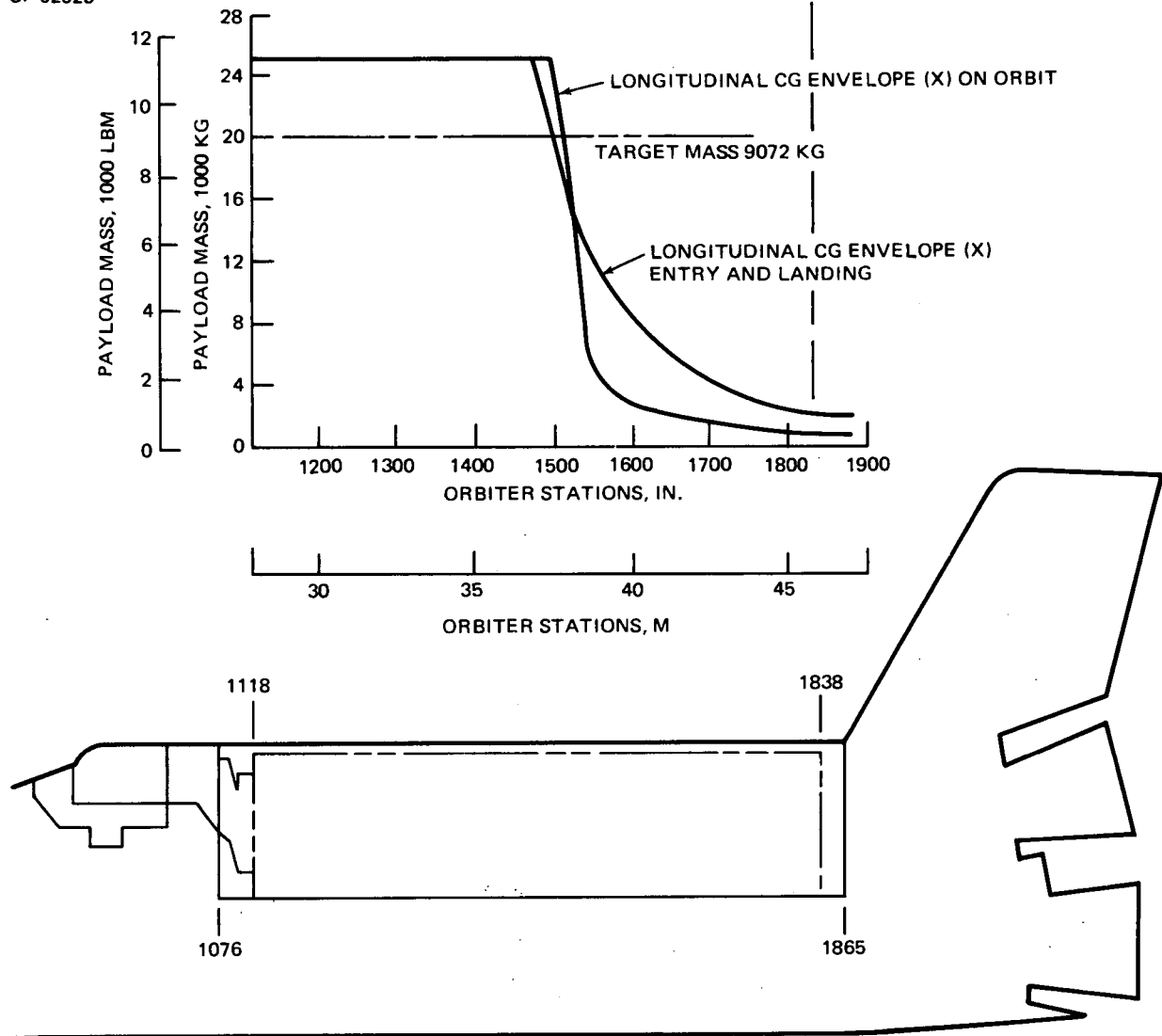


Figure 15. Longitudinal Center of Gravity Limitations

- 3.2.2.5.3 Entrances into all individual compartments within ISS modules shall be at least 0.6 m (2 ft) in diameter. These shall be capable of accommodating removal and replacement of the largest replaceable equipment item contained in the compartment.
- 3.2.2.5.4 The GPL shall provide for the movement of through cargo having a maximum spherical diameter of 1.5 m (5 ft).

3.2.2.6 Ingress and Egress

3.2.2.6.1 Primary Mission Mode of Operation

The ISS design shall be compatible with the requirement for convenient crew ingress and egress through any docking port. This shall consider nominal shirtsleeve ingress and egress and both normal and contingent IVA and EVA operations. It shall provide alternate personnel escape routes which do not terminate into a common module area and shall provide, as a minimum, the general capability illustrated in Figure 16 below:

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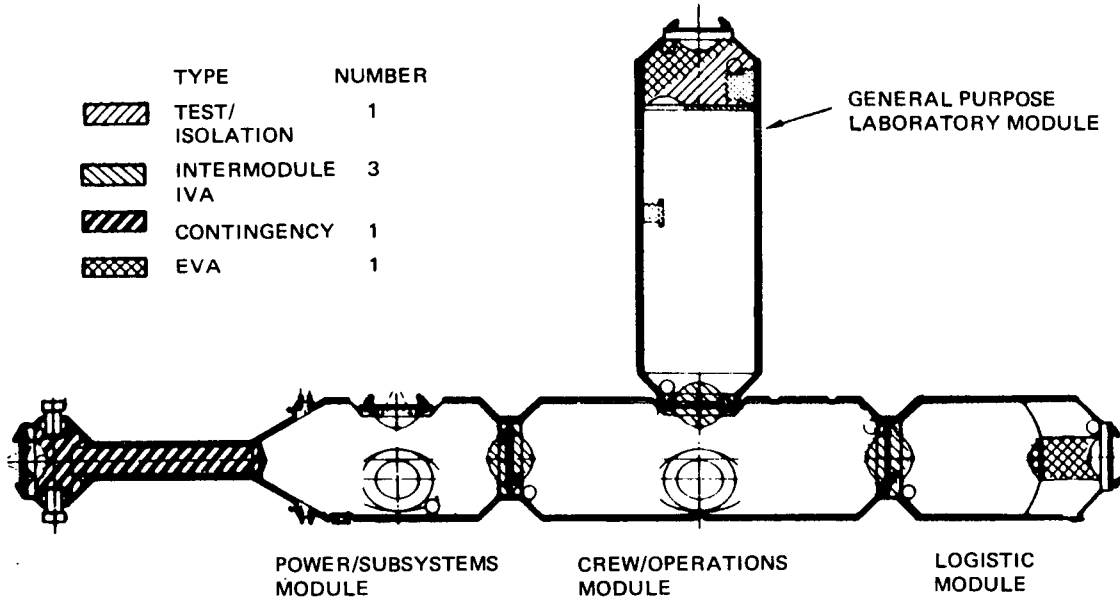


Figure 16. Ingress/Egress Locations

3.2.2.6.1.1 Logistics Module—The ISS design shall be compatible with utilization of a docked Logistics Module for ingress and egress from the ISS for:

- a) Crew transfer to and from Shuttle Orbiter, including initial manning.
- b) Frequent access to supplies, spares and other stores which remain stocked in the Log M.
- c) EVA—One mode of EVA from the ISS shall utilize the Log M EVA airlock.
- d) Use of the Log M as a refuge.

- 3.2.2.6.1.2           RAM—The ISS shall be compatible with the requirement for crew access to docked RAM modules.
- 3.2.2.6.1.3           Shuttle Orbiter—The ISS design shall be compatible with utilization of a direct docked Logistics Module for crew ingress and egress.
- 3.2.2.6.1.4           EVA —The ISS shall provide capability for direct EVA utilizing the Log M EVA airlock or the test and isolation cell in the General Purpose Laboratory Module. Backup EVA capability shall be provided utilizing the antenna boom tunnel in the Power/Subsystems Module. Contingency EVA shall be achievable by depressurizing any module and utilizing any free docking port.
- 3.2.2.6.1.5           IVA—The ISS shall provide and retain the capability for intermodule IVA. In addition, the ISS shall be capable of IVA operations in the test and isolation cell of the GPL.
- 3.2.2.6.2            ISS Buildup Operations Mode
- 3.2.2.6.2.1           Each Module shall be compatible with the requirement for the two-man activation crew to ingress or egress the Shuttle Orbiter through the erection system tunnel. This capability is required after module erection, before and after docking.
- 3.2.2.6.2.2           Each Module, or module cluster at each stage of buildup shall provide contingency egress and ingress for EVA operations.
- 3.2.2.6.3            Prelaunch
- 3.2.2.6.3.1           Each ISS module shall be designed to accommodate the requirement to gain interior access after installation of the module in the orbiter with the Shuttle in the horizontal position. Modules shall not require personnel onboard to accomplish normal prelaunch activities, occurring during and after installation in the Orbiter.

3.2.2.6.3.2 Each ISS module shall not be designed to preclude limited ingress and egress to gain interior access after installation of the module in the orbiter with the Shuttle vertical. Crew support ladders, platforms, etc., shall be provided as ground-support equipment.

3.2.3 Reliability

The ISS shall be designed to operate for a mission of 10 years of space operation with maintenance and minimum reasonable prelaunch verification and checkout. The functional design shall optimize the reliability with respect to weight, with secondary considerations of cost, volume, and maintenance time. The reliability measure which shall be used is the probability that the system will be available for manning and then to perform required functions to specification levels for 120 days of operation with maintenance.

3.2.3.1 Availability for Manning

The ISS shall be designed for a 0.97 probability of availability for manning after 90 days of buildup operation with maintenance commensurate with the time available during buildup flights. The reliability allocation by subsystem is as follows:

<u>Subsystem</u>	<u>Allocation</u>
Structural/mechanical	0.9997
Electrical power	0.9860
EC/LS	0.9915
Propulsion	0.9980
Guidance and navigation, and stability and attitude control	0.9990
Communications	0.9990
Data management	0.9985
Crew habitability and protection	---
Onboard checkout and fault isolation	0.9980
Experiment support equipment	---
Total Probability	0.97

3.2.3.2 Availability for Sustained Operations

System Availability ( $A_s$ ) is a probability value representing the combined effects of system capability to function without maintenance and capability to repair failures critical to the operations planned for any discrete time period. This is expressed by the term:

$$A_s = \prod_{i=1}^N (R_i + [(1-R)_i \cdot P_{s_i} \cdot P_{M_i}])$$

where  $R_i$  = probability of no failure of the  $i$ th part during the mission time requiring this part.

$P_{s_i}$  = probability of having sufficient spares of the  $i$ th part to correct all failures during any discrete time period (buildup or 120 days of mission).

$P_{M_i}$  = probability that any failures of the  $i$ th part can be repaired prior to the loss of experimental data (or prior to loss during buildup).

Reliability performance shall be based on analyses representing system events and functions, required equipment probability of having the required spares to repair failures, and probability of repair in time.

Spares inventory to achieve the required Space Station availability for any 120-day period shall be determined on the basis of individual subassembly/component effectiveness. The design objective is to provide the required Space Station availability (0.96 Ref) with an initial spares and redundancy inventory for 120 days not to exceed (TBD) kilograms.

The reliability and weight allocations (redundant units and initial spares added to a simplex system to achieve predicted availability equal to the objective) by subsystem are as follows:

<u>Subsystem</u>	<u>Allocation</u>	
	<u>Reliability</u>	<u>Weight (kg)</u>
Structure/mechanical	0.996	45
Electrical power	0.996	454
EC/LS	0.997	490
Propulsion	0.996	159
Guidance and navigation, and stabilization and attitude control	0.996	249
Communications	0.995	145
Data management	0.996	177
Crew habitability and protection	0.993	68
Onboard checkout and fault isolation	0.997	27
Experimental support equipment	0.997	91
Total Probability	0.96	1,905

3.2.4 Maintainability

The Space Station shall be designed for 100 percent replacement maintenance capability at the subassembly or component level or by functional substitution. No routine or planned maintenance will require use of a pressure suit (EVA or IVA) unless no other solution is reasonable.

Maintainability design performance shall be measured in terms of two parameters: probability of repair of the subsystem, and maintenance man-hours per month (average).

3.2.4.1 Probability of Repair

Probability of repair  $\Pr \{ t_R \leq t_A \}$  is a measure of expectation that the downtime (time to repair) is equal to or less than the allowable time (prior to mission performance deterioration below specification requirements). The individual repair time distributions are described by a median (50th-percentile) time and a 90th-percentile time.

3.2.4.1.1 Downtime  
Downtime includes all time from detection of a sub-performance condition to return to specification performance, including fault localization/isolation, removal, replacement, and retest or verification. Subsystem downtimes include a proportionate share of part procurement, data retrieval, and travel, which are included in the Space Station probability of repair performance.

3.2.4.1.2 Probability of Repair Objectives  
The probability of repair objectives for individual repair actions shall be as specified in the following paragraphs. Each of these objectives are assumed to be independent of the probability of parts availability ( $P_s$ ).

3.2.4.1.2.1 Subassemblies and components that must be available to ensure against a mission safety or mission abort event shall have a probability of repair of at least 0.9999.

3.2.4.1.2.2 Subassemblies and components that must be available to ensure against temporary loss of experiment data shall have a probability of repair of at least 0.995.

3.2.4.1.2.3 Subassemblies and components that must be replaced or repaired to reinstate crew comforts or similar degraded operation modes shall have a probability of repair of at least 0.99.

3.2.4.1.3 Standby Redundancy  
Standby redundancy may be considered as a candidate means for improving availability when there are extremely short allowable downtimes, as when time to repair is affected by location (EVA) or operational considerations.

3.2.4.2 Maintenance Man-Hours  
ISS subsystems shall be designed to minimize required maintenance man-hours. As a goal, maintenance



man-hours per month (MMH/MO) to provide the specified Space Station availability shall be less than 5 percent of available crew duty hours. Maintenance man-hours per month (average) is defined as the total expected man-hours of maintenance (corrective or preventive) per year divided by 12 months.

3.2.4.2.1 Preventive Maintenance

Preventive maintenance shall include replacement of wearout items and routine tests and servicing. It shall not include daily inspections for condition, leaks, etc., or for cleaning or documentation of these daily inspections.

3.2.4.2.2 Corrective Maintenance

Corrective maintenance design goals shall be for median (50th-percentile) and maximum (90th-percentile) times. Corrective maintenance time shall include subsystem safing and draining and other actions to permit maintenance. The ISS shall be designed for IVA/EVA maintenance tasks to be performed by two pressure-suited men.

3.2.4.2.3 Maintenance Man-Hours Objectives

Maintenance man-hours design objective allocations, based on initial predictions shall be as follows:

<u>Subsystem</u>	<u>MMH/Mo (Avg) Allocation</u>	
	<u>Preventive (percent)</u>	<u>Corrective (median, percent)</u>
Structure/mechanical	0.046	0.046
Electrical power	0.278	0.232
EC/LS	1.111	1.389
Propulsion	0.139	0.093
Guidance and Navigation, Stabilization and Attitude Control	0.093	0.139
Communications		0.093

<u>Subsystem</u>	MMH/Mo (Avg) Allocation	
	<u>Preventive (percent)</u>	<u>Corrective (median, percent)</u>
Data management	0.093	0.232
Crew habitability and protection	0.093	0.093
Onboard checkout and fault isolation	0.232	0.185
Experimental support equipment	<u>0.139</u>	<u>0.278</u>
Total	2.224	2.780 (median) 9,500 (maximum, 90)

3.2.5 Operational Availability

ISS modules shall be designed and tested to assure a high probability of function when placed in functional operation on orbit. The design shall permit prelaunch test and verification of all mission and life critical functions, except deployment of solar arrays and ordnance devices.

3.2.5.1

The ISS modules as launched shall have the capability of being assembled in orbit in less than (8) hours elapsed time for two men, with no planned EVA and a minimum of time in protective clothing (space suit). The modules shall incorporate sufficient system verification and/or test capability, in combination with the modules to which they are being docked, to identify critical equipment parameters below optimum performance for the remaining unmanned time period and which must be modified or repaired prior to separation from the orbiter, in order to achieve the specified premanning reliability objective (reference Paragraph 3.2.3.1).

3.2.5.2

ISS Modules shall have the capability for a prelaunch hold of up to 2 days without requiring a recycle through prelaunch verification tests. Recycle after initial verification and a hold of over 2 days, shall require not more than 3 days.

3.2.5.3 Individual modules shall have the following premanning performance capability including prelaunch status and on orbit operation.

	<u>Availability—30 Days</u>
Power/Subsystems Module	Initial: 0.9780 Sustained: 0.9826
Crew/Operations Module	Initial: 0.9932 Sustained: 0.9950
GPL Module	Initial: 0.9960 Sustained: 0.9974

Availability is identified as the probability that critical functions required for rendezvous, docking of arriving modules, boarding, initial start-up, and continual operations are functional 30 days without maintenance. Availability of the Space Station for manning shall be enhanced by man intervention and repair of malfunctions or degraded performance prior to Orbiter separation at each successive module delivery to orbit.

3.2.6 Safety

The Space Station Module shall conform to the safety requirements of Space Station Project Specification No. RS-02927 and to the specific requirements of the following paragraphs. Definitions of terms used are:

- a) Critical Functions—Functions that are required for personnel safety and mission continuation.
- b) Nominal Level—The level of performance or operations for which the system was designed.

- c) Reduced Level—A level of performance that is lower than that for which the system or operation was designed, but is still adequate for personnel safety.
- d) Emergency Level—A level of performance that is sufficient only for personnel survival.
- e) Catastrophic—No recovery is possible or an immediate crew hazard exists (i. e. , pressure vessel rupture or premature activation of explosive devices).

3.2.6.1 Personnel Safety

3.2.6.1.1 No single malfunction or credible combination of malfunctions or accidents shall result in injury to personnel or loss of mission.

3.2.6.1.2 Catastrophic and critical hazards shall be eliminated or controlled.

3.2.6.1.3 Capability shall be provided for performing critical functions at a nominal level, with failure of any single component or with any portion of a subsystem inactive for maintenance.

3.2.6.1.4 Capability shall be provided for performing critical functions at a reduced level, with any credible combination of two component failures or with any portion of a subsystem inactive for maintenance.

3.2.6.1.5 Capability shall be provided for performing critical functions at an emergency level until the affected function can be restored or until the crew can be returned to Earth, with any one compartment inactivated, isolated, and vacated as the result of an accident; or with any credible combination of subsystems inactivated as the result of an accident and a portion of a redundant or backup system being inoperative.

3.2.6.1.6 For malfunctions or hazards that may result in time-critical emergencies, provision shall be made for the automatic switching to a safe mode of operation and for cautioning or warning of personnel.

3.2.6.1.7 Subsystem Safety Requirements  
Specific safety requirements of subsystem design shall be as specified in the following paragraphs.

3.2.6.1.7.1 Personnel escape routes shall be provided for all situations of high-hazard potential. Each normally habited compartment shall have a minimum of two escape routes that do not terminate in a common area.

3.2.6.1.7.2 The ISS shall provide storage for emergency space suits in readily accessible locations.

3.2.6.1.7.3 The ISS shall provide location for potentially explosive containers, such as high-pressure vessels or volatile-gas storage containers outside of, and as remote as possible with respect to the crew's living and operating quarters, and wherever possible isolated.

3.2.6.1.7.4 The chemical composition of the environmental atmosphere shall be continuously monitored for any buildup of toxic or noxious gases, and to provide early fire hazard warning by detection of fire precursors or material decomposition products.

3.2.6.1.7.5 Fire detection equipment shall detect incipient fires in components, behind panels, and in wire bundles or cabling assemblies.

3.2.6.1.8 Fire suppression equipment shall be capable of extinguishing any fire in the most severe oxidizing environment prior to failure of primary pressure structural materials.

3.2.6.1.9 Space Station EVA activities shall be conducted using the "buddy" system. All routine EVA shall be conducted in a tethered mode.

3.2.6.2 Equipment Safety

3.2.6.2.1 Redundancy and Separation

3.2.6.2.1.1 Space Station subsystems, shall be designed for fail-safe operation and shall ensure selective degradation.

3.2.6.2.1.2 Space Station safety-critical equipment shall be designed to allow emergency operation by employing redundancy and separation of parallel or similar functions. The placing of such redundant or parallel equipment in isolated compartments or locations shall ensure that a single emergency or failure will not destroy both the primary and redundant system.

3.2.7 Environment

Natural and induced environments shall be as specified in Modular Space Station Project, Specification RS02927.

3.2.8 Transportability/Transportation

The ISS module shall be designed for compatibility with surface transportation on a transporter, shipment by air, and shipment by an ocean-going vessel.

3.2.8.1 Handling Equipment

Handling equipment in service or in storage shall be inspected, proof tested, and certified in accordance with the requirements presented in MSFC-STD-126.

3.2.8.2 Packaging

Packaging, packing, marking, handling and shipping of space vehicle equipment shall conform to the requirements of MSFC-STD-343A/NHB 6000.1 (1A).

3.2.9 Storage

Flight hardware storage requirement shall be in agreement with provisioning and logistics support requirements. Storage and preservation requirements shall be based on equipment utilization, spares consumption, protection and requirements for availability during the operational life of the program. Hydraulic system storage requirements shall be as specified in MSFC-STD-492(1). Mechanical and electrical GSE storage requirements shall be as specified in MSFC-STD-501 and MSFC-STD-503 respectively.

3.3 Design and Construction Standards

3.3.1 Selection of Specifications and Standards

All materials, parts, and processes shall be defined by standards and specifications. Standards and specifications shall be selected from Government, industry, and contractor specifications and standards in accordance with MIL-STD-143. Rationale for the selection of contractor specifications and standards over existing higher order or precedence standards and specifications shall be compiled

and maintained for historical record. This rationale shall include an identification of each higher order or precedence specification or standard examined and state why each was unacceptable.

For purposes of this order or precedence, commercial materials, parts, and processes shall be considered equivalent to contractor standards.

3.3.2 General

3.3.2.1 Design and construction standards for hardware obtained from the Saturn, Apollo, Gemini, or other Space programs shall be in accordance with existing specifications for those items and in accordance with the standards below, as appropriate. New Initial Space Station hardware shall be designed and constructed in accordance with standards in the following sections.

3.3.2.2 Dangerous Materials and Components

3.3.2.2.1 Initial Space Station hardware shall be designed in accordance with MSFC-SPEC-101B.

3.3.2.2.2 Where functional requirements preclude meeting flammability requirements, materials may be isolated from the environment by fireproof storage compartments or barrier materials which meet these requirements.

3.3.2.2.3 All materials shall be nonflammable when tested in the most oxygen rich environments to which they will be exposed except for food, medical supplies, etc., which shall be stored in fireproof containers at all times unless being used or consumed.

3.3.2.2.4 Materials which offgas, outgas, or evolve toxic or noxious products capable of personnel impairment or hazard shall not be used. If mandatory for operational performance, such materials will be isolated by compartmentalism, sealing or contained in barrier materials.

3.3.2.2.5 All ordnance shall conform to the requirements of MSFC-SPEC-491.



- 3.3.2.2.6 Heat transport fluids located within pressurized crew compartments shall be nontoxic and nonflammable at ambient atmosphere pressure and composition.
- 3.3.2.2.7 All materials selected for use in habitability areas will be nontoxic, nonflammable, and nonexplosive to the maximum extent practical.
- 3.3.2.3 Configuration and Design Control
- 3.3.2.3.1 Drawing Standards  
Engineering drawings shall be in accordance with Category E, Form 1 of MIL-D-1000.
- 3.3.2.3.2 Weight and Mass Data  
Weight and mass data shall be submitted according to agreements based on MIL-M-38310A.
- 3.3.2.3.3 Air Transportable Equipment  
Air Transportable Equipment shall be designed to conform to the requirements of Specification MIL-A-8421.
- 3.3.2.3.4 LOX Compatibility  
The requirements established in MSFC-SPEC-106B shall be implemented in the selection of materials proposed for use in a LOX environment.
- 3.3.2.4 Gases and Liquified Gases  
Instrument Grade (High Purity) shall conform to MSFC-SPEC-233. Nitrogen shall conform to MSFC-SPEC-234A. Helium shall conform to MSFC-SPEC-364C. Oxygen shall conform to MSFC-SPEC-399A.
- 3.3.2.5 Lubricants  
Lubricants shall be compatible with the hardware with which used, and the anticipated service environments.

Where possible, lubricants shall be selected which conform to MSFC-SPEC-502, MIL-L-8937A, MIL-L-46010A, or MIL-L-81329A. The use of lubricants other than those specified requires approval of the responsible MSFC design activity.

3.3.2.6

Fluids

Procurement and Control of fluids for Space Shuttle Systems shall be in accordance with MSC-04265.

3.3.2.7

Colors

FED-STD-595A shall be used for color identification.

3.3.2.8

Rubber

Age control of synthetic rubber shall be in accordance with MSFC-STD-105A(4).

3.3.3

Aeronautical

3.3.4

Civil

Federal, state, and local cases shall be observed as necessary for construction, fabrication, transportation, communications, and safety.

3.3.5

Electrical

3.3.5.1

Electromagnetic Interference

The Space Station Project as a total system shall comply with the requirements of MIL-E-6051D. The Space Station Project as a subsystem of the Space Station Program shall comply with the requirements of MIL-STD-461A and 462.

3.3.5.2

Containers

Electrical systems containers shall be hermetically sealed, purged, pressurized, or encapsulated, where necessary. Solenoids, transducers, squirrel-cage induction motors, and similar hardware having no circuit-switching devices, shall be hermetically sealed, purged, pressurized, or encapsulated with compatible material.

Precautions against sparking of metal-to-metal contacts shall be taken for all devices which have moving parts.

3. 3. 5. 3                      Relays

All relays in Flight Critical Items shall be vibration scan-tested in accordance with MSFC-SPEC-339. DC relays of established reliability and hermetically sealed for space, launch vehicle and associated support equipment shall be in accordance with 40M37496F.

3. 3. 5. 4                      Electronic Modules

Any welded electronic modules used shall be fabricated using components with lead materials which meet the requirements of MSFC-STD-271. For general use, potting or encapsulation materials used in conjunction with welded modules shall conform to Type II, Type III, or Type IV of MSFC-SPEC-222. Materials other than vinyl may be used as a sleeve or the protection of glass components as defined in Paragraph 5. 1. 5 of MSFC-SPEC-222.

3. 3. 5. 5                      Soldering Requirements

Soldering of electrical connections shall conform to the requirements of MSFC-PROC-158 and NHB5300. 4(3A).

3. 3. 5. 6                      Potting, Molding, and Encapsulating

Potting, molding, and encapsulating with materials conforming to MSFC specifications shall be performed in accordance with MSFC-PROC-186C, MSFC-PROC-196B(1), MSFC-PROC-257A(3), MSFC-PROC-293A(4), MSFC-PROC-310, MSFC-PROC-380(1), MSFC-PROC-412(2) or MSFC-PROC-442 as appropriate.

Potting molding, conformal coating and encapsulation materials shall conform to MSFC-SPEC-202B(1), MSFC-SPEC-222C(1), MSFC-SPEC-379B(1), MSFC-SPEC-393B(1), MSFC-SPEC-411(1), or MSFC-SPEC-418(2), as appropriate for the application.

3.3.5.7 Printed Wiring Boards

Design, documentation and fabrication of printed wiring boards shall be in accordance with MSFC-STD-154A. Connectors shall be in accordance with MSFC-SPEC-119A. Plated through holes shall be in accordance with 50M60444. Printed wiring board part leads shall be installed in accordance with MSFC-STD-147.

Development of multilayer printed wiring boards for flight equipment shall be in accordance with 50M60420.

3.3.5.8 Terminals

Insulated screw type and swage solder terminals shall be in accordance with MSFC-SPEC-278B(1). Installation of terminals on printed circuit and terminal boards shall conform to MSFC-PROC-274A(1).

3.3.5.9 Parts Mounting

Design requirements for mounting parts for soldered printed circuit boards shall conform to MSFC-SPEC-136.

3.3.5.10 Electrical Cables

Flexible multiconductor cables for GSE shall conform to MSFC-SPEC-332C(1). RF cables shall conform to MIL-C-17D(1).

Jacketed, shielded, electrical cable shall be in accordance with 40M39526A. Design of electrical harness shall conform to 40M39582.

3.3.5.11 Electrical Harness Installation

Electrical harness assemblies shall be installed in accordance with MSFC-SPEC-494. Fabrication and terminations of shielded electrical harness and cable assemblies, and wiring of electrical and electronic circuits and subassemblies shall be in accordance with MIL-E-45782B. Crimping, when used, shall be in accordance with MSC/MSFC-JD-001.

3. 3. 5. 12                    Hookup Wire

Insulated high temperature wire used for wiring meters, panels, and electrical and electronic equipment shall conform to the requirements of MIL-W-16878D(1), except silver plated wire shall not be used.

3. 3. 5. 13                    Connectors

Electrical miniature connectors (200°C) shall conform to 40M39569A. Electrical connectors for Zero G application shall conform to 40M39580A. Installation and mounting of electrical connectors shall be in accordance with 40M39581.

3. 3. 5. 14                    Flat Cable and Connectors

Flat conductor cable shall be in accordance with MIL-C-55543. Flat conductor connectors shall be in accordance with MIL-C-55544.

3. 3. 5. 15                    Thermistors

Thermally sensitive insulated resistors shall conform to MIL-T-23648A(2).

3. 3. 5. 16                    Terminal Junctions

Electrical distribution and bussing terminal junctions shall be in accordance with 40M39589.

3. 3. 5. 17                    Environmental Protection

Safety design policies for all electrical equipment located in areas where hazardous gases may be present shall conform to 10M01071.

3. 3. 5. 18                    Safety Wiring

Safety wiring shall conform to MS33540F.

3.3.5.19 Gap Welding Electronic Equipment

Gap welding low power electronic micro-components to weldable printed wiring boards shall be in accordance with MSFC-PROC-429.

3.3.5.20 Insulation Tubing

Tubing intended for electrical insulation for high temperatures (+275°C), high frequency, or both, shall be in accordance with MIL-I-22129C(1).

3.3.6 Mechanical

The structural and mechanical systems shall have sufficient strength and rigidity to sustain yield load without failure, without deformation which would prevent any portion of the vehicle from performing its intended function and without deleterious permanent set. The simultaneous application of accompanying environmental effects (temperature, pressure, slush, and vibration) shall be applied to determine the critical loading conditions. These systems shall have sufficient strength and rigidity to withstand the maximum design load without failure and without deformation which would result in premature failure of any safety critical function. Simultaneous application of accompanying environmental effects shall be considered in determining the critical loads. Extremes of the environmental effects with appropriate loads shall be considered. Analysis shall be performed to assess the effects of dynamic magnification, shock factors, and surge phenomena as applicable. Design data and materials properties shall be obtained from MIL HDBK 5, MIL HDBK 17, MIL HDBK 23 or alternatively from other sources which meet the approval of the procuring agency.

3.3.6.1 Design Safety Factors

3.3.6.1.1 General Safety Factors

Yield factor of safety: 1.10 x load limit  
Ultimate factor of safety: 1.40 x load limit

- 3.3.6.1.2 Flexible Hose, Tubing, Ducts, and Fittings
- |                 |                       |
|-----------------|-----------------------|
| Proof pressure: | 2.00 x limit pressure |
| Yield pressure: | 1.10 x proof pressure |
| Burst pressure: | 4.00 x limit pressure |
- 3.3.6.1.3 Actuating Cylinders, Valves, and Switches
- |                 |                       |
|-----------------|-----------------------|
| Proof pressure: | 1.50 x limit pressure |
| Yield pressure: | 1.10 x proof pressure |
| Burst pressure: | 2.50 x limit pressure |
- 3.3.6.1.4 Reservoirs
- |                 | Liquid | Gas, or Liquids and Gases |
|-----------------|--------|---------------------------|
| Proof pressure: | 1.50   | 2.00 x limit pressure     |
| Yield pressure: | 1.10   | 1.10 x proof pressure     |
| Burst pressure: | 2.50   | 4.00 x limit pressure     |
- 3.3.6.2 Configuration and Design Control
- 3.3.6.2.1 Design Data
- All structural and mechanical design shall be in accordance with MSFC-HDBK-505.
- 3.3.6.2.2 Torque Values
- Torque values for threaded fasteners shall be established in accordance with MSFC-STD-486(1).
- 3.3.6.2.3 Fluid Fittings
- All critical fluid fittings shall conform to MSFC-SPEC-143C(1).
- 3.3.6.2.4 Screw Threads
- Unified and unified miniature screw threads shall conform to MIL-S-7742B. Screw threads for critical and high strength applications shall conform to MIL-S-8879.

3. 3. 6. 3                   Hydraulic System

The design, installation, and testing of hydraulic systems and equipment shall conform to the requirements established in MIL-H-25475A or MIL-H-5440, as appropriate considering mission requirements. Fluids used in hydraulic systems shall conform to MIL-H-5606B(3).

3. 3. 6. 4                   Heat Treatment

Heat treatment of aluminum alloys shall be in accordance with MIL-H-6088D(2). Heat treatments of titanium and titanium alloys shall be in accordance with MSFC-SPEC-469.

3. 3. 6. 5                   Welding

Welding of aluminum shall conform to MSFC-SPEC-504. Welding of constructional steels shall conform to MIL-STD-1261A. Spot and seam welding shall be in accordance with MIL-W-6858C. Fusion welding of alloys, other than aluminum, shall conform to MSFC-SPEC-135.

Welding of the vehicle structure shall meet the "materials," "welding procedure," "visual inspection," and "radiographic inspection" requirements of MSFC-SPEC-135, Welding, Fusion Specification.

3. 3. 6. 6                   Adhesive Bonding

Adhesive bonding shall be performed in accordance with process specifications prepared in accordance with MSFC-SPEC-445.

3. 3. 6. 7                   Brazing

Brazing shall conform to MIL-B-7883B.

3. 3. 6. 8                   Solid Propellant Auxiliary Motors

Solid propellant auxiliary motor procurement specifications shall conform to the requirements of 10M01818.



3. 3. 6. 9                    Metal Duct Acceptability

Criteria for acceptability of metal duct assemblies and formed parts with minor defects, after installed, shall be in accordance with MSFC-STD-487.

3. 3. 7                      Nuclear

Design practice associated with the containment, handling, and safety of nuclear materials and devices shall comply and be subject to AEC policies and practices defined by Title 10, Code of Federal Regulations.

3. 3. 8                      Moisture and Fungus Resistance

Materials which are not nutrients for fungus shall be used whenever possible. The use of materials which are nutrients for fungus shall not be prohibited in hermetically sealed assemblies and other accepted and qualified uses, such as paper capacitors and treated transformers. If it is necessary to use nutrient materials in other than such qualified applications, these nutrient materials shall be treated by a method which will render the resulting exposed surface fungus resistant. The treated surface must satisfactorily pass the fungus tests in MIL-STD-810.

3. 3. 9                      Corrosion of Metal Parts

3. 3. 9. 1                    Whenever possible metals shall be used which are corrosion resistant to the anticipated environmental exposure conditions. Material selection shall be based on the criteria established by MIL-STD-889 and 10M33107. When required, protective treatment shall conform to MSFC-SPEC-250(1) as modified by requirements of MSFC-SPEC-101B and MSFC-SPEC-106B. Chemical coating conforming to MIL-C-5541A shall be used on aluminum surfaces where electrical bonding must be made.

Verification of the corrosion resistance of various components shall be accomplished by using metals with proven corrosion resistant characteristics or those that are protected by suitable surface treatment specified above.

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Type 304 corrosion resistant tubing shall conform to MSFC-SPEC-131D.  
Types 321 and 347 shall conform to MSFC-SPEC-248.

3.3.9.2                   Dissimilar Metals

Dissimilar metals are defined by MIL-STD-889 which are subject to electrolytic corrosion, shall not be used in combination unless suitably coated, sealed, or separated by barrier material compatible with both metals. Special consideration will be given to electrical bonding requirements where dissimilar metals are involved.

3.3.9.3                   Painting and Coating

Finishes shall be applied to metal parts to ensure environmental protection. Consideration shall be given to weight, thermal emissivity, outgassing and electrical bonding requirements. All exposed, unpainted, machined surfaces which could corrode shall be finished with an inorganic coating such as plating or anodizing. Anodizing shall be used where electrical bonding must be made.

3.3.10                   Contamination Control

3.3.10.1               Special cleanliness levels imposed by equipment involving hydraulics, pneumatics, life support and special experimental procedures shall not be imposed on the entire interior or exterior of Space Station or supporting equipment.

3.3.10.2               Special high levels of atmospheric or surface cleanliness shall not be required for transportation handling, assembly and checkout of prime elements.

3.3.10.3               Specific areas of activity or design wherein special cleanliness is mandatory shall have equipment and/or support tooling to maintain local cleanliness during assembly, handling and servicing of such equipment. As a goal, extensive cleanroom facilities should be avoided.

3.3.10.4               As a design goal, venting and dumping of liquids and gases shall be directed to prevent contamination of outer surfaces of the Space Station and to eliminate recontamination from

fungus and bacteria vented overboard. Outgassing from materials, leaks from coolant systems, and leaks from pressurized spacecraft environments or the effects thereof, or both, shall be minimized.

3.3.10.5 Any contaminant expulsion from Space Station shall be coordinated with experiments so as not to negate experiment data and to minimize experiment "downtime."

3.3.10.6 Initial Space Station flight hardware shall be designed, manufactured, tested, handled, and operated in such a manner as to assure contamination-free operation for critical surfaces or elements.

3.3.10.7 Cleaning Area

Cleaning shall be accomplished in an appropriate class of clean area or clean work station as defined in MSFC-STD-246A.

3.3.10.8 Oxygen, Fuel, and Pneumatic Systems

Significant surfaces of closed loop oxygen, fuel, and pneumatic systems shall be cleaned, handled and protected in accordance with MSFC-SPEC-164A. Cleaning shall be accomplished at the highest practical level of assembly. Following cleaning operations, contamination critical surfaces shall be protected from re-contamination in accordance with MSFC-PROC-151.

3.3.10.9 Purge Gas

Purge gas and purge gas supply systems used for purging contamination critical systems shall be in accordance with MSFC-PROC-404.

3.3.10.10 Flammability, Odor, and Toxicity

The requirements established in MSFC-SPEC-101B shall be implemented in the selection of materials proposed for use in environments containing oxygen in excess of 21 percent, or

at elevated pressures. Where offgassing is a design consideration and control must be exercised, consideration for applicability must first be given to the approved materials listed in TBD.

3.3.11 Coordinate Systems

3.3.11.1 Coordinate axes and reference planes shall be in accordance with Project Apollo Coordinate System Standard dated June 1965, SE-008.001.1.

3.3.12 Interchangeability and Replaceability

Mechanical and electrical interchangeability shall exist between identical replaceable parts, assemblies and subassemblies, regardless of manufacturer or supplier. All parts having the same part number, regardless of source, shall be functionally and dimensionally interchangeable.

3.3.13 Identification and Marking

Nameplates and markings shall be made and affixed in accordance with MIL-STD-130, and MIL-STD-129, or equivalent. All configuration identification information on these nameplates and markings shall be taken from and agree with production or construction drawings and/or their engineering release records.

Equipment, assemblies, and parts shall be marked for identification in accordance with MM 8040.12 Exhibit IV. Engraved marking on GSE equipment shall be in accordance with MSFC-STD-275A. Marking of packaging shall conform to MSFC-STD-343A. Color coding shall be in accordance with MSFC-STD-146 for facilities and associated ground equipment. Identification of pipe, hose, and tube lines in flight systems shall conform to MIL-STD-1247B. Markings shall be repeated as often as necessary on wiring and fluid lines to facilitate identification and traceability.

Marking ink or paint used shall be permanent, nonconductive, and fungus resistant. Lettering shall be in accordance with MSFC-STD-373. Silk screening shall be in accordance with MSFC-STD-372A. Rubber stamping shall be in accordance with MSFC-STD-383A. Metal die stamping shall not be used on the film template or on the finished module.

3.3.14 Workmanship

Initial Space Station hardware, including all parts and accessories shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be paid to neatness and thoroughness of soldering, wiring, impregnation of coils, markings of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.15 Human Performance/Human Engineering

Human engineering shall be implemented in design of all hardware in accordance with MIL-H-46855(1) employing the human engineering criteria of MIL-STD-1472A, MSFC-STD-267A and 10M32447A. The principles and procedures of human engineering shall be applied during the system analysis to maximize the effectiveness of man (as a systems component) during the operation and maintenance of the system. This effort shall consider the following:

- (a) Standardization
- (b) Function allocation
- (c) User capabilities and limitations
- (d) Control and display arrangement and interaction
- (e) Space requirements
- (f) Crew Safety
- (g) Environment
- (h) Simplicity
- (i) Restraints
- (j) Critical human performance criteria
- (k) Maintainability

3.4 Logistics

3.4.1 Maintenance

3.4.1.1 The ISS design shall not preclude scheduled (preventive) maintenance from being planned as an

integration of required subsystem maintenance tasks and crew operations and experiment duty time to provide an approximately flat-loaded duty time for the personnel who are most capable of conducting prescribed maintenance activities.

3.4.1.2                   The design shall permit noncritical limited-life items to remain in service until they fail; if items are critical, they shall be installed redundantly or so that a degraded alternate operating mode is available.

3.4.1.3                   The ISS shall include sufficient spares to support preventive and corrective maintenance requirements so that the missing of one regularly scheduled resupply will not jeopardize functions essential to life and mission survival. Spares shall have had the same qualification and receive the same functional tests as the initial equipment.

3.4.1.4                   Subsystems shall be designed to permit ease of access for scheduled maintenance and repair. Subsystems shall be designed to maximize capability for in-place repair by modular replacement of components or subassemblies at the installed location. Guidelines which shall be utilized in subsystems design are specified in the following paragraphs.

3.4.1.4.1                 The ISS shall be designed for prelaunch repair at the preplanned component or assembly level determined for in-space primary repair and permitted by the onboard checkout and fault isolation subsystem and fault-isolation/verification GSE.

3.4.1.4.2                 Onboard checkout capability for maintenance support will be provided to the extent required to achieve subsystem fault isolation and verification determined for individual equipment items on the basis of maintainability analyses and mission effectiveness criteria. Ancillary equipment and related calibration equipment for support

of GPL secondary maintenance functions will be determined on the same basis.

3.4.1.4.3                Each item of equipment (i. e., assembly, subassembly, and component) shall be installed with mechanical connections permitting removal and replacement with common handtools.

3.4.1.4.4                Access to maintainable equipment shall be designed in accordance with applicable portions of MSFC STD-267A. Access doors shall be captive with positive hold-open provisions.

3.4.1.4.5                Special tools shall be provided for mission-survival repairs determined from contingency analyses, such as soldering, metal-cutting, and drilling, although repairs of these types shall not be considered routine maintenance.

3.4.1.4.6                Protective clothing or protective work areas shall be provided for planned hazardous maintenance tasks, such as those involving fuels.

3.4.1.4.7                The onboard checkout and fault isolation subsystem shall provide automated maintenance procedures and stock location data for planned maintenance and repair activities.

3.4.1.4.8                An automated onboard inventory control system for spares shall be provided. An essential feature of the automated system shall be the ability to relay spares control information to the ground inventory system.

3.4.1.4.9                Maintenance support stockrooms or stowage facilities for maintenance spares shall be located in an area that provides for ease of inventory control and ready accessibility to docking locations or transfer passages. Maintenance support items for safety-critical equipment shall be given preference for ease of access.

- 3.4.1.4.10 All components associated with enabling the crew to recognize, isolate and correct critical system malfunctions for a given vehicle shall be located onboard and be functionally independent of ground support and external interfaces.
- 3.4.1.4.11 The ISS shall have the capability of being checked out either while electrically independent of or electrically integrated with other program elements.
- 3.4.1.4.12 Space Station designs shall utilize fault isolation capability to replacement level.
- 3.4.1.4.13 The Space Station structure and equipment supported by the structure must be designed and arranged to provide access for damage control and repair by suited crewmen.
- 3.4.1.4.14 Provisions shall be made for detecting, locating, and repairing meteoroid damage.
- 3.4.1.4.15 Critical items (life-essential and mission-survival equipment) require active or standby redundancy. Critical items must be readily accessible, and redundant items should be physically separated if possible.
- 3.4.1.4.16 Repair, replacement, and assembly tasks shall have a minimum of exposure to hazards.
- 3.4.1.4.17 The order of precedence for design to accommodate maintenance will be:
- Shirtsleeve environment
  - Space suit (IVA)
  - Space suit (EVA)
- 3.4.1.4.18 Replacement of wearout items will be at the lowest feasible level of assembly.
- 3.4.1.4.19 Fail-safe operation or degraded noncatastrophic operation shall be provided for critical items.



- 3.4.1.4.20 Means shall be provided to functionally isolate items to permit maintenance and to provide standby operating modes when mission constraints require "on-line" maintenance.
- 3.4.1.4.21 Contingent onboard repair and failure isolation capability for failed items shall be included in the ISS design. Cannibalization will be permitted unless the functional performance of the item is compromised.
- 3.4.1.4.22 Maximum emphasis shall be placed on commonality and standardization. This includes functional modules as well as nonfunctional items such as fittings, racks, and fasteners.
- 3.4.1.4.23 When dictated by safety requirements, provision shall be made within the ISS capability and in the critical spare configuration for onboard functional verification of spares prior to installation.
- 3.4.1.4.24 Equipment shall be designed so that replacement and repair can be accomplished by a minimum number of tools. Tools should have multiple uses.
- 3.4.1.4.25 Captive fasteners shall be used for all equipment which has planned maintenance capability.
- 3.4.1.4.26 Access for maintenance shall be accomplished with minimum disconnection of equipment.
- 3.4.1.4.27 Preferential access shall be provided for mission critical, scheduled replacement and higher failure risk items.

- 3.4.1.4.28 All wire bundles shall be routed in troughs which will permit minimum ties and maximum capability to replace damaged single wires. Redundant wire bundles for critical functions shall be physically separated and routed separately.
- 3.4.1.4.29 Access doors leading to items which may induce a potentially hazardous environment or incur injury shall be labeled with proper precautionary information and instructions.
- 3.4.1.4.30 All fluid lines and components shall be marked in the vicinity of break points to identify the fluid and show direction of flow.
- 3.4.1.4.31 The design shall provide repair capability of the maximum number of fluid handling items without penetration of fluid plumbing (separate solenoid and valve, pump and motor, etc.).
- 3.4.1.4.32 Locate functions to reduce traffic through modules and to minimize operations interruptions during maintenance activities.
- 3.4.1.4.33 Provide common installation method for like items in different modules to reduce maintenance procedures, training, and tools.
- 3.5 Personnel and Training  
Personnel and training requirements shall be as specified in Section 3.5 of Space Station Project Specification No. RS-02927.

3.6 Interface Requirements

3.6.1 Interprogram

3.6.1.1 ISS Modules CEI/Orbiter CEI, Reference RS02928, "Interface and Support Requirements, Modular Space Station Project/Orbiter Project," Appendix A, dated December 1971.

3.6.2 Intraprogram

3.6.2.1 ISS Modules CEI/RAM CEI, Reference RS02936, "Interface and Support Requirements, Modular Space Station Project/RAM Project," dated December 1971.

3.6.3 Intraproject

3.6.3.1 ISS Modules CEI/Logistics Modules CEI, Reference RS02927, "Modular Space Station Project Specification, Appendix A," dated December 1971.

4. VERIFICATION

This section specifies the requirements for verification of each requirements stated in Section 3. Section 4.2 contains the requirements which must be met for verification. The relationship of these requirements in Section 3 and the methods to be used in verification are identified in Section 4.3. The requirements specified herein are limited to the specification of those verification requirements required to implement project-level policy in the structuring of a cost-effective test program, and do not address detailed testing requirements and procedures.

4.1 General

4.1.1 Responsibility for Verification

4.1.1.1 Verification Management

Unless otherwise specified, the contractor is responsible for the verification of requirements in Section 3. Verification shall be performed in accordance with the requirements established herein.

4.1.1.2 Phase Responsibilities

4.1.1.2.1 Development

Development is conducted to establish the feasibility of the design approach and provides the contractor with confidence in the ability of his CEI to pass qualification. Development tests and assessments shall be conducted primarily to obtain empirical data to support the design and development process. As such, the extent of development shall be left to the contractor for determination, definition, performance, and supportive documentation.

In those special cases, whereby agreement of the contractor and NASA development test data verifies performance/design requirements, the responsibilities for performance and support specified for qualification shall pertain.

4.1.1.2.2 Qualification

Qualification shall be performed and documented by the contractor using standard, supportive practices as specified in NHB 5300.4 (1B). The extent and scope of qualification shall be identified and controlled by NASA/contractor action.

4.1.1.2.3 Acceptance

Acceptance verification shall be performed and supported by the CEI contractor with complete buy-off documentation such as logs, test history, test results, records of inspection, discrepancies, deficiencies, review board activities and corrective action. These activities shall be performed by the contractor under NASA surveillance to verify that the end item conforms to system performance

requirements. NASA shall participate in acceptance to the extent necessary for it to verify that item being accepted has been built in accordance with the qualified design.

4.1.1.2.4 Integrated Systems

Integrated systems verification shall be performed by the ISS module contractor under NASA direction to verify integration of the ISS, Log M, GSE, and Integral Experiments. This verification shall be performed using the Flight Integration Tool (FIT) which is the complete responsibility of the ISS module contractor.

4.1.1.2.5 Prelaunch Checkout

The contractor under the cognizance of the CEI Manager shall be responsible for verifying that the system and ground support equipment are ready for launch and launch support following transport to the launch site. This responsibility may be delegated to a centralized operation at the launch site but definition of requirements and procedures shall reside with the originating CEI Office. The CEI Management office/contractor shall interface with the Space Shuttle Launch Operations Project Office which will be responsible for the integration and overall management of these verifications. These requirements will be stated in the appropriate Interface and Support Requirements documents.

4.1.1.2.6 Flight/Mission Operation

4.1.1.2.6.1 Responsibility for verification that a system will function in its prescribed manner during Orbiter delivery to and from orbit shall be the responsibility of the contractor.

4.1.1.2.6.2 Orbital buildup and operations verification is the responsibility of the Project Office and shall be supported by the ISS Module contractor.

4.1.1.2.7 Post Flight

Post Flight evaluation shall be conducted on all modules, equipment or experiments returned to Earth from the Space Station either because of failure or planned return.

The evaluation is conducted to determine cause of failure or to verify that the item performed in accordance with specification requirements.

#### 4.1.2 Verification Method Selection

Each requirement of Section 3 shall be verified appropriately by either assessment of test.

Section 4.3 contains a matrix which identifies the method selected for verifying Section 3 requirements and also references the applicable verification requirements which are specified in Section 4.2 herein. This section specifies the criteria for verification method selection for the ISS.

##### 4.1.2.1 Selection Criteria

Verification requirements are defined based upon design margins and technical parameters specified in Section 3.0 of this document. They are also based on the criticality categories specified in paragraph 4.1.2.4 of the Space Station Project Specification, CM-02.

Table VI specifies the verification methods appropriate to each phase and criticality category. Selection of verification method is guided by this table and constrained as follows for each technical parameter.

- a. Reliability shall be assessed by analytical evaluation of test data acquired for other purposes. No tests shall specifically be designed for verifying reliability.
- b. Maintainability shall be verified primarily by analysis and demonstration. Verification by test shall be limited to mission critical maintenance tasks.
- c. Operational availability requirements shall be verified by the analysis of lower level verification data and demonstration performed in conjunction with integrated systems testing.
- d. Physical requirements shall be verified by inspection and/or test.
- e. Crew useability shall be verified by demonstration.
- f. Hardware that has been used on previous programs shall only be tested for those additional critical environments, properly allowing for interaction of environments and including lifetime when possible.

Table VI  
 VERIFICATION METHOD REQUIREMENTS

		Verification Phases																					
		Development			Qualification					Acceptance				Inte- grated Systems			Pre- launch Check- out			Flight/ Mission Oper- ations			
		Analysis	Demonstration	Test	Similarity	Analysis	Inspection	Demonstration	Test	Analysis	Inspection	Demonstration	Test	Analysis	Demonstration	Test	Inspection	Demonstration	Test	Analysis	Demonstration	Test	
Types of Hardware	Hardware General Level																						
		X	X	X	X	X	X	X	X	X	X	X	X										
Space-Station Module peculiar (including integral experiments)	Component	X	X	X	X	X	X	X	X	X	X	X											
	Assembly Subsystem	X	X	X	X	X	X	X	X	X	X	X											
	Module	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	System	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Modified/existing	Component				X	X	X	X	X	X	X	X											
	Assembly/ Subsystem				X	X	X	X	X	X	X	X											

4.1.2.2 Assessment

Assessment shall be performed in accordance with one of the following methods:

4.1.2.2.1 Similarity

Similarity is used whenever the article is similar or identical in design and manufacturing process to another article that has been previously qualified to similar criteria and analysis of dissimilarities either in design, manufacturing process or verification criteria substantiates that the article will perform its intended function within the specified envelope.

Similarity shall pertain to characteristics such as material, configuration, and functional elements or assembly, and is applied selectively for applicable environments.

4.1.2.2.2 Analysis

Analytical techniques used to verify compliance to specification requirements shall include system engineering analysis, statistics, qualitative analysis, and computer simulation. Analysis shall not be the sole basis of qualification. Analysis lends itself to the verification of items which require extrapolation from empirical data to prove satisfaction of those requirements that do not warrant the expense of acquiring empirical data.

4.1.2.2.3 Inspection

Inspection shall be used only to verify the construction features, drawing compliance, workmanship, and physical condition of the end item.

4.1.2.2.4 Demonstration

Demonstration shall be used when actual conduct/operation can verify end-item such features as service and access, maintainability, transportability, or human engineering features.



4.1.2.3                    Test  
 Testing other than development testing is performed in direct response to a Section 4 requirement and when an acceptable level of confidence is not established by any of the above assessment methods or if testing is the most cost effective method.

4.1.2.4                    Criticality Categories  
 Criticality categories are established for flight hardware to provide guidelines for determining the test emphasis consistent with attaining the objectives of mission success and crew safety. This categorization is predicated on the possibility of equipment failures which may be human or equipment induced. Table VII relates criticality categories to hardware levels. The criticality categories are as follows:

Table VII. CRITICALITY CATEGORIES

Category	Definition
1	Loss of life of crew member(s) (ground or flight).
1S	Applies to safety and hazard monitoring systems. When required to function because of failure in the related primary operations system(s), potential effect of failure is loss of life of crew member(s).
2A	Immediate mission flight termination including loss of primary mission objectives.
3	Launch delay.
4	None of the above.

4.1.3                    Relationship to Management Reviews  
 The contractor shall establish through regularly scheduled management reviews that the requirements for verification specified in Section 4.2 and the methods and phases identified in the Verification Matrix, Section 4.3, meet the specified requirements.

4.1.3.1 Preliminary Requirements Review (PRR)

4.1.3.1.1 The contractor shall support PRR by presenting verification concepts for review and assurance of compatibility overall project requirements. Development tests required to select or substantiate design approaches shall be of special concern in establishing this baseline.

4.1.3.2 Preliminary Design Review (PDR)

4.1.3.2.1 PDR, a formal technical review of the basic design approach, shall include a technical review of the basic verification approach of the CEI.

4.1.3.2.2 Test article design and operational concepts shall be reviewed at PDR.

4.1.3.2.3 Verification participation in PDR shall include identification of requirements for development testing; preliminary criteria for receiving inspection/test, in-process inspection/test, end-item test and acceptance inspection; and preliminary development and qualification test plans which include the methodology for verifying the design and performance requirements of Section 3.

4.1.3.2.4 Sufficient analyses and testing shall be conducted to provide confidence in the design approach and its producibility.

4.1.3.2.5 The Part I CEI specification listing performance/design requirements and verification methods shall be presented for approval at the PDR.

4.1.3.3 Critical Design Review (CDR)

4.1.3.3.1 The formal technical review of CEI design performed at CDR shall be supported by development verification data.

4.1.3.3.2 As a goal, all development data shall be available for comparison at CDR.

4.1.3.3.3 Test review at CDR shall cover analysis of available development and qualification test data, preliminary end-item test plans, sampling plans, and detailed inspection plans.

4.1.3.3.4 Processing and manufacturing methods specified by the design which have not been previously used shall be substantiated prior to release of drawings.

4.1.3.3.5 The Part II CEI specification indicating design solutions and verification requirements shall be presented at the CDR.

4.1.3.4 Configuration Inspection (CI)  
The Configuration Inspection is a formal technical review to determine if the end item hardware has been built and verified in accordance with the Part II CEI Specification which is presented at the CI for approval. The CI establishes that verification was performed and that the as-built hardware did in fact comply with the requirement of the Part I CEI Specification. The verification documentation and hardware presented at CI shall verify the applicable portion of Section 4.2 of this program specification.

4.1.3.5 Post-CI Reviews  
The status of verification shall be reviewed at each major milestone and documented prior to initiation of the next activity. Management reviews shall be utilized to perform these reviews. As a minimum these reviews shall occur at completion of integrated systems verification, prelaunch checkout and orbital buildup.

Specific requirements for these reviews shall be stated herein by completion of PRR.

4.1.4 Test/Equipment Failure

4.1.4.1 Failure/Retest Criteria

4.1.4.1.1 Prior to the performance of any verification, the criteria of failure must be objectively established in procedural documentation.

4.1.4.1.2 Subsequent to each failure, but prior to retest, an evaluation shall be made to determine whether partial test requirements have been met prior to failure or can be met by other means. If either is true, total retest shall not be performed.

4.1.4.1.3 Failures occurring in qualification testing shall disqualify any item with same specifications from similar use.

4.1.4.1.4 After test qualification, a posttest inspection shall be made to identify any potential failure modes.

4.1.4.1.5 Hardware used in unsuccessful tests shall be evaluated as to its further use. If the test was a failure as a result of hardware design or function, identical hardware shall be disqualified from similar use.

4.1.4.2 Hardware/Computer Program Reuse

4.1.4.2.1 As a goal, all test hardware/computer programs shall be refurbished/recompiled and reused, whenever cost effective, as higher level assembly test hardware or flight spares. In the case of failed hardware/computer programs, failure reports shall be reviewed and a determination made as to the suitability of the item for further use. This determination shall include the specification of reuse leveling (i. e., test hardware or flight spares).

4.2                                    Phased Verification Requirements

4.2.1                                Development

Development assessment and tests are performed to verify the feasibility of the design approach prior to committing to the production of flight hardware. No specific development verification requirements have been identified which are appropriate for contractual obligations with the exceptions of data management computer program functions which shall be verified using the FM.

4.2.2                                Qualification

Qualification is performed on hardware, the ISS flight modules and on the FIT to verify that design and performance specifications have been met.

4.2.2.1                              Similarity

Qualifications by similarity is not applicable to system verification. The requirements specified in the following paragraphs apply to assembly level verifications applicable to ISS qualifications by analysis, paragraph 4.2.2.2.

4.2.2.1.1                          Hardware characteristics (all or partially) qualified for use on a previous program shall be verified by similarity if the following requirements are met:

- a) Engineering evaluation reveals that design differences between the item being qualified and the previously qualified similar item are insignificant.
- b) The previously qualified similar item was designed and qualified for equal or higher environmental stress levels and time durations than those known or anticipated for the item being qualified.
- c) The item being qualified was fabricated by the same manufacturer as the similar item using the same processes, materials and quality control. Exceptions to this requirement may be granted on a case-by-case basis provided that a waiver request is submitted together with acceptable rationale to the contracting officer and that the manufacturer utilizes MSFC specified or approved process and quality control standards.

- d) Documentation is provided which assures that qualification by similarity is adequate. The submitted documentation should include as a minimum, the test specification/test procedure/test report of the item to which similarity is claimed, a description of the differences between the items and the rationale for qualification by similarity.

4.2.2.1.2                      Similarity shall be substantiated by manufacturer attestations, specifications and product inspection reports and approved by NASA.

4.2.2.2                      Analysis  
System level analysis shall be the primary method used for qualifying the ISS relative to performance under extremes of environment and other system level characteristics which may be determined by analysis of lower level data. These analyses shall appropriately translate assembly group, assembly and subassembly data reflecting similarity, analysis, demonstration and test. This data shall generally be in accordance with paragraphs 4.2.2.1 through 4.2.2.4 of this specification.

4.2.2.2.1                      Analysis shall not be the sole basis of qualification.

4.2.2.2.2                      All analyses used for qualification shall be documented as to methods and results obtained.

4.2.2.3                      Demonstration  
Demonstration is applicable to system level verification and to lower level verification applicable to ISS qualification by analysis, paragraph 4.2.2.2.

Hardware and software configurations used in demonstrations for the purpose of qualification shall be identical to flight hardware and the procedures followed must be prepared prior to the demonstration and controlled throughout the activity.

- 4.2.2.4                    Test  
Test is applicable to system level verification and to lower level verification applicable to ISS qualification by analysis, paragraph 4.2.2.2. The requirements for both applications are specified in the following paragraphs. The testing of all hardware shall be in accordance with MIL-STD-810B and MIL-STD-202D, as required.
- 4.2.2.4.1                Qualification test hardware shall be selected from a normal production run. Test hardware shall have been subjected to normal inspection and acceptance tests. If first production items are selected, then all subsequent production items shall be produced identically to the selected test items.
- 4.2.2.4.2                Hardware items subjected to qualification testing shall be so identified and shall not be utilized as life critical flight hardware.
- 4.2.2.4.3                The number of qualification test specimens selected shall be sufficient to yield a significant level of engineering confidence.
- 4.2.2.4.4                Equipment shall be qualified to nominal operations pressures and g-levels to be experienced by compartments in which they are located. In addition, equipment shall be qualified to withstand and recover from evaluation of a compartment, where critical to mission operations.
- 4.2.2.4.5                Induced environment testing shall be conducted at the assembly group level or lower. Testing shall be performed at the highest level possible within this constraint. Qualification of an item by test of a higher assembly or module is acceptable provided the item being qualified is subjected to stress levels and time durations during the higher assembly test which are equal to or higher than the environmental qualification levels and durations specified for the item in the proposed application. Interactions between the various components and subsystems must be considered and evaluated when individual hardware items are qualified as part of a higher assembly test.

- 4.2.2.4.6 The 10-year life requirement shall be verified by a combination of analysis and test.
- 4.2.2.4.7 Tests shall be conducted to verify:
- a) The performance of the hardware to perform its intended mission in the anticipated environment.
  - b) The impact of environmental sequencing and limit severity.
- 4.2.2.4.8 Qualification testing shall be conducted with controlled hardware configuration and test procedures.
- 4.2.2.4.9 Hardware that has been used on previous programs shall only be qualified for those additional critical environments.
- 4.2.2.4.10 The contractor shall verify by functional test that the electromagnetic compatibility of systems operation is within the specification of MIL-I-5061C.
- 4.2.3 Acceptance
- Acceptance shall verify that the ISS has been manufactured to the qualified design, meet the design intent and will perform during the mission as designed. All acceptance verification shall be conducted against released engineering, and shall be performed by the system contractor at the factory.
- 4.2.3.1 Analysis
- 4.2.3.1.1 Analyses shall be conducted prior to system acceptance and shall be documented in Part II (CEI) specifications.
- 4.2.3.2 Inspection
- In process inspections shall verify that prescribed methods and materials are used in the manufacturing process.



- 4.2.3.2.1 Penetrant  
Penetrant inspection shall be performed in accordance with MSFC-STD-366.
- 4.2.3.2.2 Radiographic  
Radiographic inspection of aluminum and magnesium alloy castings shall be in accordance with MSFC-STD-100(1).  
Radiographic inspection shall be performed in accordance with MSFC-SPEC-259A, MSFC-STD-355B or 10509306, as applicable.
- 4.2.3.3 Demonstration  
None identified.
- 4.2.3.4 Test  
The onboard checkout and fault isolation subsystem shall be used with GSE for ISS acceptance testing at the contractor's plant. This testing will involve the incremental acceptance of modules using the FIT with eventual ISS acceptance with the three modules as a CEI.
- 4.2.3.4.1 Leak Testing  
Leak testing shall be conducted using compounds which are compatible with the surface to which applied.  
Where service media lines are involved, the compound shall also be compatible with the applicable media. Systems or surfaces requiring the use of LOX compatible compounds shall utilize a leak detecting agent conforming to MSFC-SPEC-384A.
- 4.2.3.4.2 Ultrasonic Testing  
Ultrasonic testing of aluminum plate, if required, shall be conducted in accordance with the criteria established in MSFC-SPEC-283A.

- 4.2.4                    Integrated Systems  
Integrated systems verification is conducted to ensure the compatibility of system-level interfaces and interelement performance. The requirement for integrated systems verification has been identified at project level, but the requirements to be met by the ISS module contractor during that activity are specified herein.
- 4.2.4.1                Analysis
- 4.2.4.1.1             Analyses conducted to verify compatibility shall be documented for CDR.
- 4.2.4.1.2             Analysis shall not be the sole verification of integrated systems performance.
- 4.2.4.2                Test  
The performance of the ISS shall be tested while interfaced with the Log M, Integral Experiments and GSE. The FIT or Flight Modules shall be utilized for integration testing. This test shall be accomplished prior to transport to the launch site.
- 4.2.4.3                Demonstration
- 4.2.4.3.1             Demonstrations shall be conducted by the contractor using accepted modules or the ISS FIT may be utilized.
- 4.2.5                    Prelaunch Checkout  
Prelaunch verification shall ascertain the readiness of the flight hardware for launch and ground support equipment to support that launch.
- 4.2.5.1                Inspection
- 4.2.5.1.1             A complete visual inspection of each module shall be performed at the launch site to ensure satisfactory physical condition.
- 4.2.5.2                Demonstration

- 4.2.5.2.1 Prelaunch operations shall be performed in accordance with preestablished procedures.
- 4.2.5.2.2 Successful completion of prelaunch operations shall constitute verification by demonstration.
- 4.2.5.3 Test
- 4.2.5.3.1 Prelaunch testing of modules shall be restricted to those tests necessary to ascertain integrity relative to critical functions following transport and to the checkout of module/orbiter interface.
- 4.2.5.3.2 Logistics Options shall not be functionally tested at the launch site unless degradation is apparent from transport data.
- 4.2.6 Flight/Mission Operations  
Verification during flight/mission operations is conducted by the project to ensure mission readiness and continuity while in orbit by means of inherent onboard systems.
- 4.2.7 Postflight  
None identified.
- 4.3 Verification Matrix  
This section contains a one-for-one cross-reference of each verification requirement for each Section 3 Performance Requirement and identifies the method by which each requirement is to be verified.

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.0	X								
3.1							3		4.2.6
3.1.1				4					4.2.3.2
3.1.1.1	X								
3.1.1.1.1				3/4					4.2.3.1, 4.2.3.2
3.1.1.1.2				3/4					4.2.3.1, 4.2.3.2
3.1.1.1.3				4					4.2.3.2
3.1.1.1.3.1				4					4.2.3.2
3.1.1.1.3.2				3/4					4.2.3.1, 4.2.3.2
3.1.1.1.3.3				3/4					4.2.3.1, 4.2.3.2
3.1.1.2	X								
3.1.1.2.1	X								
3.1.1.2.2	X								
3.1.1.2.3	X								
3.1.1.2.4	X								
3.1.1.2.5	X								
3.1.2	X								
3.1.2.1			3						4.2.2.2
3.1.2.2			3						4.2.2.2
3.1.2.3			3						4.2.2.2
3.1.2.4			3						4.2.2.2
3.1.2.5			3						4.2.2.2
3.1.2.6			3						4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.1.3	X								
3.1.3.1			3						4.2.2.2
3.1.3.1.1			3/5						4.2.2.2, 4.2.2.3
3.1.3.1.1.1			5						4.2.2.3
3.1.3.1.1.2			3						4.2.2.2
3.1.3.1.1.3			3						4.2.2.2
3.1.3.1.2			3						4.2.2.2
3.1.3.1.2.2			3						4.2.2.2, 4.2.5.1
3.1.3.1.2.3			3			4			4.2.2.2, 4.2.5.1
3.1.3.1.2.4			3/5			4			4.2.2.2, 4.2.2.3, 4.2.5.1
3.1.3.1.3			3						4.2.2.2
3.1.3.1.4			3/5						4.2.2.2, 4.2.2.3
3.1.3.2			3						4.2.2.2
3.1.3.3			3						4.2.2.2
3.1.3.3.1	X								
3.1.3.3.1.1			3				4/5		4.2.2.2, 4.2.6
3.1.3.3.1.2			3						4.2.2.2
3.1.3.3.1.3			3				5		4.2.2.2, 4.2.6
3.1.3.3.2	X								
3.1.3.3.2.1			1/3				1		4.2.2.4, 4.2.2.2, 4.2.6
3.1.3.3.2.2			1/3				1		4.2.2.4, 4.2.2.2, 4.2.6
3.1.3.3.2.3			1/3				1/5		4.2.2.4, 4.2.2.2, 4.2.6
3.1.3.3.3	X								

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.1.3.3.3.1			3						4.2.2.2
3.1.3.4	X								
3.1.3.4.1	X								
3.1.3.4.1.1			3						4.2.2.2
3.1.3.4.1.2			1/3						4.2.2.4, 4.2.2.2
3.1.3.4.1.3			1/3						4.2.2.4, 4.2.2.2
3.1.3.4.1.4			1/3						4.2.2.4, 4.2.2.2
3.1.3.4.1.5			3						4.2.2.2
3.1.3.4.1.6			3/5						4.2.2.2, 4.2.2.3
3.1.3.4.2			3						4.2.2.2
3.1.3.4.2.1			3						4.2.2.2
3.1.3.4.2.2			1/3						4.2.2.4, 4.2.2.2
3.1.3.4.2.3			1/3						4.2.2.4, 4.2.2.2
3.1.3.4.2.4			1/3						4.2.2.4, 4.2.2.2
3.1.3.4.3			3						4.2.2.2
3.1.3.4.4			3						4.2.2.2
3.1.3.4.4.1			3						4.2.2.2
3.1.3.4.4.2			3						4.2.2.2
3.1.3.5	X								
3.1.3.5.1			1/3						4.2.2.4, 4.2.2.2
3.1.4	X								
3.1.5	X								
3.1.6	X								

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.1.7	X								
3.2	X								
3.2.1	X								
3.2.1.1	X								
3.2.1.1.1			3						4.2.2.2
3.2.1.1.2			3						4.2.2.2
3.2.1.1.3			5						4.2.2.3
3.2.1.1.4	X								
3.2.1.1.4.1			3						4.2.2.2
3.2.1.1.4.2			3						4.2.2.2
3.2.1.1.4.3			3						4.2.2.2
3.2.1.1.5			3						4.2.2.2
3.2.1.1.6	X								
3.2.1.1.6.1			3/5						4.2.2.2, 4.2.2.3
3.2.1.1.6.2			3/5						4.2.2.2, 4.2.2.3
3.2.1.1.6.3			3						4.2.2.2, 4.2.2.3
3.2.1.1.6.4			3/5						4.2.2.2, 4.2.2.3
3.2.1.1.6.5			5						4.2.2.3
3.2.1.1.6.6			3						4.2.2.2
3.2.1.2			3						4.2.2.2
3.2.1.2.1	X								
3.2.1.2.1.1	X								
3.2.1.2.1.1.1			1						4.2.2.4

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.2.1.1.2			3						4.2.2.2
3.2.1.2.1.1.3			3						4.2.2.2
3.2.1.2.1.1.4			3/5						4.2.2.2, 4.2.2.3
3.2.1.2.1.1.5			1						4.2.2.4
3.2.1.2.1.1.6			1/3						4.2.2.4, 4.2.2.2
3.2.1.2.1.2			3						4.2.2.2
3.2.1.2.2	X								
3.2.1.2.2.1	X								
3.2.1.2.2.1.1			1						4.2.2.4
3.2.1.2.2.1.2			1/3						4.2.2.4, 4.2.2.2
3.2.1.2.2.1.3			1						4.2.2.4
3.2.1.2.2.1.4			1						4.2.2.4
3.2.1.2.2.2			3						4.2.2.2
3.2.1.2.3	X								
3.2.1.2.3.1	X								
3.2.1.2.3.1.1			1						4.2.2.4
3.2.1.2.3.1.2			1						4.2.2.4
3.2.1.2.3.1.3			1/5						4.2.2.4, 4.2.2.3
3.2.1.2.3.1.4			3						4.2.2.2
3.2.1.2.3.2			3						4.2.2.2
3.2.1.2.4	X								
3.2.1.2.4.1	X								
3.2.1.2.4.1.1			1/5						4.2.2.4, 4.2.2.3



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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.2.4.1.2			1/5						4.2.2.4, 4.2.2.3
3.2.1.2.4.2			3						4.2.2.2
3.2.1.2.5	X								
3.2.1.2.5.1	X								
3.2.1.2.5.1.1			1						4.2.2.4
3.2.1.2.5.1.2			1						4.2.2.4
3.2.1.2.5.1.3			1						4.2.2.4
3.2.1.2.5.1.4			3/5						4.2.2.2, 4.2.2.3
3.2.1.2.5.2			3						4.2.2.2
3.2.1.2.6	X								
3.2.1.2.6.1	X								
3.2.1.2.6.1.1		1	3						4.2.1, 4.2.2.2
3.2.1.2.6.1.2			1/3						4.2.2.4, 4.2.2.2
3.2.1.2.6.1.3			1/3						4.2.2.4, 4.2.2.2
3.2.1.2.6.1.4			3						4.2.2.2
3.2.1.2.6.2			3						4.2.2.2
3.2.1.2.6.3			3						4.2.2.2
3.2.1.3	X								
3.2.1.3.1	X								
3.2.1.3.2	X								
3.2.1.3.3	X								
3.2.1.3.3.1			3						4.2.2.2
3.2.1.3.3.2			3						4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.3.3.3			3						4.2.2.2
3.2.1.3.4	X								
3.2.1.3.4.1	X								
3.2.1.3.4.1.1			3						4.2.2.2
3.2.1.3.4.1.2			3						4.2.2.2
3.2.1.3.4.1.3			3						4.2.2.2
3.2.1.3.4.3			3						4.2.2.2
3.2.1.3.4.4			3						4.2.2.2
3.2.1.3.4.5			3						4.2.2.2
3.2.1.3.4.6			3						4.2.2.2
3.2.1.3.4.7			3						4.2.2.2
3.2.1.3.4.8			3						4.2.2.2
3.2.1.3.5	X								
3.2.1.3.5.1			3						4.2.2.2
3.2.1.3.5.2			3						4.2.2.2
3.2.1.3.5.3			1						4.2.2.4
3.2.1.3.5.4			1						4.2.2.4
3.2.1.3.5.5			4/5						4.2.2.4, 4.2.2.3
3.2.1.3.5.6			1/5						4.2.2.4, 4.2.2.3
3.2.1.3.5.6.1			1						4.2.2.4
3.2.1.3.5.6.2			5						4.2.2.3
3.2.1.3.5.6.3			5						4.2.2.3

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.3.5.6.4			3						4.2.2.2
3.2.1.3.5.7	X								
3.2.1.3.5.7.1			3/5						4.2.2.2, 4.2.2.3
3.2.1.3.5.7.2			5						4.2.2.3
3.2.1.3.5.7.3			1						4.2.2.4
3.2.1.3.5.7.4			5						4.2.2.3
3.2.1.3.5.7.5			5						4.2.2.3
3.2.1.3.5.8			5						4.2.2.3
3.2.1.3.5.9			5						4.2.2.3
3.2.1.3.5.10	X								
3.2.1.3.5.10.1			3						4.2.2.2
3.2.1.3.5.10.2			3						4.2.2.2
3.2.1.3.5.10.3			3						4.2.2.2
3.2.1.3.5.11			3						4.2.2.2
3.2.1.4	X								
3.2.1.4.1.1	X								
3.2.1.4.1.1.1			3				1		4.2.2.2, 4.2.6
3.2.1.4.1.1.2			3				1		4.2.2.2, 4.2.6
3.2.1.4.1.1.3			1/3						4.2.2.4, 4.2.2.2, 4.2.6
3.2.1.4.1.1.4	X								
3.2.1.4.1.1.5			3						4.2.2.2
3.2.1.4.1.1.6			3						4.2.2.2
3.2.1.4.1.1.7			3						4.2.2.2

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Flight Checkout
- F. Mission Operations
- G. Post-flight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Method								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.4.1.1.8			3						4.2.2.2
3.2.1.4.1.2	X								
3.2.1.4.1.2.1			3				1		4.2.2.2, 4.2.5.3, 4.2.6
3.2.1.4.1.2.2			3				1		4.2.2.2, 4.2.5.3, 4.2.6
3.2.1.4.1.2.3			3				1		4.2.2.2
3.2.1.4.1.3	X								
3.2.1.4.1.3.1			3						4.2.2.2
3.2.1.4.1.3.2			3						4.2.2.2
3.2.1.4.1.3.3			3/5						4.2.2.2, 4.2.2.3
3.2.1.4.2	X								
3.2.1.4.2.1	X								
3.2.1.4.2.1.1			1/3						4.2.2.4, 4.2.2.2
3.2.1.4.2.1.2			3						4.2.2.2
3.2.1.4.2.1.3			3						4.2.2.2
3.2.1.4.2.1.4			1						4.2.2.4
3.2.1.4.2.1.5			3						4.2.2.2
3.2.1.4.2.1.6			3						4.2.2.2
3.2.1.4.2.2			3						4.2.2.2
3.2.1.4.2.3			3			1			4.2.2.2, 4.2.5.3
3.2.1.4.2.4			3			1			4.2.2.2, 4.2.5.3
3.2.1.4.3	X								
3.2.1.4.3.1	X								
3.2.1.4.3.1.1			1/3						4.2.2.4, 4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.4.3.1.2			1/3						4.2.2.4, 4.2.2.2
3.2.1.4.3.1.3			3						4.2.2.2
3.2.1.4.3.1.4			3						4.2.2.2
3.2.1.4.3.1.5			1/3						4.2.2.4, 4.2.2.2
3.2.1.4.3.1.6			5						4.2.2.3
3.2.1.4.3.1.7			3						4.2.2.2
3.2.1.4.3.1.8			3						4.2.2.2
3.2.1.4.3.1.9			5				5		4.2.2.3, 4.2.6
3.2.1.4.3.2	X								
3.2.1.4.3.2.1			3/5						4.2.2.2, 4.2.2.3
3.2.1.4.3.3	X								
3.2.1.4.3.3.1			3				1		4.2.2.2, 4.2.6
3.2.1.4.3.3.2			3						4.2.2.2, 4.2.6
3.2.1.4.3.4	X								
3.2.1.4.3.4.1			3			1			4.2.2.2, 4.2.5.3
3.2.1.4.3.5	X								
3.2.1.4.3.5.1			3						4.2.2.2
3.2.1.4.3.5.2			3						4.2.2.2
3.2.1.4.4	X								
3.2.1.4.4.1	X								
3.2.1.4.4.1.1	X								
3.2.1.4.4.1.2			1						4.2.2.4
3.2.1.4.4.1.3			3						4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

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3.2.1.4.4.3.2			1						4.2.2.4
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3.2.1.4.5.4.2			3			1			4.2.2.2, 4.2.5.3
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3.2.1.4.6.1	X								
3.2.1.4.6.1.1	X								
3.2.1.4.6.1.2			1						4.2.2.4
3.2.1.4.6.1.3			1						4.2.2.4

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
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3.2.1.4.6.1.5			1						4.2.2.4
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3.2.1.4.7.1.3			3						4.2.2.2
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3.2.1.5.1.1			3						4.2.2.2
3.2.1.5.1.2	X								
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3.2.1.5.2.2.2			3						4.2.2.2
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3.2.1.5.3	X								
3.2.1.5.3.1			3						4.2.2.2
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3.2.1.5.3.3	X								
3.2.1.5.4	X								
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3.2.1.5.4.2			3						4.2.2.2
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3.2.1.6	X								
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3.2.1.7.1			3						4.2.2.2
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3.2.1.7.1.1.2			3						4.2.2.2
3.2.1.7.1.1.3			1/3						4.2.2.4, 4.2.2.2
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3.2.1.7.3.1.1			3						4.2.2.2
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3.2.1.8	X								
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3.2.1.8.1.1	X								
3.2.1.8.1.1.1			1/3						4.2.2.4, 4.2.2.2
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3.2.1.8.1.1.4			1/3						4.2.2.4, 4.2.2.2
3.2.1.8.1.1.5			1/3						4.2.2.4, 4.2.2.2
3.2.1.8.1.1.6			1/3						4.2.2.4, 4.2.2.2
3.2.1.8.1.2	X								
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3.2.1.8.2.2			3						4.2.2.2
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3.2.1.8.3			3				1		4.2.2.2, 4.2.6
3.2.1.8.3.1	X								
3.2.1.8.3.1.1			1/3						4.2.2.4, 4.2.2.2
3.2.1.8.3.1.2			1/3						4.2.2.4, 4.2.2.2
3.2.1.8.3.1.3			1/3						4.2.2.4, 4.2.2.2
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3.2.1.8.3.2	X								
3.2.1.8.3.3	X								
3.2.1.8.4			3						4.2.2.2
3.2.1.8.4.1	X								
3.2.1.8.4.1.1			1/3						4.2.2.4, 4.2.2.2
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
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Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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3.2.1.9	X								
3.2.1.9.1			3						4.2.2.2
3.2.1.9.1.1	X								
3.2.1.9.1.1.1			1						4.2.2.4
3.2.1.9.1.1.2		1	3						4.2.1, 4.2.2.2
3.2.1.9.1.1.3			1/3						4.2.2.4, 4.2.2.2
3.2.1.9.1.1.4			1						4.2.2.4, 4.2.2.2
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3.2.1.9.1.1.12			1						4.2.2.4
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3.2.1.9.2			1/3						4.2.2.4, 4.2.2.2
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3.2.1.9.2.1.1			1/3						4.2.2.4, 4.2.2.2
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
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3.2.1.9.2.1.6			5						4.2.2.3
3.2.1.9.2.1.7			1/3						4.2.2.4, 4.2.2.2
3.2.1.9.2.1.8			3				1		4.2.2.2, 4.2.6
3.2.1.9.2.2			3						4.2.2.2,
3.2.1.9.3	X								
3.2.1.9.3.1	X								
3.2.1.9.3.1.1		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
3.2.1.9.3.1.2			1/3						4.2.2.4, 4.2.2.2
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3.2.1.9.4.1.2			1						4.2.2.4
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3.2.1.9.4.1.8			1/5						4.2.2.4, 4.2.2.3
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**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
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5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

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3.2.1.9.4.1.12			1/5						4.2.2.4, 4.2.2.3
3.2.1.9.4.2			3						4.2.2.2
3.2.1.9.5	X								
3.2.1.9.5.1	X								
3.2.1.9.5.1.1			3						4.2.2.2
3.2.1.9.5.1.2			3						4.2.2.2
3.2.1.9.5.1.3			3						4.2.2.2
3.2.1.9.6	X								
3.2.1.9.6.1	X								
3.2.1.9.6.1.1			3						4.2.2.2
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3.2.1.9.7.1.7		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
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3.2.1.10.1	X								

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3.2.1.10.1.3			3						4.2.2.2
3.2.1.10.1.3.1			3						4.2.2.2
3.2.1.10.1.3.2			3						4.2.2.2
3.2.1.10.1.3.3			3						4.2.2.2
3.2.1.10.1.3.3.1			3						4.2.2.2
3.2.1.10.1.3.3.2			3						4.2.2.2
3.2.1.10.1.3.4			3						4.2.2.2
3.2.1.10.1.3.4.1			3						4.2.2.2
3.2.1.10.1.3.4.2			3						4.2.2.2
3.2.1.10.1.3.5			3						4.2.2.2
3.2.1.10.1.3.6			3						4.2.2.2
3.2.1.10.2	X								4.2.2.2
3.2.1.10.2.1			3						4.2.2.2
3.2.1.10.2.2			3						4.2.2.2
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- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.10.3	X								
3.2.1.10.3.1			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.1.1			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.1.2			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.1.3			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.1.4			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.1.5			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.2	X								
3.2.1.10.3.2.1			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.2.2			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.2.3			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.2.4			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.2.5			3/5						4.2.2.2, 4.2.2.3
3.2.1.10.3.2.6			3						4.2.2.2,
3.2.1.10.3.2.7			3						4.2.2.2
3.2.1.10.3.3			3						4.2.2.2
3.2.1.10.3.3.1			3						4.2.2.2
3.2.1.10.3.3.2			3						4.2.2.2
3.2.1.10.3.3.3			3						4.2.2.2
3.2.1.10.3.3.4			3						4.2.2.2
3.2.1.10.4			1/3						4.2.2.4, 4.2.2.2
3.2.1.10.4.1			1/3						4.2.2.4, 4.2.2.2
3.2.1.10.4.2	X								

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.10.4.2.1			5						4.2.2.3
3.2.1.10.4.2.2			5						4.2.2.3
3.2.1.10.4.3			1						4.2.2.4
3.2.1.10.4.4			3						4.2.2.2
3.2.1.10.5			3						4.2.2.2
3.2.1.10.5.1	X								
3.2.1.10.5.1.1			3						4.2.2.2
3.2.1.10.5.1.2			3						4.2.2.2
3.2.1.10.5.1.3			3						4.2.2.2
3.2.1.10.5.2			3						4.2.2.2
3.2.1.10.5.3			3						4.2.2.2
3.2.1.10.5.4			3						4.2.2.2
3.2.1.10.6			3						4.2.2.2
3.2.1.10.7			3						4.2.2.2
3.2.1.10.7.1	X								
3.2.1.10.7.1.1	X								
3.2.1.10.7.1.1.1			3						4.2.2.2
3.2.1.10.7.1.1.2			3						4.2.2.2
3.2.1.10.7.1.1.3			3						4.2.2.2
3.2.1.10.7.1.1.4			3						4.2.2.2
3.2.1.10.7.1.1.5			3						4.2.2.2
3.2.1.10.7.1.2			3						4.2.2.2
3.2.1.10.7.1.2.1			3						4.2.2.2



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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.10.7.1.2.2			3						4.2.2.2
3.2.1.10.7.1.3			3						4.2.2.2
3.2.1.10.7.1.3.1			3						4.2.2.2
3.2.1.10.7.1.3.2			3						4.2.2.2
3.2.1.10.7.1.3.3			3						4.2.2.2
3.2.1.10.7.1.3.4			3						4.2.2.2
3.2.1.10.7.1.3.5			3						4.2.2.2
3.2.1.10.7.1.3.6			3						4.2.2.2
3.2.1.10.7.1.3.7			3						4.2.2.2
3.2.1.10.7.1.4			3						4.2.2.2
3.2.1.10.7.2	X								
3.2.1.10.7.2.1			3						4.2.2.2
3.2.1.10.7.2.2			3						4.2.2.2
3.2.1.10.7.3			3						4.2.2.2
3.2.1.10.8			3						4.2.2.2
3.2.1.10.9			3						4.2.2.2
3.2.1.10.9.1			3						4.2.2.2
3.2.1.10.10			3						4.2.2.2
3.2.1.11			3						4.2.2.2
3.2.1.11.1	X								
3.2.1.11.1.1	X								
3.2.1.11.1.1.1			1/3						4.2.2.4, 4.2.2.2
3.2.1.11.1.1.2			1						4.2.2.4, 4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

<b>VERIFICATION METHOD:</b> 1. Test 2. Similarity 3. Analysis 4. Inspection 5. Demonstration  N/A - Not Applicable	<b>VERIFICATION PHASE:</b> A. Development B. Qualification C. Acceptance D. Integrated Systems E. Prelaunch Checkout F. Flight/Mission Operations G. Postflight
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Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.11.1.1.3			1						4.2.2.4, 4.2.2.2
3.2.1.11.1.2			3						4.2.2.2
3.2.1.11.1.3			3						4.2.2.2
3.2.1.11.2			1						4.2.2.4
3.2.1.11.2.1	X								
3.2.1.11.2.1.1			1						4.2.2.4
3.2.1.11.2.1.2			1						4.2.2.4
3.2.1.11.2.2			1/3						4.2.2.2, 4.2.2.4
3.2.1.11.2.3			3						4.2.2.2
3.2.1.11.3			1						4.2.2.4
3.2.1.11.3.1	X								
3.2.1.11.3.1.1			1						4.2.2.4
3.2.1.11.3.1.2			1						4.2.2.4
3.2.1.11.3.1.2.1			1						4.2.2.4
3.2.1.11.3.1.2.2			1						4.2.2.4
3.2.1.11.3.1.2.3			1						4.2.2.4
3.2.1.11.3.1.2.4			1						4.2.2.4
3.2.1.11.3.1.2.5			1						4.2.2.4
3.2.1.11.3.1.2.6			1						4.2.2.4
3.2.1.11.3.1.2.7			1/3						4.2.2.2, 4.2.2.4
3.2.1.11.3.1.2.8			1/3						4.2.2.2, 4.2.2.4
3.2.1.11.3.1.2.9			1/3						4.2.2.2, 4.2.2.4
3.2.1.11.3.1.3			1/3						4.2.2.2, 4.2.2.4

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.11.3.1.3.1			3/1						4.2.2.2, 4.2.2.4
3.2.1.11.3.1.3.2			3/1						4.2.2.2, 4.2.2.4
3.2.1.11.3.1.3.3			1/3						
3.2.1.11.3.1.3.4			3						4.2.2.2
3.2.1.11.3.2			3						4.2.2.2
3.2.1.11.3.3			3						4.2.2.2
3.2.1.11.4			3						4.2.2.2
3.2.1.11.4.1	X								
3.2.1.11.4.1.1		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
3.2.1.11.4.1.2		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
3.2.1.11.4.1.3		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
3.2.1.11.4.1.4		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
3.2.1.11.4.1.5		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
3.2.1.11.4.1.6		1	1/3						4.2.1, 4.2.2.4, 4.2.2.2
3.2.1.11.4.2			3						4.2.2.2
3.2.1.11.4.3			3						4.2.2.2
3.2.1.12			3						4.2.2.2
3.2.1.12.1			3						4.2.2.2
3.2.1.12.1.1			3						4.2.2.2
3.2.1.12.1.2			3						4.2.2.2
3.2.1.12.1.3			3						4.2.2.2
3.2.1.12.1.4			3						4.2.2.2
3.2.1.12.1.5			3						4.2.2.2

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.12.1.6			3						4.2.2.2
3.2.1.12.2			3						4.2.2.2
3.2.1.12.2.1			3						4.2.2.2
3.2.1.12.2.2			3						4.2.2.2
3.2.1.12.2.3			5						4.2.2.3
3.2.1.12.3			3						4.2.2.2
3.2.1.12.3.1			3/5						4.2.2.2, 4.2.2.3
3.2.1.12.3.2			3/5						4.2.2.2, 4.2.2.3
3.2.1.12.3.3			3/5						4.2.2.2, 4.2.2.3
3.2.1.12.3.4			3/5						4.2.2.2, 4.2.2.3
3.2.1.12.3.5			3/5						4.2.2.2, 4.2.2.3
3.2.1.12.4			3						4.2.2.2
3.2.1.12.4.1			1/3						4.2.2.4, 4.2.2.2
3.2.1.12.4.2			3/5						4.2.2.2, 4.2.2.3
3.2.1.12.5			3/5						4.2.2.2, 4.2.2.3
3.2.1.12.5.1			5						4.2.2.3
3.2.1.12.5.2			3/5						4.2.2.3,
3.2.1.12.5.3			3/5						4.2.2.3
3.2.1.12.5.4			3/5						4.2.2.3
3.2.1.12.6			3						4.2.2.2
3.2.1.12.6.1			5						4.2.2.3
3.2.1.12.6.2			5						4.2.2.3
3.2.1.12.6.3			5						4.2.2.3

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0. Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.12.6.4			5						4.2.2.3
3.2.1.12.6.5			5						4.2.2.3
3.2.1.12.7			3						4.2.2.3
3.2.1.12.7.1			5						4.2.2.3
3.2.1.12.7.2			5						4.2.2.3
3.2.1.12.7.3			5						4.2.2.3
3.2.1.12.7.4			5						4.2.2.3
3.2.1.12.7.5			1/3						4.2.2.4, 4.2.2.2
3.2.1.12.7.6			3						4.2.2.2
3.2.1.12.7.7			3/5						4.2.2.3,
3.2.2	X								
3.2.2.1									
3.2.2.1.1			1/5						
3.2.2.1.2			3	3					4.2.2.2
3.2.2.1.3			3						4.2.2.2
3.2.2.1.4			3						4.2.2.2
3.2.2.1.5			3	3					4.2.2.2
3.2.2.1.6			3						4.2.2.2
3.2.2.1.7			3						4.2.2.2
3.2.2.2	X								
3.2.2.2.1			3						4.2.2.2
3.2.2.2.2			3	3/4					4.2.2.2, 4.2.3.1, 4.2.3.2
3.2.2.3	X								

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.2.3.1			3	4					4.2.2.2, 4.2.3.2
3.2.2.3.2			3	4					4.2.2.2, 4.2.3.2
3.2.2.4	X								
3.2.2.4.1			3						4.2.2.2
3.2.2.4.2			3						4.2.2.2
3.2.2.4.3			3						4.2.2.2
3.2.2.4.4			3						4.2.2.2
3.2.2.5	X								
3.2.2.5.1			3						4.2.2.2
3.2.2.5.1.1			3						4.2.2.2
3.2.2.5.1.2			3						4.2.2.2
3.2.2.5.1.3			3						4.2.2.2
3.2.2.5.1.4			3						4.2.2.2
3.2.2.5.1.5			3						4.2.2.2
3.2.2.5.2	X								
3.2.2.5.2.1			3/5						4.2.2.2, 4.2.2.3
3.2.2.5.2.2			3						4.2.2.2
3.2.2.5.3	X								
3.2.2.5.3.1			3						4.2.2.2
3.2.2.5.3.2			3						4.2.2.2
3.2.3			3						4.2.2.2
3.2.3.1			3						4.2.2.2
3.2.3.2			3						4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

<b>VERIFICATION METHOD:</b> 1. Test 2. Similarity 3. Analysis 4. Inspection 5. Demonstration  N/A - Not Applicable	<b>VERIFICATION PHASE:</b> A. Development B. Qualification C. Acceptance D. Integrated Systems E. Prelaunch Checkout F. Flight/Mission Operations G. Postflight
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Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.4			3						4.2.2.2
3.2.4.1	X								
3.2.4.1.1	X								
3.2.4.1.2	X								
3.2.4.1.2.1			3/5						4.2.2.2, 4.2.2.3
3.2.4.1.2.2			3/5						4.2.2.2, 4.2.2.3
3.2.4.1.2.3			3/5						4.2.2.2, 4.2.2.3
3.2.4.2			3						4.2.2.2
3.2.4.2.1	X								
3.2.4.2.2	X								
3.2.4.2.3			3/5						4.2.2.2, 4.2.2.3
3.2.5				1					4.2.3.4
3.2.5.1			3						4.2.3.4
3.2.5.2			3						4.2.3.4
3.2.5.3			3						4.2.3.4
3.2.6	X								
3.2.6.1	X								
3.2.6.1.1			3						4.2.2.2
3.2.6.1.2			3						4.2.2.2
3.2.6.1.3			3						4.2.2.2
3.2.6.1.4			3						4.2.2.2
3.2.6.1.5			3						4.2.2.2
3.2.6.1.6			3						4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.6.1.7	X								
3.2.6.1.7.1			3						4.2.2.2
3.2.6.1.7.2			3						4.2.2.2
3.2.6.1.7.3			3						4.2.2.2
3.2.6.1.7.4			3						4.2.2.2
3.2.6.1.7.5			3						4.2.2.2
3.2.6.1.8			3						4.2.2.2
3.2.6.1.9			3						4.2.2.2
3.2.6.2	X								
3.2.6.2.1	X								
3.2.6.2.1.1			3						4.2.2.2
3.2.6.2.1.2			3						4.2.2.2
3.2.7			3						4.2.2.2
3.2.8			3						4.2.2.2
3.2.9	X								
3.3	X								
3.3.1			3						4.2.2.2
3.3.2	X								
3.3.2.1	X								
3.3.2.2	X								
3.3.2.2.1			3						4.2.2.2
3.3.2.2.2			3						4.2.2.2
3.3.2.2.3			3						4.2.2.2



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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

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2. Similarity
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4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
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- C. Acceptance
- D. Integrated Systems
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- F. Flight/Mission Operations
- G. Postflight

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**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

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**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
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- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
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N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
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- 4.4 Test Support Requirements
  - 4.4.1 Facilities and Equipment
    - 4.4.1.1 Test equipment needed to simulate inputs/outputs to subsystems shall be compatible with the onboard checkout and fault isolation system and other interfacing subsystems.
    - 4.4.1.2 All test equipment shall be certified to ensure that no damage or degradation is introduced into the test hardware or that results will not include test equipment error.
    - 4.4.1.3 Special high levels of atmospheric or surface cleanliness shall not be required for verification processes unless necessary to the requirement being verified.
  - 4.4.2 Articles
    - ISS Test Articles shall consist of and be limited to a Functional Model (FM) and a Flight Integration Tool (FIT) unit. Performance and design requirements specified in the following paragraphs shall determine the characteristics of the test articles, as integrated with the test article GSE.
    - 4.4.2.1 Functional Model
      - 4.4.2.1.1 FM Capability Requirements
        - 4.4.2.1.1.1 The ISS Functional Model shall provide the capability of being utilized to develop the functional integration of ISS subsystems. As a design goal it shall provide design assurance that all ISS equipment shall perform properly when subsequently the FIT and flight articles are tested.
        - 4.4.2.1.1.2 The FM shall be capable of providing a computer program development facility for the ISS.
        - 4.4.2.1.1.3 The FM shall be capable of being used for development of preliminary operations procedures, relative to crew utilization of the control consoles.

4.4.2.1.2 FM Composition

4.4.2.1.2.1 The FM shall functionally represent the entire ISS. This shall be accomplished either by interconnection of flight equipment or by simulation.

4.4.2.1.2.2 All critical functional interfaces shall be simulated, including representative interfaces with the Log M, integral experiments and RAM's and the communications interface with the ground (direct and via the DRSS).

4.4.2.1.2.3 As a design goal the entire electrical/electronic function shall be represented by flight hardware. Exceptions include equipment such as solar arrays which are not feasible for test article application, and redundant features which are not required for design integration. As a minimum, the following shall be included:

- a) The complete data management subsystem including displays and controls of the Crew/Operations Module and the GPL Module.
- b) All automatic redundancy management equipment.
- c) A highly representative portion of the onboard checkout and fault isolation subsystem.
- d) Representative data sensors or data source devices from all subsystems.

4.4.2.1.2.4 Flight equipment shall be composed of a combination of production flight hardware and assemblies or components from the development program which shall be functionally equivalent to production equipment.

4.4.2.1.3 FM Design and Construction Standards

4.4.2.1.3.1 Structural

The FM design shall provide for physical installation of hardware in equipment racks suitable for a laboratory environment. The installation shall represent the modular allocation of equipment. Control consoles shall physically represent the flight article.

4.4.2.1.3.2            Functional

The FM design shall provide interconnect of equipment which shall duplicate flight vehicle interconnect design, with the exception of detail cable lengths and arrangements. The connections at the module interfaces shall be duplicated and the FM design shall provide for easy access to disconnect the interface and for convenient connection of any FM module representation to some other equipment (such as a FIT Module).

4.4.2.1.3.3            Operating Life

The FM shall be designed to be operated for three years.

4.4.2.1.4            FM Configuration Control

The FM design shall accommodate a change control system which shall, as a minimum, provide traceability of interconnect changes and provide the capability to establish, at the FM facility, a specific detailed functional configuration.

4.4.2.2            Flight Integration Tool

4.4.2.2.1            FIT Capability Requirements

4.4.2.2.1.1            The ISS FIT shall provide the capability of being utilized on the ground to physically represent, in detail, the orbiting configuration of the ISS, including:

- a) All interior structural provisions, arrangements, and equipment installations.
- b) Access to interior equipment and capability to remove or replace hardware as required in orbit for either normal maintenance, contingency maintenance, or design growth modification.
- c) Interface with the integral experiments and experiment integration hardware to the extent required to be utilized to verify the interface physically.

4.4.2.2.1.2           The FIT shall provide the capability of being utilized on the ground to functionally represent the orbiting configuration of the ISS to a limited extent, including:

- a) The complete electrical/electronic network including all devices which may conveniently be operated in a ground facility.
- b) Interfaces with integral experiments, experiment integration hardware and RAM's, to the extent required to functionally verify the interfaces.
- c) All redundancy management functions required to represent normal and contingency switchover.
- d) Capability to conduct onboard checkout and fault isolation; requiring, as a minimum, functional data source devices associated with all subsystems.

4.4.2.2.2           FIT Composition

4.4.2.2.2.1           The FIT shall represent the entire ISS interior, accomplished by physically installing and inter-connecting flight equipment. Simulation shall be limited to items which are not feasible for ground facility installation.

4.4.2.2.2.2           All critical interfaces shall be represented to the extent required for the FIT to be utilized to represent flight vehicle operations. In addition, at least one FIT docking port shall be capable of interfacing functionally with any other module test article, interface substitute or flight article.

4.4.2.2.2.3           The FIT shall include special access provisions such as handrails, ladders, safety devices, or air-conditioning ducts which shall be added as required; maintaining the integrity of the representation of flight vehicle interiors to the greatest extent possible.

4.4.2.2.3           FIT Design and Construction Standards

4.4.2.2.3.1           Structural  
FIT Structure shall be the same as flight article structure relative to all features affecting the interiors.

Structure from the test program or development fixture hardware shall be acceptable.

4.4.2.2.3.2            Functional

The FIT design shall provide interconnect of equipment which shall duplicate flight vehicle interconnect design including cable lengths and arrangements. The three modules may be physically separated and functionally interconnected by jumpers which are not representative of flight hardware. The FIT design shall provide for easy access to disconnect the interface and for convenient connection of any FIT module to some other equipment (such as the FM).

4.4.2.2.3.3            Operating Life

The FIT shall be designed to be operated for 12 years.

4.4.2.2.4            FIT Configuration Control

The FIT design shall accommodate a change control system which shall, as a minimum, provide configuration control equivalent to that of the flight vehicle for all designs which are utilized to represent the flight vehicle.

PRIME EQUIPMENT DETAIL SPECIFICATION  
PART I OF TWO PARTS  
PERFORMANCE, DESIGN AND VERIFICATION REQUIREMENTS  
FOR  
LOGISTICS MODULE  
(CEI NUMBER CP-02930)  
FOR  
MODULAR SPACE STATION PROJECT

APPROVED BY J.D. Smith  
(Preparing Activity)

APPROVED BY W.G. Brinkley  
(NASA Office)

DATE 15 December 1971

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1. SCOPE

This part of this specification establishes the requirements for performance, design and verification for one type-model-series of equipment identified as the Logistics Module (Log M), CEI\_\_\_\_\_.

It constitutes the logistics vehicle for the Modular Space Station Project during the first 5 years of operation, designated the Initial Space Station phase of the Modular Space Station Program. It is a system of the Modular Space Station Project. Other Systems of the Modular Space Station Project include the integral experiments which are accommodated in the ISS and the Ground Support Equipment and Facilities which support the project from development through operations.

The Modular Space Station Project, when integrated with the Research and Application Module (RAM) Project and supported by the Space Shuttle Program forms the Space Station Program, providing a laboratory in Earth orbit to conduct and support scientific and technological experiments for beneficial application and for further development of space exploration capability.

This document is subordinate and constrained by the requirements specified in MSFC Data Procurement Document 235, Data Requirement CM-02, Specification, Modular Space Station Project.

2. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced, and other detailed contents of this specification, the detailed requirements herein shall be considered superseding.

SPECIFICATIONS

Text Reference

Federal

- MSFC-SPEC-250,  
Protective Finishes for Space Vehicle  
Structures, February 1964 3.3.9.1
- MSFC-SPEC-491,  
Space Vehicle Ordnance Systems,  
January 1970 3.3.2.2.5

Military

- MIL-B-5087B(ASG),  
Bonding, Electrical, and Lighting  
Protection for Aerospace Systems,  
31 August 1970 3.3.5.1
- MIL-E-6051D,  
Electromagnetic Compatibility Requirements,  
System, 5 July 1968 3.3.5.1
- MIL-H-25475A,  
Hydraulic Systems, Missile, Design,  
Installation Tests, and Date Require-  
ments, General Requirements for,  
19 January 1961 3.3.6.2
- MIL-I-6181D,  
Interference Control Requirements,  
Aircraft Equipment, 22 June 1965 3.3.5.1

STANDARDS

Federal

- MSFC-PROC-158,  
Soldering of Electrical Connections,  
Notice-1 August 1968 3.3.5.5
- MSFC-STD-267A,  
Human Engineering Design Criteria,  
September 1968 3.2.4.1,  
3.4.1.3.4

Military

- MIL-STD-129E,  
Marking for Shipment and Storage,  
20 April 1970 3.3.13
- MIL-STD-130C,  
Identification Marking of U. S. Military  
Property, 29 September 1967 3.3.13

MIL-STD-143B, Standards and Specifications, Order of Precedence for the Selection of 12 November 1969	3.3.1
MIL-STD-721B, Definition of Effectiveness Terms for Reliability Maintainability, Human Factors, and Safety, 25 August 1966	3.3.12
MIL-STD-810B Environmental Test Method	3.3.8

OTHER PUBLICATIONS

Manuals

MM8040.12 Standard Contractor Configuration Management Requirements MSFC Programs, July 28, 1971	
NHB 5300.4 (1A), Reliability Program Provisions	
NHB 5300.4 (1B) Quality Program Provisions	

Regulations

U. S. Atomic Energy Commission Title 10 Code of Federal Regulations	3.3.7
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Handbooks

MIL-HDBK-5, Metallic Materials and Elements for Aerospace Vehicle Structures	3.3.6
MIL-HDBK-17, Plastics for Flight Vehicles, Part II Transparent Glazing Materials, 14 August 1961	3.3.6
MIL-HDBK-23, Structural Sandwich Composites, 30 December 1968	3.3.6

3. REQUIREMENTS

3.1 CEI Definition

The Logistics Module is utilized for Shuttle transport of cargo (exclusive of crewmen) and on-orbit storage of cargo to support the Modular Space Station during the ISS phase. At least one Logistics Module shall remain on orbit at all times after ISS activation. Logistics Modules shall be utilized to provide support for the ISS with a six-man crew, onboard experiments, and up to four RAM's in the attached mode. In order to achieve a high degree of program flexibility, the Log M shall:

- a) Be capable of accommodating the transport of ISS subsystems off loaded during ISS activation.
- b) Be capable of providing logistics support to new experiments, subsystems and laboratory equipments without extensive modification.
- c) Be capable, after five years of operation, of being used for an additional five years or of being modified to a Crew Cargo Module configuration capable of transporting six crewmen as well as cargo in support of the Growth Space Station.
- d) Be capable of rescue of a six-man crew.

3.1.1 General Description

3.1.1.1 Functional Allocation

The Logistics Module shall provide functions generally allocated as shown in typical arrangement profile, Figure 1, and as described below.

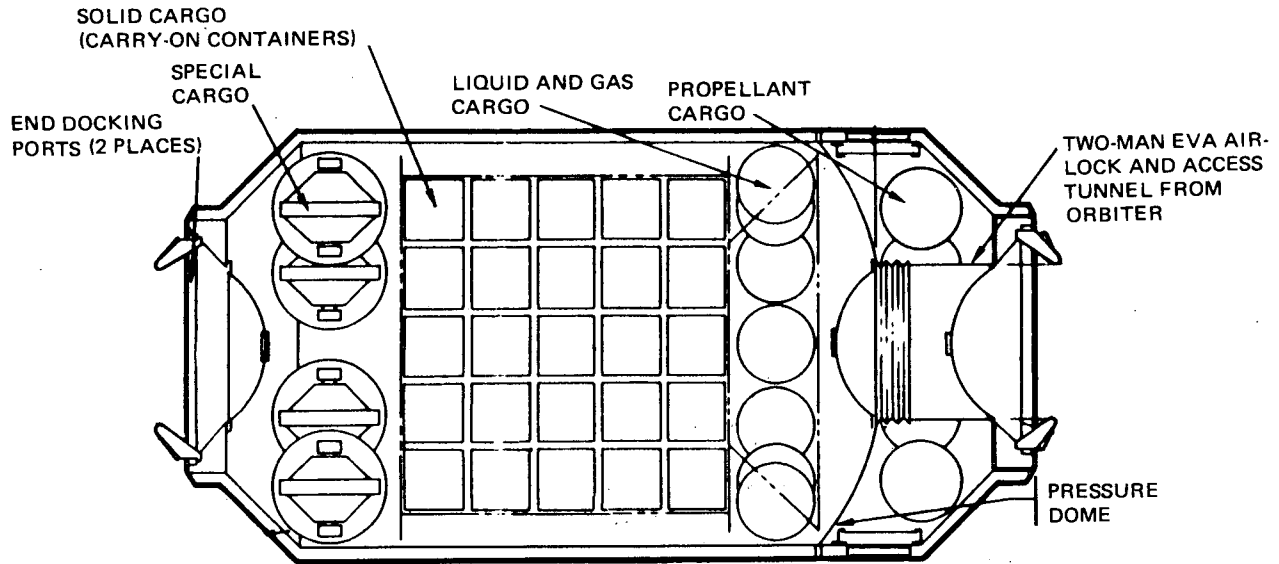


Figure 1. Logistics Module Arrangement

3.1.1.1.1

Cargo Transport and Storage

The cargo transport and storage function shall provide pressurized volumes for special cargo, containerized cargo and liquid/gas cargo. In addition, an unpressurized compartment shall be provided for toxic fluid or propellant cargo.

3.1.1.1.2

Crew Transfer

The Log M shall provide clear passage for crew transfer between the ISS and the orbiter, including an access tunnel capable of serving as an EVA airlock.

3.1.1.1.3

Contingency Crew Support

The Log M shall provide a refuge compartment during an emergency and shall be capable of being utilized for Shuttle transport of 6 crewmen from orbit in a rescue mode.

3.1.1.2 Relationship to Interfacing CEI's

3.1.1.2.1 ISS

For normal logistics support, the Log M shall interface with the ISS at one of the radial docking ports or the end docking port of the ISS Crew Operations Module, as shown in Figure 2. For contingency crew transfer, the Log M shall interface with any ISS docking port.

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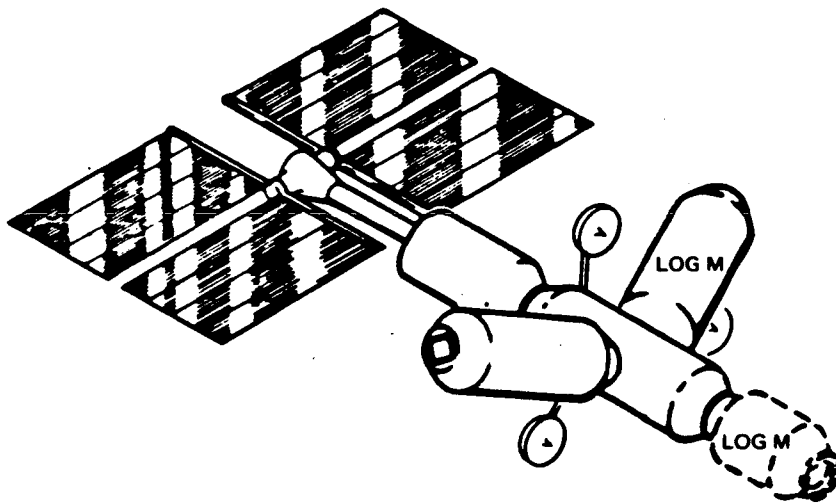


Figure 2. ISS Relationship to Logistics Module

3.1.1.2.2 RAM's

The Log M interface with RAM shall be limited to the logistics support functions, except that the design shall not preclude end docking of the Log M with a RAM.

3.1.1.2.3 Experiments

The Log M interface with the experiments shall be limited to the Logistics support function.

3.1.1.2.4 Space Shuttle Orbiter

The Log M shall interface with the Space Shuttle Orbiter for delivery and return from orbit. In addition, the Log M shall provide the normal orbital interface for "Shuttle only" crew rotation.

3.1.2 Missions

3.1.2.1 The ISS phase of the Modular Space Station Program requires Logistics Modules which are Shuttle launched to remain on-orbit for logistics supply storage. They shall be returned to Earth for refurbishment and reuse as described in the following paragraphs.

3.1.2.1.1 Activation

The first Log M launch occurs in the ISS activation phase. The Log M shall be capable of supporting the final activation tasks leading to initial manned operations. The first Log M remains on-orbit, supporting the first 30 days of operations, with a crew of two.

3.1.2.1.2 ISS Orbital Operations Support

Following the initial Log M launch, Log M's are launched at 30-, 60-, or 90-day intervals. The nominal ISS logistics launch delivers a Log M and returns another to Earth. The Log M shall be designed for an uninterrupted on-orbit stay time of 180 days.

3.1.2.1.3 Mission Duration

The Log M shall be designed to withstand up to 50 flights with maintenance, but without the requirement for major retrofit.

3.1.2.1.4 Ground Operations

For any flight, the Log M shall be compatible with ground processing time of no greater than 6 weeks.

This shall include:

- Unloading of return cargo.
- Repair and Maintenance of Log M.
- Checkout Log M.
- Loading of next cargo to be delivered.
- Installation in Orbiter.

3.1.2.2 The Log M shall be capable of use in an orbit of 55 degrees inclination at an altitude between 445 to 500 km (240 and 270 nautical miles).

3.1.3 Operational Concepts

3.1.3.1 Prelaunch

The Log M shall be designed to meet the requirement for repeated prelaunch operations. These requirements shall apply to operations which start after factory acceptance or after Shuttle landing and terminate at launch.

3.1.3.1.1 Test and Checkout

3.1.3.1.1.1 The Log M shall be designed to require a minimum of test during prelaunch operations.

3.1.3.1.1.2 As a design goal, it shall be possible to determine launch readiness status through the combination of Shuttle monitoring of the Log M and limited transfer of data through the Shuttle to GSE.



3.1.3.1.1.3           The Log M shall be designed for isolation of malfunctions and conduct of maintenance at the orbital level, utilizing onboard systems and GSE, independent of the Shuttle orbiter. This capability shall exist both before and after Log M installation in the Shuttle.

3.1.3.1.2           Access  
The Log M shall be designed for entry, to isolate malfunctions and conduct maintenance at the orbital level or for other prelaunch contingency requirements. This shall be limited to operations during which the module is in a horizontal position. In addition, the Log M shall be designed for access to load time critical cargo when the module is in a vertical position, installed in the Shuttle cargo bay. Use of GSE to achieve physical access, provide atmosphere, electrical power, etc., shall be acceptable.

3.1.3.1.3           Shuttle Installation  
The Log M shall be designed to be compatible with Shuttle loading facilities, including provision for direct attachment of hoisting GSE used to install modules in the Shuttle.

3.1.3.1.4           Repair and Refurbishment  
As a design goal, the Log M shall require no specific repair or refurbishment after return from a normal logistics mission.

3.1.3.1.5           Cargo-Handling  
The Log M shall be designed for rapid and convenient loading and unloading of cargo on the ground utilizing GSE. Except for time critical cargo, this shall be accomplished with the Log M in a horizontal position.

3.1.3.2                   Launch

The Log M shall be designed to be launched by the Shuttle with a minimum of active functions at the interface, to include the capability for redundant monitoring of critical functions by the Shuttle. Critical functions shall be limited to those which are safety-related.

3.1.3.3                   ISS Buildup Operations

3.1.3.3.1                The Log M shall be compatible with ISS buildup concepts which are based on the limitation of 30 days between Shuttle launches. The design shall be compatible with the activation concept which limits each of the four activation steps to 48 hours. The 48-hours limitation includes deployment of arrays or antennas, installation of off-loaded equipment, completion of interface connections, checkout and all other normal activities required to support activation. It does not include fault isolation, repair or other contingency or unplanned activity. The 48-hour limitation in the final activation step includes activation of the first Logistics Module.

3.1.3.3.2                The Log M shall be designed to be compatible with a maximum Shuttle on-orbit activation support time of 115 hours.

3.1.3.3.3                The Log M shall be designed for shirtsleeve activation. In addition, the design shall provide for the crew to enter in IVA pressure suits, maintaining atmospheric separation from the Shuttle by utilization of the docking port airlock. Equipment shall be designed for achieving and confirming module habitability as early as possible and completing activation in shirtsleeves with free access to the Shuttle.

3.1.3.4                   Primary Mission Mode

The Log M is operated in the primary mission mode following the first logistics flight when certification for continuous manned operations is completed and the Shuttle departs for return to Earth.

3.1.3.4.1 Crew Operations

3.1.3.4.1.1 The Log M shall be designed to free the crew from routine operations.

3.1.3.4.1.2 The Log M shall operate under control of ISS onboard checkout and fault isolation, providing the crew with the capability to recognize, isolate and correct malfunctions, independent of ground support and automatically notifying the crew of conditions requiring crew attention for critical failures.

3.1.3.4.2 Monitoring

The Log M shall provide the ISS with the capability of continuously monitoring subsystem and logistics stores status information. This shall be primarily automatic, supplemented by manual entry.

3.1.3.4.3 Compartmentation

The ISS, including one attached Log M and exclusive of the GPL, shall constitute one of the two required pressurized habitable compartments. It shall provide independent life support capability and other essential services.

3.1.3.4.4 Contamination

The Log M shall be designed to prevent local contamination of the immediate environment surrounding the Space Station.

3.1.3.5 Unmanned Mode

3.1.3.5.1 The Log M shall be designed to be placed in a standby, unmanned mode and be activated after a period of one year. It shall be assumed that the module is docked to another module which shall be capable of providing electrical power, limited to TBD kw average. No specific attitude control shall be assumed, however, resupply flights, if required, shall be permissible.

- 3.1.4                   Organizational and Management Relationships  
These relationships shall be as specified in Modular  
Space Station Project Specification No. RS-02927.
- 3.1.5                   System Engineering Requirements  
System Engineering shall be performed in accordance  
with the requirements of Project Specification  
No. RS-02927.
- 3.1.6                   Government-Furnished-Property List  
No government-furnished-property requirements have  
been identified.
- 3.1.7                   Critical Components  
No critical components have been identified.
- 3.2                     CHARACTERISTICS
- 3.2.1                   Performance  
The Logistics Module performance requirements are  
grouped according to six functional areas:
- Environmental control and life support
  - Crew habitability and protection
  - Structural/mechanical
  - Propulsion
  - Electrical power
  - Communications
  - Data management, and
  - Onboard checkout
- 3.2.1.1                Environmental Control and Life Support  
The environmental control and life support subsystem  
shall operate in conjunction with the ISS subsystems  
to provide a continuously habitable shirtsleeve environment for the crew when  
the Log M is docked to the ISS.
- 3.2.1.1.1             Atmosphere Supply
- 3.2.1.1.1.1           The Log M shall be designed to transport to orbit and  
store 480 kg (1,068 lb) of oxygen.

- 3.2.1.1.1.2 The Log M shall be designed to transport to orbit and store 24.6 kg (54 lb) of nitrogen.
- 3.2.1.1.1.3 The Log M shall provide the high pressure gas regulation and control provisions to supply the oxygen and nitrogen to the ISS at 410k N/m<sup>2</sup> (60 psia).
- 3.2.1.1.1.4 The Log M shall provide atmosphere supply monitoring parameters to the ISS utilizing the data bus or direct wiring in a manner compatible with the ISS onboard checkout and fault isolation subsystem.
- 3.2.1.1.2 Atmosphere Control  
Atmosphere distribution and circulation within the Log M shall be provided. This shall be based on the availability of up to 540 cm<sup>3</sup>/sec (136 cfm) of conditioned air at the ISS interface.
- 3.2.1.1.3 Airlock Control  
The Log M shall provide the ISS with the necessary lines and control equipment to permit pressurization and depressurization of the EVA airlock.
- 3.2.1.2 Crew Habitability and Protection
- 3.2.1.2.1 Food Management  
The Logistics Module shall provide for storage of a 60-day supply of food for six crewmen. This shall include provisions for dried, freeze dried, dehydro-frozen, wet pack, and perishable foods.
- 3.2.1.2.2 IVA/EVA Support  
Two individually fitted IVA/EVA suits shall be located in the Logistics Module.
- 3.2.1.2.2.1 The Log M shall be compatible with all ISS IVA/EVA support requirements, providing accommodation for support equipment such as tethers, monitoring and surveillance equipment and emergency lighting.

3.2.1.2.2.2           Emergency Oxygen Supply

Three oxygen masks shall be located in the Logistics Module with supply from the emergency pallet located in the module. The emergency masks shall also be usable for prebreathing of oxygen prior to EVA. In this case, oxygen shall be supplied by EC/LS.

3.2.1.2.3           Emergency Pallet

3.2.1.2.3.1           The Logistics Module shall provide accommodation for two 96-hour pallets containing critical supplies of oxygen, lithium hydroxide for CO<sub>2</sub> control, a water boiler for thermal control, food, water, waste collection bags, and a battery power supply.

3.2.1.2.3.2           The Logistics Module shall be compatible with utilization of the 96-hour pallet in an emergency, providing a crew refuge.

3.2.1.2.3.3           Installation of the 96-hour pallet shall permit convenient transfer of the pallet between modules during the resupply appointment interval.

3.2.1.2.4           Crew Aids

3.2.1.2.4.1           Crew accommodations shall provide restraints and locomotion aids throughout the Log M to assure safe and convenient crew operations. Fixed restraints and locomotion aids shall be at specific locations as required by frequently performed tasks. Portable equipment shall be provided for infrequent or unplanned tasks.

3.2.1.2.4.2           Additional aids shall include portable lighting (flash light), portable fans to provide air circulation, and portable (high intensity) lighting for use in remote work areas.

3.2.1.2.5           Crew Compartments and Work Stations

The following general requirements and design goals shall be used to guide the overall habitability design effort:

- a) All compartments shall be designed for maximum habitability.

- b) Interiors shall be optimized with due consideration to ground checkout and evaluation requirements and constraints.
- c) Volume allocation, equipment location, and interior arrangement shall be designed to minimize "casual" interference, i. e., to avoid crowding while performing tasks.
- d) The opportunity for freedom of choice in facility usage shall be maximized.
- e) The common use of free space shall be applied where appropriate.

#### 3.2.1.2.6

##### Meteoroid Protection

Meteoroid protection shall provide for detection and location in the event a penetration does occur. Leak detection sensors are required at strategic locations throughout the module to alert the crew of a hazardous condition. This shall operate in conjunction with the ISS meteoroid protection provisions.

#### 3.2.1.2.7

##### Fire Protection

Fire protection shall be provided by the location of fire extinguishers throughout the Log M to suppress any fire after it has been isolated. Emergency oxygen masks and protective clothing shall be provided to protect the crew against related hazards. An automatically (heat sense) extinguishing system shall be located in areas where a fire hazard exists.

#### 3.2.1.3

##### Structure/Mechanical

The structure/mechanical subsystem for the Log M provides the habitability enclosures, operable mechanical mechanisms, and the primary/secondary structural elements upon which other subsystems are integrated and the payload is carried and serviced. It shall include, but not be limited to:

- a) Pressure Shells
- b) Floors
- c) Walls
- d) Access and Viewing Provisions

- e) Support and Transfer Equipment
- f) Docking Equipment
- g) Meteoroid Protection

3.2.1.3.1 Commonality

"Commonality" shall be a primary consideration throughout the design and evolution phase. The design goal for the structure/mechanical subsystem shall be to provide maximum commonality with the ISS Modules, within the bounds of acceptable design and cost effectiveness.

3.2.1.3.2 Strength and Rigidity

3.2.1.3.2.1 Yield Load

The structural/mechanical subsystem shall have sufficient strength and rigidity to sustain yield load without failure, and without deformation which would prevent any portion of the vehicle from performing its intended function without deleterious permanent set. The simultaneous application of accompanying environmental effects (temperature, pressure and vibration) shall be applied to determine the critical loading conditions.

3.2.1.3.2.2 Ultimate Load

The structural/mechanical subsystem shall have sufficient strength and rigidity to withstand the ultimate load without failure and without deformation which would result in premature failure of any safety critical function. Environmental effects shall be applied as specified in 3.2.1.3.2.1.

3.2.1.3.2.3 Dynamic Magnification, Shock, and Surge

The structural/mechanical subsystem shall have sufficient strength and rigidity to withstand the effects of dynamic magnification, shock factors, and surge phenomena, as applicable.

3.2.1.3.2.4 Shuttle-Induced Environment

Design and analysis of the subsystem for strength and rigidity shall reflect the mass and resultant loading conditions of the evolved configuration design and the physical, thermal and



other induced environment conditions specified for shuttle payloads in Program Interface and Support Requirement Specification No. PS-02926.

3.2.1.3.3 Design Criteria

3.2.1.3.3.1 Design Safety Factors

The structural/mechanical subsystem shall be designed in conformance with the general design safety factors specified in paragraph 3.3.6.1 and the following paragraphs.

3.2.1.3.3.1.1 Cabin, Internal Pressure Only

Proof Pressure:	1.50 x limit pressure
Yield Pressure:	1.10 x proof pressure
Ultimate Pressure:	2.00 x limit pressure

3.2.1.3.3.1.2 Window, Internal Pressure Only

Proof Pressure:	2.00 x limit pressure
Ultimate Pressure:	3.00 x limit pressure

3.2.1.3.3.1.3 Astronaut Restraints

Tether ultimate factor of safety: 2.0  
Tether attachment ultimate factor of safety: 2.0

3.2.1.3.3.2 Radiation Limits

The structural/mechanical subsystem design shall be compatible with the following allowable quarterly radiation limits:

<u>Organ</u>	<u>Limit Dose (rem)</u>
Skin (0.0 mm)	105
Eye (3.0 mm)	52
Marrow (5.0 cm)	35

3.2.1.3.3.3 Fatigue

Fatigue criteria shall be based on a load history profile showing usage cycles, load intensities, and

environments. Structural members shall be designed to the following factors times that of the maximum expected load history profile.

Low-cycle fatigue: 4.0  
High-cycle fatigue: 10.0

3.2.1.3.3.4

Safe Life

All major load-carrying structures of the structural/mechanical subsystem shall be designed to a safe life of 10 years in orbit.

3.2.1.3.3.5

Meteoroid Protection

Meteoroid protection shall be provided by the Log M design so that when exposed to the meteoroid flux given in TM X-53865, Second Edition, dated August 1970, a 0.90 probability of no puncture in a 10-year mission life is met.

3.2.1.3.3.6

Fail-Safe Design

Fail-safe design concepts shall be applied to all critical structure so that failure of a single structural member shall not degrade the strength or stiffness of the structure to the extent that the crew is in immediate jeopardy.

The structural shall also be designed to resist damage resulting from accidental impact during normal crew activities.

3.2.1.3.3.7

Explosive Ordinance

All ordinance design shall conform to the requirements of MSFC-Spec-491.

3.2.1.3.3.8

Structural Welds

Welding of the vehicle structure shall meet the "materials," "welding procedure," "visual inspection," and "radiographic inspection" requirements of MSFC-Spec-135, Welding, Fusion Specification.

3.2.1.3.4 Design Requirements

3.2.1.3.4.1 Operating Pressure

The Log M structure subsystem shall be designed for an oxygen-nitrogen mixture at a normal operating pressure of  $101 \text{ kN/m}^2$  (14.7 psia), and a partial pressure of oxygen at reduced pressures with a minimum operating pressure of  $69 \text{ kN/m}^2$  (10 psia).

3.2.1.3.4.2 Differential Pressure

The differential pressures across the pressurized compartment shell, for the conditions noted, shall not exceed:

- a) Collapse:  $0 \text{ kN/m}^2$  (0 psi)
- b) Proof:  $151 \text{ kN/m}^2$  (22 psi)
- c) Leak check:  $101 \text{ kN/m}^2$  (14.7 psi)
- d) Burst:  $202 \text{ kN/m}^2$  (29.4 psi)

A positive pressure of 0.5 psi above ambient shall be maintained for modules returning to earth.

3.2.1.3.4.3 Leakage Rate

The total leak rate of the Log M three module cluster shall not exceed 0.001 kg/day (0.002 lb/day).

3.2.1.3.4.4 Venting

Vents shall be capable of maintaining a positive pressure differential relative to all bulkheads during the worst-case combination of three-sigma deviation to the ascent trajectory, during ground conditioning and associated venting, and during orbital pressurization of pressurizable compartments.

3.2.1.3.4.5 Separate Volumes

The structure/mechanical subsystem design shall provide a portion of one separate pressurized habitable compartment with independent life support capability, compatible with basic compartmentation requirements of paragraph 3.1.3.4.3. This capability shall recognize and be compatible with the dual path ingress and egress considerations in paragraph 3.2.2.4.

- 3.2.1.3.4.6            Docking Ports
- The Log M shall contain a total of two docking ports, one at each end. The docking port design shall meet the criteria specified in the following paragraphs.
- 3.2.1.3.4.6.1        The docking ports shall be structurally identical to ISS ports to permit docking with any other docking port.
- 3.2.1.3.4.6.2        The docking port and latches shall provide a nominal clear diameter of 1.7 m (5 feet).
- 3.2.1.3.4.6.3        With a module attached, a pressurized section of sufficient volume shall be provided to maintain or repair the docking mechanism (less the seal) in a shirtsleeve environment. All utility interfaces between modules shall be with this pressurized section.
- 3.2.1.3.4.6.4        The docking mechanisms and supporting structure shall be designed to meet the following design criteria:
- |                            |                          |
|----------------------------|--------------------------|
| Axial closing velocity:    | 0.3 m/sec (1.0 ft/sec)   |
| Lateral velocity:          | 7.6 cm/sec (0.25 ft/sec) |
| Pitch, yaw and roll Rates: | 0.5 deg/sec              |
| Angular misalignment:      | ±5.0 deg                 |
| Lateral displacement:      | ±0.3 m/sec (±1.0 ft)     |
- 3.2.1.3.4.7            Doors and Hatches
- All pressure doors and hatches shall be designed for pressure in either direction. The pressure door and hatch operating mechanism design shall include features as specified in the following paragraphs. Hatches and intermodule interfaces shall provide the capability of an IVA airlock. Sufficient volume shall be included between the two hatches to permit two suited crewmen.
- 3.2.1.3.4.7.1        All hatches shall be capable of operation by one crewman.
- 3.2.1.3.4.7.2        The capability for equalization of pressure across the hatches shall be provided and appropriate indicators of conditions in adjacent compartments shall be displayed near the doors and hatches.

3.2.1.3.4.7.3 Each manually operated pressure hatch and door mechanism design shall include a secondary safety latch to contain the door if opened under a differential pressure condition.

3.2.1.3.4.7.4 Pressure hatch design shall provide a means of visual verification that proper closure has been accomplished.

3.2.1.3.4.8 Viewports  
Viewports shall be incorporated in the Log M to provide diametric viewing areas. Viewport installations shall provide a 90-degree unobstructed view cone from a focal point equal to one-half the window diameter.

<u>Type</u>	<u>Quantity</u>	<u>Diameter</u>	<u>Location</u>
Viewing	Two	15 cm (6 in.)	One per pressure hatch
Viewing	One	15 cm (6 in.)	One per EVA airlock

The viewports shall be designed to protect the modules interior from meteoroid penetration. The window design shall permit on orbit removal/replacement (with supplemental aids) for maintenance in a shirt sleeve environment.

3.2.1.3.4.9 EVA Airlocks  
The Log M shall provide a two-man EVA airlock utilizing the Orbiter access tunnel.

3.2.1.3.4.10 Cargo Transfer Equipment  
Equipment and provisions shall be provided to facilitate the movement of cargo and replacement items within the Log M. Transfer equipment shall be designed to:

- a) Interface with ISS transfer provisions
- b) Minimize crew involvement and time
- c) Be operational in a shirtsleeve environment
- d) Provide methods for guidance and a means of restraining the generated inertia.

This equipment shall be compatible with ISS cargo transfer equipment.

3.2.1.4

Propulsion

The propulsion subsystem shall provide for on orbit storage of 226 kg (500 lb) of monopropellant hydrazine ( $N_2H_2$ ) and for the control and monitoring equipment to transfer propellant. This shall include propellant and pressurant ( $GN_2$ ) umbilicals.

3.2.1.5

Electrical Power

3.2.1.5.1

The electrical power subsystem shall distribute power provided either by the ISS or the Shuttle Orbiter.

3.2.1.5.2

Electrical power distribution shall be consistent with the 24-hour average power limitation of 250 watts at 115 vdc ( $\pm 3$  vdc) orbital operations with the Log M docked to the ISS.

3.2.1.5.3

During prelaunch and activation, the electrical power subsystem shall be active utilizing Space Shuttle power.

3.2.1.6

Communications, Data Management, and Onboard Checkout

3.2.1.6.1

Data Transfer

3.2.1.6.1.1

The Logistics Module shall provide analog and digital data buses, accessible at either end of the Log M and compatible with both ISS and Space Shuttle data transfer functions.

3.2.1.6.1.2

The Log M data transfer function shall include the capability to couple devices to the data bus which shall operate:

- a) With the ISS data management function to provide a flexible data transfer capability equivalent to that of any other ISS habitable compartment.
- b) With the Space Shuttle during prelaunch, launch, and activation to permit Shuttle monitoring of Log M functions.

- 3.2.1.6.2 Audio Communications  
Voice communications between the Logistics Module and the ISS shall be provided by three audio terminal units.
- 3.2.1.6.3 Caution Warning Annunciators  
Three panels shall be strategically located within the Logistics Module to provide caution and warning indications of hazardous conditions. A small panel shall also be located within the airlock displaying conditions such as airlock controls and door status, pressure within and without the airlock and rate of pressure buildup and decay. Warning functions shall be hardwired to the crew module while caution signals shall be carried on the data bus.
- 3.2.1.6.4 Digital Data Transfer  
Three data terminals shall be provided to interface with the data bus.
- 3.2.1.6.4.1 Data Acquisition  
Remote data acquisition devices interfacing with the data terminals and multiplexing subsystem signals from various Logistic Module locations shall be provided.
- 3.2.1.6.4.2 Commands  
Equipments located in the Logistics Module shall accept 5 VDC for control purposes from the remote data acquisition units.
- 3.2.1.6.4.3 Checkout  
Signals acquired by the RDAUs shall be continuously limit checked unless otherwise commanded by the central processing system. Single channels and data frames shall be available for fault isolation and checkout on demand.
- 3.2.1.6.4.4 Display and Control  
Information shall be accessed from the ISS via a portable display and control console which shall also provide control of systems within the logistics module.

3.2.2 Physical

3.2.2.1 Weight Limitation

3.2.2.1.1 The empty weight (mass) of each Log M shall not exceed 3,000 kg (6,620 lbm).

3.2.2.1.2 The Log M shall be compatible with the requirement that the total weight of the module and its cargo shall not exceed 9,072 kg (20,000 lbm) at launch or during module return.

3.2.2.1.3 The Log M shall have standard cargo accommodation provisions within its weight limitation. Any unique packaging or fastening devices or storage provisions shall be considered as part of the cargo.

3.2.2.2 Center of Gravity

3.2.2.2.1 Longitudinal center of gravity shall be limited to the envelope shown in Figure 3 below (the orbiter payload envelope is shown in reference).

3.2.2.2.2 Lateral and vertical center of gravity axis limits are  $\pm 0.30\text{m}$  (12 in.).

3.2.2.3 External Dimensions

3.2.2.3.1 The Log M external dimensions shall be limited to 4.3m (14 ft) in diameter and 17.7m (58 ft) in length.

3.2.2.3.2 Mechanisms that are attached to the module during launch but are external to the pressure shell, such as handling rings, attachments for deployment, docking mechanisms, etc., shall be contained, at launch, within an envelope of 4.6m (15 ft) diameter and 18.3m (60 ft) in length. Exceptions are the structural support fittings at the Shuttle payload interface support points which are outside of the 4.6m (15 ft) envelope.



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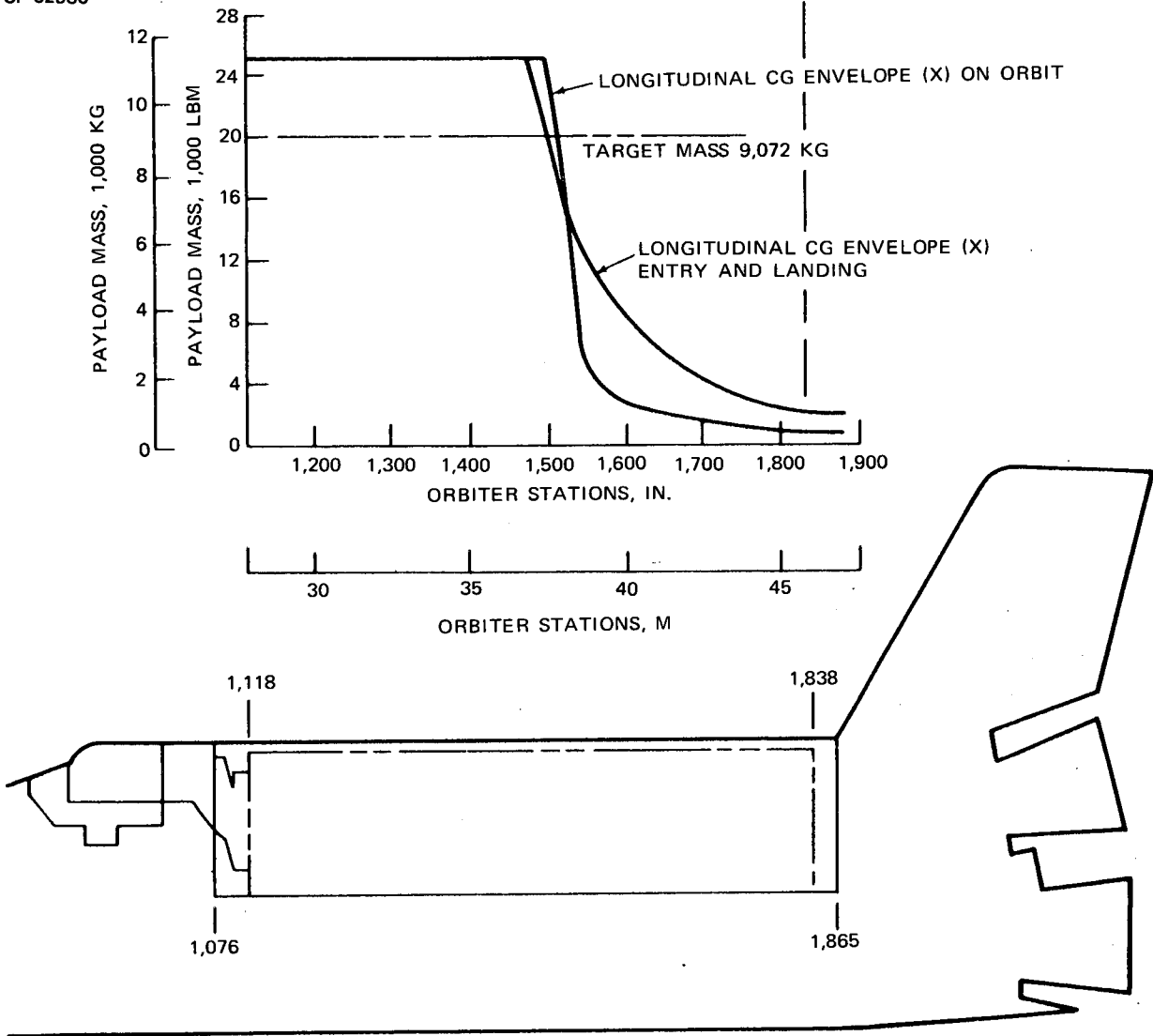


Figure 3. Longitudinal Center of Gravity Limitations

- 3.2.2.4 Cargo Transfer
  - 3.2.2.4.1 Docking port hatches in the Log M shall provide a cargo transfer opening of 1.5m (5 ft) minimum. The Log M shall be capable of transporting a cargo having a spherical diameter of 1.5 m (5 ft) to the ISS.
  - 3.2.2.4.2 The Log M shall provide a through passageway for cargo having a spherical diameter no greater than 0.9 m (3 ft).

3.2.2.5                    Ingress and Egress

3.2.2.5.1                Primary Mission Mode of Operation

The Log M design shall be compatible with the requirement for convenient crew ingress and egress through any docking port. This shall consider nominal shirtsleeve ingress and egress and both normal and contingent IVA and EVA operations. It shall provide a personnel escape route from any ISS module to which it is docked.

3.2.2.5.1.1            ISS—The Log M design shall be compatible with the utilization of a docked Log M for ingress and egress from the ISS for:

- a) Crew transfer to and from Shuttle Orbiter, including initial manning.
- b) Frequent access to supplies, spares and other stores which remain stocked in the Log M.
- c) EVA—One mode of EVA from the ISS shall utilize the Log M EVA airlock.
- d) Use of the Log M as a refuge.

3.2.2.5.1.2            Shuttle Orbiter—The Log M design shall be compatible with normal crew rotation either as a Shuttle payload or providing the preferred docking port for "Shuttle only" crew transfer. It shall be compatible with the requirement for a two-man crew to ingress or egress the Shuttle Orbiter through the erection system tunnel. This capability is required after module erection, before and after docking.

3.2.2.5.1.3            EVA—The Log M shall provide capability for its Shuttle interface docking port and transfer tunnel to be utilized as an EVA airlock.

3.2.2.5.1.4            IVA—The Log M, when docked to the ISS, shall provide and retain the capability for intermodule IVA.

3.2.2.5.2                Prelaunch

3.2.2.5.2.1            The Log M shall be designed to accommodate the requirement to gain interior access in a horizontal position. This shall apply before and after installation of the module in the

orbiter. Crew support ladders, platforms, etc., shall be provided by GSE as required.

3.2.2.5.2.2           The Log M shall be designed to accommodate the requirement to gain limited interior access after installation of the module in the Orbiter, with the Shuttle in a vertical position. This shall as a minimum, provide for convenient and rapid stowage of time-critical cargo.

3.2.2.6               Cargo Stowage Provisions

3.2.2.6.1            The Log M interior shall be designed to be readily reconfigured to accommodate a variety of cargo.

3.2.2.6.2            The Log M shall provide stowage for solid cargo in standardized containers. Their size shall be 0.6m (2 ft) in each dimension, or subunits thereof.

3.2.2.6.3            All cargo shall be fully accessible without removing adjacent items.

3.2.2.6.4            An unpressurized section shall provide storage for liquids and high pressure gases. Transfer of these fluids and gases shall be accomplished through umbilicals in an on-demand basis. Provisions to install additional tanks for liquids and gases shall be included.

3.2.2.7               Cargo Transfer Provisions

3.2.2.7.1            The Logistics Module shall provide the latches, hooks, etc., to accommodate the ISS cargo handling equipment, utilized on-orbit for the occasional transfer of cargo or heavy cargo.

3.2.2.7.2            The Logistics Module shall provide hand holds, foot restraints, etc., for the crew to assist in movement and transfer of cargo.

3.2.3 Reliability

The Log M shall be designed to operate for a ten year mission in space with ground maintenance and minimum prelaunch verification and checkout. The functional design shall optimize the reliability with respect to weight, cost, volume, and maintenance time. The reliability measure which shall be used is the probability that the system will be available to perform required functions to specification levels. The Log M shall have a reliability of at least 0.9995 for 120 days.

3.2.4 Maintainability

The Log M shall be designed for 100% replacement maintenance capability at the subassembly or component level or by functional substitution. As a goal there shall be no planned on-orbit maintenance. Capability shall be provided, however, for the on-orbit repair/replacement of equipment essential for safety or mission completion.

Subassemblies and components that must be available to ensure against a mission safety or mission abort event shall have a probability of repair of at least 0.9999.

3.2.5 Operational Availability

The Log M shall be designed and tested to assure a high probability of function when placed in functional operation on orbit. The design shall permit prelaunch test and verification of any mission and life-critical functions.

3.2.5.1 The Log M shall incorporate sufficient system verification and/or test capability, in combination with the modules to which it is being docked, to identify critical equipment parameters below optimum performance and which must be modified or repaired prior to separation from the orbiter.

3.2.5.2 The Log M shall have the capability for a prelaunch hold of up to 2 days without requiring a recycle through prelaunch verification tests. Recycle after initial verification and a hold of over 2 days, shall require not more than 3 days.

3.2.6 Safety

The Logistics Module shall conform to the safety requirements of Space Station Project Specification No. RS-02927 and to the specific requirements of the following paragraphs. Definitions of terms used are:

- a) Critical Functions—Functions required for personnel safety and mission continuation.
- b) Nominal Level—The level of performance or operations for which the system was designed.
- c) Reduced Level—A level of performance lower than that for which the system or operation was designed but still adequate for personnel safety.
- d) Emergency Level—A level of performance sufficient only for personnel survival.

3.2.6.1 Personnel Safety

3.2.6.1.1 No single malfunction or credible combination of malfunctions or accidents shall result in injury to personnel or loss of mission.

3.2.6.1.2 Catastrophic and critical hazards shall be eliminated or controlled.

3.2.6.1.3 Capability shall be provided for performing critical functions at a nominal level with failure of any single component or with any portion of a subsystem inactive for maintenance.

3.2.6.1.4 Capability shall be provided for performing critical functions at a reduced level, with any credible combination of two component failures or with any portion of a subsystem inactive for maintenance.

3.2.6.1.5 Capability shall be provided for performing critical functions at an emergency level until the affected function can be restored or until the crew can be returned to Earth, with any one compartment inactivated, isolated, and vacated as the result of an accident;

or with any credible combination of subsystems inactivated as the result of an accident and a portion of a redundant or backup system being inoperative.

3.2.6.1.6 For malfunctions or hazards that may result in time-critical emergencies, provision shall be made for the automatic switching to a safe mode of operation and for cautioning or warning of personnel.

3.2.6.1.7 Subsystem Safety Requirements  
Specific safety requirements of subsystem design shall be as specified in the following paragraphs.

3.2.6.1.7.1 Personnel escape routes shall be provided for all situations of high-hazard potential. Each normally inhabited compartment shall have a minimum of two escape routes that do not terminate in a common area.

3.2.6.1.7.2 The Log M shall provide storage for emergency space suits in readily accessible locations.

3.2.6.1.7.3 The Log M shall provide location for potentially explosive containers, such as high-pressure vessels or volatile-gas storage containers outside of, and as remote as possible with respect to the crew's living and operating quarters, and wherever possible isolated.

3.2.6.1.7.4 The chemical composition of the environmental atmosphere shall be continuously monitored for any buildup of toxic or noxious gases, and to provide early fire hazard warning by detection of fire precursors or material decomposition products.

3.2.6.1.7.5 Fire detection equipment shall detect incipient fires in components, behind panels, and in wire bundles or cabling assemblies.

3.2.6.1.8 Fire suppression equipment shall be capable of extinguishing any fire in the most severe oxidizing environment prior to failure of primary pressure structural materials.

- 3.2.6.1.9. Space Station EVA activities shall be conducted using the "buddy" system.
- 3.2.6.2 Equipment Safety
  - 3.2.6.2.1 Redundancy and Separation.
    - 3.2.6.2.1.1 Space Station subsystems, in general, shall be designed for fail-safe operation and shall ensure selective degradation.
    - 3.2.6.2.1.2 Logistics Module safety-critical equipment shall be designed to allow emergency operation by employing redundancy and separation of parallel or similar functions. The placing of such redundant or parallel equipment in isolated compartments or locations shall ensure that a single emergency failure will not destroy both the primary and redundant system.
- 3.2.7 Environment
  - Natural and induced environments shall be as specified in Modular Space Station Project Specification No. RS-02927.
- 3.2.8 Transportability/Transportation
  - The Log M shall be designed for compatibility with surface transportation on a transporter, shipment by air, and shipment by an ocean-going vessel.
- 3.2.9 Storage
  - No storage requirements have been identified.
- 3.3 Design and Construction Standards
  - 3.3.1 Selection of Specifications and Standards
    - All materials, parts, and processes shall be defined by standards and specifications. Standards and specifications shall be selected from Government, industry, and contractor specifications and standards in accordance with MIL-STD-143. Rationale for the selection of contractor specifications and standards over existing higher

order or precedence standards and specifications shall be compiled and maintained for historical record. This rationale shall include an identification of each higher order or precedence specification or standard examined and state why each was unacceptable.

For purposes of this order or precedence, commercial materials, parts and processes shall be considered equivalent to contractor standards.

### 3.3.2 General

3.3.2.1 Design and construction standards for hardware obtained from the Saturn, Apollo, Gemini, or other Space programs shall be both in accordance with existing specifications for those items and in accordance with the standards below, as appropriate. New Logistics Module hardware shall be designed and constructed in accordance with standards in the following sections.

#### 3.3.2.2 Dangerous Materials and Components

3.3.2.2.1 Logistics Module hardware shall be designed in accordance with MSFC-SPEC-101B.

3.3.2.2.2 Where functional requirements preclude meeting flammability requirements, materials may be isolated from the environment by fireproof storage compartments or barrier materials which meet these requirements.

3.3.2.2.3 All materials shall be nonflammable when tested in the most oxygen-rich environments to which they will be exposed except for food, medical supplies, etc., which shall be stored in fireproof containers at all times unless being used or consumed.

3.3.2.2.4 Materials which offgas, outgas or evolve toxic or noxious products capable of personnel impairment or hazard shall not be used. If mandatory for operational performance such materials will be isolated by compartmentalism, sealing or contained in barrier materials.



3.3.2.2.5 All ordnance shall conform to the requirements of MFSC-SPEC-491.

3.3.2.2.6 Heat transport fluids located within pressurized crew compartments shall be nontoxic and nonflammable at ambient atmosphere pressure and composition.

3.3.2.2.7 All materials selected for use in habitability areas will be nontoxic, nonflammable, and nonexplosive to the maximum extent.

3.3.3 Aeronautical

3.3.4 Civil

Federal, state, and local codes shall be observed as necessary for construction, fabrication, transportation, communications, and safety.

3.3.5 Electrical

3.3.5.1 Electromagnetic Interference

The design requirements incorporated to ensure electromagnetic compatibility shall be generally in accordance with MIL-I-6181.

3.3.5.2 Containers

Electrical systems containers shall be hermetically sealed, purged, pressurized, or encapsulated, where necessary. Solenoids, transducers, squirrel-cage induction motors, and similar hardware having no circuit-switching devices, shall be hermetically sealed, purged, pressurized, or encapsulated with compatible material. Precautions against sparking of metal-to-metal contacts shall be taken for all devices which have moving parts.

3.3.5.3

Relays

All relays in Flight Critical Items shall be vibration scan tested in accordance with MSFC-SPEC-339.

3.3.5.4

Electronic Modules

Any welded electronic modules used shall be fabricated using components with lead materials which meet the requirements of MSFC-STD-271. For general use, potting or encapsulation materials used in conjunction with welded modules shall conform to Type II, Type III, or Type IV of MSFC-SPEC-222. Materials other than vinyl may be used as a sleeve or the protection of glass components as defined in Paragraph 5.1.5 of MSFC-SPEC-222.

3.3.5.5

Soldering Requirements

Soldering of electrical connections shall conform to the requirements of MSFC-PROC-158.

3.3.6

Mechanical

The structural and mechanical systems shall have sufficient strength and rigidity to sustain yield load without failure, without deformation which would prevent any portion of the vehicle from performing its intended function and without deleterious permanent set. The simultaneous application of accompanying environmental effects (temperature, pressure, slush and vibration) shall be applied to determine the critical loading conditions. These systems shall have sufficient strength and rigidity to withstand the ultimate load without failure and without deformation which would result in premature failure of any safety critical function. Simultaneous application of accompanying environmental effects shall be considered in determining the critical loads. Extremes of the environmental effects with appropriate loads shall be considered. Analysis shall be performed to assess the effects of dynamic magnification, shock factors and surge phenomena as applicable. Design data and materials properties shall be obtained from MIL HDBK 5, MIL HDBK 17,

MIL HDBK 23 or alternatively from other sources which meet the approval of the procuring agency.

3.3.6.1 Design Safety Factors

3.3.6.1.1 General Safety Factors

Yield factor of safety: 1.10 x limit load  
 Ultimate factor of safety: 1.40 x limit load

3.3.6.1.2 Flexible Hose, Tubing, Ducts and Fittings

Proof pressure: 2.00 x limit pressure  
 Yield pressure: 1.10 x proof pressure  
 Burst pressure: 4.00 x limit pressure

3.3.6.1.3 Actuating Cylinders, Valves, and Switches

Proof pressure: 1.50 x limit pressure  
 Yield pressure: 1.10 x proof pressure  
 Burst pressure: 2.50 x limit pressure

3.3.6.1.4 Reservoirs

	<u>Liquid</u>	<u>Gas, or Liquids and Gases</u>
Proof pressure	1.50	2.00 x limit pressure
Yield pressure	1.10	1.10 x proof pressure
Burst pressure	2.50	4.00 x limit pressure

3.3.6.2 Hydraulic System

Hydraulic system design, installation, test and data requirements shall be in accordance with MIL-H-25475.

3.3.7 Nuclear

Design practice associated with the containment, hand-line, and safety of nuclear materials and devices shall comply and be subject to AEC policies and practices defined by Title 10, Code of Federal Regulations.

3.3.8                   Moisture and Fungus Resistance

Materials which are not nutrients for fungus shall be used whenever possible. The use of materials which are nutrients for fungus shall not be prohibited in hermetically sealed assemblies and other accepted and qualified uses, such as paper capacitors and treated transformers. If it is necessary to use nutrient materials in other than such qualified applications, these nutrient materials shall be treated by a method which will render the resulting exposed surface fungus resistant. The treated surface must satisfactorily pass the fungus tests in MIL-STD-810.

3.3.9                   Corrosion of Metal Parts

3.3.9.1               Parts including spares shall be protected against corrosion. Protective methods and materials for cleaning, surface treatment, and application of finishes and protective coating shall be accomplished in accordance with MSFC-SPEC-250.

3.3.9.2               Dissimilar Metals

Dissimilar metals are defined by MS-33586 which are subject to electrolytic corrosion, shall not be used in combination unless suitably coated, sealed, or separated by barrier material compatible with both metals. Special consideration will be given to electrical bonding requirements where dissimilar metals are involved.

3.3.9.3               Painting and Coating

Finishes shall be applied to metal parts to ensure environmental protection. Consideration shall be given to weight, thermal emissivity, outgassing and electrical bonding requirements. All exposed, unpainted, machined surfaces which could corrode shall be finished with an inorganic coating such as plating or anodizing. Anodizing shall be used where electrical bonding must be made.

3.3.10                Contamination Control

3.3.10.1             Special cleanliness levels imposed by equipment involving hydraulics, pneumatics, life support and

special experimental procedures shall not be imposed on the entire interior or exterior of the Log M or supporting equipment.

3.3.10.2 Special high levels of atmospheric or surface cleanliness shall not be required for transportation handling, assembly and checkout of prime elements.

3.3.10.3 Specific areas of activity or design wherein special cleanliness is mandatory shall have equipment and/or support tooling to maintain local cleanliness during assembly, handling and servicing of such equipment. As a goal, extensive cleanroom facilities should be avoided.

3.3.10.4 As a design goal, venting and dumping of liquids and gases shall be directed to prevent contamination of outer surfaces of the Space Station and to eliminate recontamination from fungus and bacteria vented overboard. Outgassing from materials, leaks from coolant systems, and leaks from pressurized spacecraft environments or the effects thereof, or both, shall be minimized.

3.3.10.5 Any contaminant expulsion from Space Station shall be coordinated with experiments so as not to negate experiment data and to minimize experiment "downtime."

3.3.10.6 Logistics Module flight hardware shall be designed, manufactured, tested, handled, and operated in such a manner as to assure contamination-free operation for critical surfaces or elements.

3.3.11 Coordinate Systems

3.3.11.1 Coordinate axes and reference planes specified for the Logistics Module are TBD.

3.3.12 Interchangeability and Replaceability  
Mechanical and electrical interchangeability shall exist between identical replaceable parts, assemblies and subassemblies, regardless of manufacturer or supplier. All parts having

the same part number, regardless of source, shall be functionally and dimensionally interchangeable as defined in MIL-STD-721.

3.3.13 Identification and Marking

Nameplates and markings shall be made and affixed in accordance with MIL-STD-130, and MIL-STD-129, or equivalent. All configuration identification information on these nameplates and markings shall be taken from and agree with production or construction drawings and/or their engineering release records.

3.3.14 Workmanship

Space Station Project hardware, including all parts and accessories shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be paid to neatness and thoroughness of soldering, wiring, impregnation of coils, markings of parts and assemblies, plating, painting, riveting, machine-screw assembly, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.15 Human Performance/Human Engineering

The criteria specified in MIL-STD-803 shall be met as a minimum in the design of project hardware. The following crew requirements shall be considered:

- a) Standardization
- b) Function allocation
- c) User capabilities
- d) Control and display arrangement and interaction
- e) Space requirements
- f) Crew safety
- g) Environment
- h) Simplicity
- i) Restraints

3.4 Logistics

3.4.1 Maintenance

3.4.1.1 The design shall permit noncritical limited-life items to remain in service until they fail; if items are critical, they shall be installed redundantly or so that a degraded alternate operating mode is available.

3.4.1.2 The Log M shall include sufficient spares to support corrective maintenance requirements so that the missing of one regularly scheduled resupply will not jeopardize functions essential to life and mission survival. Spares shall have had the same qualification and receive the same functional tests as the initial equipment.

3.4.1.3 Subsystems shall be designed to permit ease of access for maintenance and repair. Subsystems shall be designed to maximize capability for in-place repair by modular replacement of components or subassemblies at the installed location. Guidelines which shall be utilized in subsystems design are specified in the following paragraphs.

3.4.1.3.1 The Log M shall be designed for prelaunch repair at the preplanned component or assembly level determined for in-space primary repair and permitted by the onboard checkout and fault isolation subsystem and fault-isolation/verification GSE.

3.4.1.3.2 Onboard checkout capability for maintenance support will be provided to the extent required to achieve subsystem fault isolation and verification determined for individual equipment items on the basis of maintainability analyses and mission effectiveness criteria.

3.4.1.3.3 Each item of equipment (i. e., assembly, subassembly, and component) shall be installed with mechanical connections permitting removal and replacement with common handtools.

- 3.4.1.3.4 Access to maintainable equipment shall be designed in accordance with applicable portions of MSFC STD-267A. Access doors shall be captive with positive hold-open provisions.
- 3.4.1.3.5 Special tools shall be provided for mission-survival repairs determined from contingency analyses, such as soldering, metal-cutting, drilling, although repairs of these types shall not be considered routine maintenance.
- 3.4.1.3.6 Protective clothing or protective work areas shall be provided for planned hazardous maintenance tasks, such as those involving fuels.
- 3.4.1.3.7 The Log M shall function with the ISS onboard checkout and fault isolation subsystem to provide automated maintenance procedures and stock location data for planned maintenance and repair activities.
- 3.4.1.3.8 The Log M shall function with the ISS automated onboard inventory control system for spares. An essential feature of the automated system shall be the ability to relay spares control information to the ground inventory system.
- 3.4.1.3.9 Maintenance support stockrooms or stowage facilities for maintenance spares shall be located in an area that provides for ease of inventory control and ready accessibility to docking locations or transfer passages. Maintenance support items for safety-critical equipment shall be given preference for ease of access.
- 3.4.1.3.10 Log M structure, design, and arrangement shall provide access for damage control and repair.
- 3.4.1.3.11 Provisions shall be made for detecting, locating, and repairing meteoroid damage.
- 3.4.1.3.12 Critical items (life-essential and mission-survival equipment) require active or standby redundancy.



Critical items must be readily accessible, and redundant items should be physically separated if possible.

- 3.4.1.3.13 Repair, replacement, and assembly tasks shall have a minimum of exposure to hazards.
- 3.4.1.3.14 The order of precedence for design to accommodate maintenance will be:
- Shirtsleeve environment
  - Space suit (IVA)
  - Space suit (EVA)
- 3.4.1.3.15 Replacement of wearout items will be at the lowest feasible level of assembly.
- 3.4.1.3.16 Fail-safe operation or degraded noncatastrophic operation shall be provided for critical items.
- 3.4.1.3.17 Maximum emphasis shall be placed on commonality and standardization. This includes functional modules as well as nonfunctional items such as fittings, racks, and fasteners.
- 3.4.1.3.18 Equipment shall be designed so that replacement and repair can be accomplished by a minimum number of tools. Tools should have multiple uses.
- 3.4.1.3.19 Captive fasteners shall be used for all equipment which has planned maintenance capability.
- 3.4.1.3.20 Access for maintenance shall be accomplished with minimum disconnection of equipment.
- 3.4.1.3.21 Preferential access shall be provided for mission critical, scheduled replacement, and higher failure risk items.
- 3.4.1.3.22 All wire bundles shall be routed in troughs which will permit minimum ties and maximum capability to replace damaged single wires.

- 3.4.1.3.23            Access doors leading to items which may induce a potentially hazardous environment or incur injury shall be labeled with proper precautionary information and instructions.
- 3.4.1.3.24            All fluid lines and components shall be marked in the vicinity of break points to identify the fluid and show direction of flow.
- 3.4.1.3.25            The design shall provide repair capability of the maximum number of fluid-handling items without penetration of fluid plumbing (separate solenoid and valve, pump and motor, etc.).
- 3.5                    Personnel and Training  
                        Personnel and training requirements shall be as specified in Section 3.5 of Space Station Project Specification No. RS-02927.
- 3.6                    Interface Requirements
- 3.6.1                  Interprogram
- 3.6.1.1                Logistics Modules CEI/Orbiter CEI, Reference RS02928, Interface and Support Requirements, Modular Space Station Project/Orbiter Project, Appendix B, dated (TBD).
- 3.6.2                  Intraprogram
- 3.6.2.1                Logistics Module CEI/RAM CEI  
                        None identified.
- 3.6.3                  Intraproject
- 3.6.3.1                Logistics Module CEI/ISS Modules CEI, Reference RS02927, Modular Space Station Project Specification, Appendix A, dated (TBD).

4. VERIFICATION

This section specifies the requirements for verification of each requirement stated in Section 3. Section 4.2 contains the requirements which must be met for verification. The relationship of these requirements in Section 3 and the methods to be used in verification are identified in Section 4.3. The requirements specified herein are limited to the specification of those verification requirements required to implement project-level policy in the structuring of a cost-effective test program, and do not address detailed testing requirements and procedures.

4.1 General

4.1.1 Responsibility for Verification

4.1.1.1 Verification Management

Unless otherwise specified, the contractor is responsible for the verification of requirements in Section 3. Verification shall be performed in accordance with the requirements established herein.

4.1.1.2 Phase Responsibilities

4.1.1.2.1 Development

Development is conducted to establish the feasibility of the design approach and provides the contractor with confidence in the ability of his CEI to pass qualification. Development tests and assessments shall be conducted primarily to obtain empirical data to support the design and development process. As such, the extent of development shall be left to the contractor for determination, definition, performance, and supportive documentation.

In those special cases, whereby agreement of the contractor and NASA development test data verifies

performance/design requirements, the responsibilities for performance and support specified for qualification shall pertain.

4. 1. 1. 2. 2                    Qualification

Qualification shall be performed and documented by the contractor using standard, supportive practices as specified in NHB 5300.4 (1B). The extent and scope of qualification shall be identified and controlled by NASA/contractor action.

4. 1. 1. 2. 3                    Acceptance

Acceptance verification shall be performed and supported by the CEI contractor with complete buy-off documentation such as logs, test history, test results, records of inspection, discrepancies, deficiencies, review board activities and corrective action. These activities shall be performed by the contractor under NASA surveillance to verify that the end item conforms to system performance requirements. NASA shall participate in acceptance to the extent necessary for it to verify that item being accepted has been built in accordance with the qualified design.

4. 1. 1. 2. 4                    Integrated Systems

Integrated systems verification shall be performed by the ISS module contractor under NASA direction to verify integration of the ISS, Log M, GSE, and Integral Experiments. This verification shall be performed using the Flight Integration Tool (FIT) which is the responsibility of the ISS module contractor.

4. 1. 1. 2. 5                    Prelaunch Checkout

The contractor under the cognizance of the CEI Manager shall be responsible for verifying that the system and ground support equipment are ready for launch and launch support following transport to the launch site. This responsibility may be delegated to a centralized operation at the launch site, but definition of requirements and procedures shall reside with the originating CEI Office. The CEI Management office/contractor shall interface with the Space Shuttle Launch Operations Project Office which will be responsible for the integration and launch of the Station and Shuttle Orbiter. The Space Station Project Office

which will be responsible for the integration and overall management of these verifications. These requirements will be stated in the appropriate Interface and Support Requirements documents.

4.1.1.2.6 Flight/Mission Operation

4.1.1.2.6.1 Responsibility for verification that a system will function in its prescribed manner during Orbiter delivery to and from orbit shall be the responsibility of the contractor.

4.1.1.2.6.2 Orbital buildup and operations verification is the responsibility of the Project Office and shall be supported by the Log M Module contractor.

4.1.1.2.7 Postflight

Postflight evaluation shall be conducted on each module returned to Earth from the Space Station either because of failure or planned return. The evaluation is conducted to determine cause of failure or to verify that the item performed in accordance with specification requirements.

4.1.2 Verification Method Selection

Each requirement of Section 3 shall be verified appropriately by either assessment or test. Section 4.3 contains a matrix which identifies the method selected for verifying Section 3 requirements and also references the applicable verification requirements which are specified in Section 4.2 herein. This section specifies the criteria for verification method selection for the Log M.

4.1.2.1 Selection Criteria

Using a systems engineering approach, verification requirements are defined based upon criticality categories, design margins and technical parameters and compatible with NHB 5300.4 (1A) and NHB 5300.4 (1B). Table I specifies the verification methods appropriate to each phase and criticality category. Selection of

Table I  
 VERIFICATION METHOD REQUIREMENTS

		Verification Phases																		
		Development			Qualification				Acceptance				Pre-launch Checkout			Flight/Mission Operations				
Types of Hardware	Verification Method	Analysis	Demonstration	Test	Similarity	Analysis	Inspection	Demonstration	Test	Analysis	Inspection	Demonstration	Test	Inspection	Demonstration	Test	Analysis	Demonstration	Test	
		Logistics-Module peculiar	Component	X	X	X	X	X	X	X	X	X	X	X	X					
Assembly/subsystem	X		X	X	X	X	X	X	X	X	X	X	X							
System	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Modified/existing	Component				X	X	X	X	X	X	X	X	X							
	Assembly/subsystem				X	X	X	X	X	X	X	X	X							

verification method is guided by this table and constrained as follows for each technical parameter.

- a. Reliability shall be assessed by analytical evaluation of test data acquired for other purposes. No tests shall specifically be designed for verifying reliability.
- b. Maintainability shall be verified primarily by analysis and demonstration. Verification by test shall be limited to mission critical maintenance tasks.
- c. Operational availability requirements shall be verified by the analysis of lower level verification data and demonstration performed in conjunction with integrated systems testing.
- d. Physical requirements shall be verified by inspection and/or test.
- e. Crew usability shall be verified by demonstration.
- f. Hardware that has been used on previous programs shall only be tested for those additional critical environments, properly allowing for interaction of environments and including lifetime when possible.

4.1.2.2                      Assessment

Assessment shall be performed in accordance with one of the following methods:

4.1.2.2.1                    Similarity

Similarity is used whenever the article is similar or identical in design and manufacturing process to another article that has been previously qualified to similar criteria and analysis of dissimilarities either in design, manufacturing process or verification criteria substantiates that the article will perform its intended function within the specified envelope. Similarity shall pertain to characteristics such as material, configuration, and functional elements or assembly, and is applied selectively for applicable environments.

4.1.2.2.2                    Analysis

Analytical techniques used to verify compliance to specification requirements shall include system engineering analysis, statistics, qualitative analysis, and computer simulation.

(10) (A)

Analysis shall not be the sole basis of qualification. Analysis lends itself to the verification of items which require extrapolation from empirical data to prove satisfaction of those requirements that do not warrant the expense of acquiring empirical data.

4.1.2.2.3                    Inspection  
Inspection shall be used only to verify the construction features, drawing compliance, workmanship, and physical condition of the end item.

4.1.2.2.4                    Demonstration  
Demonstration shall be used when actual conduct/operation can verify end-item such features as service and access, maintainability, transportability, or human engineering features.

4.1.2.3                      Test  
Testing other than development testing is performed in direct response to a Section 4 requirement and when an acceptable level of confidence is not established by any of the above assessment methods or if testing is the most cost-effective method.

4.1.2.4                      Criticality Categories  
Criticality categories are established for flight hardware to provide guidelines for determining the test emphasis consistent with attaining the objectives of mission success and crew safety. This categorization is predicated on the possibility of equipment failures which may be human or equipment induced. Table II relates criticality categories to hardware levels. The criticality categories are as follows.



Table II  
 CRITICALITY CATEGORIES

Category	Definition
1	Loss of life of crew member(s) (ground or flight).
1S	Applies to safety and hazard monitoring systems. When required to function because of failure in the related primary operations system(s), potential effect of failure is loss of life of crew member(s).
2A	Immediate mission flight termination including loss of primary mission objectives.
3	Launch delay.
4	None of the above.

4.1.3 Relationship to Management Reviews  
 The contractor shall establish through regularly scheduled management reviews that the requirements for verification specified in Section 4.2 and the methods and phases identified in the Verification Matrix, Section 4.3, meet the specified requirements.

4.1.3.1 Preliminary Requirements Review (PRR)

4.1.3.1.1 The contractor shall support PRR by presenting verification concepts for review and assurance of compatibility overall project requirements. Development tests required to select or substantiate design approaches shall be of special concern in establishing this baseline.

4.1.3.2 Preliminary Design Review (PDR)

4.1.3.2.1 PDR, a formal technical review of the basic design approach, shall include a technical review of the basic verification approach of the CEI.

4. 1. 3. 2. 2            Test article design and operational concepts shall be reviewed at PDR.
4. 1. 3. 2. 3            Verification participation in PDR shall include verification of requirements for development testing; preliminary criteria for receiving inspection/test, in-process inspection/test, end-item test and acceptance inspection; and preliminary development and qualification test plans which include the methodology for verifying the design and performance requirements of Section 3.
4. 1. 3. 2. 4            Sufficient analyses and testing shall be conducted to provide confidence in the design approach and its producibility.
4. 1. 3. 2. 5            The Part I CEI specification listing performance/ design requirements and verification methods shall be presented for approval at the PDR.
4. 1. 3. 3                Critical Design Review (CDR)
4. 1. 3. 3. 1            The formal technical review of CEI design performed at CDR shall be supported by development verification data.
4. 1. 3. 3. 2            As a goal, all development data shall be available for comparison at CDR.
4. 1. 3. 3. 3            Test review at CDR shall cover analysis of available development and qualification test data, preliminary end-item test plans, sampling plans, and detailed inspection plans.
4. 1. 3. 3. 4            Processing and manufacturing methods specified by the design which have not been previously used shall be substantiated prior to release of drawings.
4. 1. 3. 3. 5            The Part II CEI specification indicating design solutions and verification requirements shall be presented at the CDR.

4.1.3.4 Configuration Inspection (CI)

The Configuration Inspection is a formal technical review to determine if the end item hardware has been built and verified in accordance with the Part II CEI Specification which is presented at the CI for approval. The CI establishes that verification was performed and that the as-built hardware did in fact comply with the requirement of the Part I CEI Specification. The verification documentation and hardware presented at CI shall verify the applicable portion of Section 4.2 of this program specification.

4.1.3.5 Post-CI Reviews

The status of verification shall be reviewed at each major milestone and documented prior to initiation of the next activity. Management reviews shall be utilized to perform these reviews. As a minimum these reviews shall occur at completion of integrated systems verification, prelaunch checkout, and orbital buildup.

Specific requirements for these reviews shall be stated herein by completion of PRR.

4.1.4 Test/Equipment Failure

4.1.4.1 Failure/Retest Criteria

4.1.4.1.1 Prior to the performance of any verification, the criteria of failure must be objectively established in procedural documentation.

4.1.4.1.2 Subsequent to each failure, but prior to retest, an evaluation shall be made to determine whether partial test requirements have been met prior to failure or can be met by other means. If either is true, total retest shall not be performed.

4.1.4.1.3 Failures occurring in qualification testing shall disqualify any item with same specifications from similar use.

4.1.4.1.4 After test qualification, a posttest inspection shall be made to identify any potential failure modes.

4.1.4.1.5 Hardware used in unsuccessful tests shall be evaluated as to its further use. If the test was a failure as a result of hardware design or function, identical hardware shall be disqualified from similar use.

4.1.4.2 Hardware/Computer Program Reuse

4.1.4.2.1 As a goal, all test hardware/computer programs shall be refurbished/recompiled and reused, whenever cost effective, as higher level assembly test hardware or flight spares. In the case of failed hardware/computer programs, failure reports shall be reviewed and a determination made as to the suitability of the item for further use. This determination shall include the specification of reuse leveling, i. e., test hardware or flight spares.

4.2 Phased Verification Requirements

4.2.1 Development

Development assessment and tests are performed to verify the feasibility of the design approach prior to committing to the production of flight hardware. No specific development verification requirements have been identified which are appropriate for contractual obligations with the exceptions of data management computer program functions which shall be verified using the Functional Model.

4.2.2 Qualification

Qualification is performed on Log M flight modules to verify that design and performance specifications have been met.

4.2.2.1 Similarity

Qualifications by similarity is not applicable to system and verification. The requirements specified in the following paragraphs apply to assembly level verifications applicable to Log M qualifications by analysis, paragraph 4.2.2.2.

4.2.2.1.1 Hardware characteristics (all or partially) qualified for use on a previous program shall be verified for by similarity if the following requirements are met:

- (a) Engineering evaluation reveals that design differences between the item being qualified and the previously qualified similar item are insignificant.
- (b) The previously qualified similar item was designed and qualified for equal or higher environmental stress levels and time durations than those known or anticipated for the item being qualified.
- (c) The item being qualified was fabricated by the same manufacturer as the similar item using the same processes, materials and quality control. Exceptions to this requirement may be granted on a case-by-case basis provided that a waiver request is submitted together with acceptable rationale to the contracting officer and that the manufacturer utilizes MSFC specified or approved process and quality control standards.
- (d) Documentation is provided which assures that qualification by similarity is adequate. The submitted documentation should include as a minimum, the test specification/test procedure/test report of the item to which similarity is claimed, a description of the differences between the items and the rationale for qualification by similarity.

4.2.2.1.2 Similarity shall be substantiated by manufacturer attestations, specifications and product inspection reports and approved by NASA.

4.2.2.2 Analysis  
System level analysis shall be the primary method used for qualifying the Log M relative to performance under extremes of environment and other system level characteristics which may be determined by analysis of lower level data. These analyses shall appropriately translate assembly group, assembly and subassembly data reflecting similarity, analysis, demonstration and test. This data shall generally be in accordance with paragraphs 4.2.2.1 through 4.2.2.4 of this specification.

- 4.2.2.2.1 Analysis shall not be the sole basis of qualification.
- 4.2.2.2.2 All analyses used for qualification shall be documented as to methods and results obtained.
- 4.2.2.3 Demonstration  
Demonstration is applicable to system level verification and to lower level verification applicable to Log M qualification by analysis, paragraph 4.2.2.2.  
Hardware and software configurations used in demonstrations for the purpose of qualification shall be identical to flight hardware and the procedures followed must be prepared prior to the demonstration and controlled throughout the activity.
- 4.2.2.4 Test  
Test is applicable to system level verification and to lower level verification applicable to Log M qualification by analysis, paragraph 4.2.2.2. The requirements for both applications are specified in the following paragraphs.
- 4.2.2.4.1 Qualification test hardware shall be selected from a normal production run. Test hardware shall have been subjected to normal inspection and acceptance tests. If first production items are selected, then all subsequent production items shall be produced identically to the selected test items.
- 4.2.2.4.2 Hardware items subjected to qualification testing shall be so identified and shall not be utilized as life critical flight hardware.
- 4.2.2.4.3 The number of qualification test specimens selected shall be sufficient to yield a significant level of engineering confidence.
- 4.2.2.4.4 Equipment shall be qualified to nominal operations pressures and g-levels to be experienced by compartments in which they are located. In addition, equipment shall be qualified to

withstand and recover from evaluation of a compartment, where critical to mission operations.

4.2.2.4.5 Induced environment testing shall be conducted at the assembly group level or lower. Testing shall be performed at the highest level possible within this constraint. Qualification of an item by test of a higher assembly or module is acceptable provided the item being qualified is subjected to stress levels and time durations during the higher assembly test which are equal to or higher than the environmental qualification levels and durations specified for the item in the proposed application. Interactions between the various components and subsystems must be considered and evaluated when individual hardware items are qualified as part of a higher assembly test.

4.2.2.4.6 The 10-year life requirement shall be verified by a combination of analysis and test.

4.2.2.4.7 Tests shall be conducted to verify:

- (a) The performance of the hardware to perform its intended mission in the anticipated environment.
- (b) The impact of environmental sequencing and limit severity.

4.2.2.4.8 Qualification testing shall be conducted with controlled hardware configuration and test procedures.

4.2.2.4.9 Hardware that has been used on previous programs shall only be qualified for those additional critical environments.

4.2.2.4.10 The contractor shall verify by functional test that the electromagnetic compatibility of systems operation is within the specifications of MIL-I-5061C.

4.2.3 Acceptance  
Acceptance shall verify that the Log M has been manufactured to the qualified design, meet the design intent

and will perform during the mission as designed. All acceptance verification shall be conducted against released engineering, and shall be performed by the system contractor at the factory.

4.2.3.1 Analysis

4.2.3.1.1 Analyses shall be conducted prior to system acceptance and shall be documented in Part II (CEI) specifications.

4.2.3.2 Inspection

In process inspections shall verify that prescribed methods and materials are used in the manufacturing processes.

4.2.3.3 Demonstration

None identified.

4.2.3.4 Test

The onboard checkout and fault isolation subsystem shall be used with GSE for Log M acceptance testing at the contractor's plant.

4.2.4 Integrated Systems

Integrated systems verification is conducted to ensure the compatibility of system level interfaces and inter-element performance. The requirement for integrated systems verification has been identified at project level and shall be met by the ISS module contractor.

4.2.5 Prelaunch Checkout

Prelaunch verification shall ascertain the readiness of the flight hardware for launch and ground support equipment to support that launch.



4.2.5.1 Inspection

4.2.5.1.1 A complete visual inspection of each module shall be performed at the launch site to ensure satisfactory physical condition.

4.2.5.2 Demonstration

4.2.5.2.1 Prelaunch operations shall be performed in accordance with preestablished procedures.

4.2.5.2.2 Successful completion of prelaunch operations shall constitute verification by demonstration.

4.2.5.3 Test

Prelaunch testing of modules shall be restricted to those tests necessary to ascertain integrity relative to critical functions following transport and to the checkout of module/orbiter interface.

4.2.6 Flight/Mission Operations

Verification during flight/mission operations is conducted by the project to ensure mission readiness and continuity while in orbit by means of inherent onboard systems.

4.2.7 Postflight

Postflight verification is required to establish readiness of the Log M for ground processing in accordance with requirements of 3.1.2.1.4.

4.3 Verification Matrix

This section contains a one-for-one cross reference of each verification requirement for each Section 3 requirement and identifies the method by which each requirement is to be verified.

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.	X								
3.1							3		4.2.6
3.1.1	X								
3.1.1.1				4					4.2.3.2
3.1.1.1.1				3					4.2.3.1
3.1.1.1.2				3/4					4.2.3.1, 4.2.3.2
3.1.1.1.3				3					4.2.3.1
3.1.1.2	X								
3.1.1.2.1	X								
3.1.1.2.2	X								
3.1.1.2.3	X								
3.1.1.2.4	X								
3.1.2	X								
3.1.2.1	X								
3.1.2.1.1				3					4.2.2.2
3.1.2.1.2				3					4.2.2.2
3.1.2.1.3				3					4.2.2.2
3.1.2.1.4				3/5				5	4.2.2.2, 4.2.2.3, 4.2.7
3.1.2.2				3					4.2.2.2
3.1.3	X								
3.1.3.1				3					4.2.2.2
3.1.3.1.1	X								
3.1.3.1.1.1				3					4.2.2.2

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.1.3.1.1.2			1/3						4.2.2.2
3.1.3.1.3			1/3	1					4.2.2.2, 4.2.2.4, 4.2.3.4
3.1.3.1.2			5						4.2.2.3
3.1.3.1.3			5						4.2.2.3
3.1.3.1.4			3						4.2.2.2
3.1.3.1.5			3/5						4.2.2.2, 4.2.2.3
3.1.3.2			3						4.2.2.3
3.1.3.3	X								
3.1.3.3.1			3						4.2.2.3
3.1.3.3.2			3						4.2.2.3
3.1.3.3.3			3						4.2.2.3
3.1.3.4	X								
3.1.3.4.1	X								
3.1.3.4.1.1			3						4.2.2.3
3.1.3.4.1.2			1/3						4.2.2.3, 4.2.2.4
3.1.3.4.2			1/3						4.2.2.3, 4.2.2.4
3.1.3.4.3			3						4.2.2.3
3.1.3.4.4			3						4.2.2.3
3.3.3.5	X								
3.1.3.5.1			3						4.2.2.2
3.1.4	X								
3.1.5	X								
3.1.6	X								

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2	X								
3.2.1	X								
3.2.1.1			3						4.2.2.2
3.2.1.1.1	X								
3.2.1.1.1.1			3						4.2.2.2
3.2.1.1.1.2			3						4.2.2.2
3.2.1.1.1.3			1/3						4.2.2.2, 4.2.2.4
3.2.1.1.1.4			1/3						4.2.2.2, 4.2.2.4
3.2.1.1.2			1/3						4.2.2.2, 4.2.2.4
3.2.1.1.3			1/3						4.2.2.2, 4.2.2.4
3.2.1.2	X								
3.2.1.2.1			3						4.2.2.2
3.2.1.2.2			3						4.2.2.2
3.2.1.2.2.1			1/3						4.2.2.2, 4.2.2.4
3.2.1.2.2.2			1/3						4.2.2.2, 4.2.2.4
3.2.1.2.3	X								
3.2.1.2.3.1			3						4.2.2.2
3.2.1.2.3.2	X								
3.2.1.2.3.3			5						4.2.2.3
3.2.1.2.4	X								
3.2.1.2.4.1			5						4.2.2.3
3.2.1.2.4.2			5						4.2.2.3
3.2.1.2.5			3/5						4.2.2.2, 4.2.2.3

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.2.6			3						4.2.2.2
3.2.1.2.7			1/3						4.2.2.2, 4.2.2.4
3.2.1.3	X								
3.2.1.3.1			3						4.2.2.2
3.2.1.3.2	X								
3.2.1.3.2.1			3						4.2.2.2
3.2.1.3.2.2			3						4.2.2.2
3.2.1.3.2.3			3						4.2.2.2
3.2.1.3.2.4			3						4.2.2.2
3.2.1.3.3			3						4.2.2.2
3.2.1.3.3.1			3						4.2.2.2
3.2.1.3.3.1.1			3						4.2.2.2
3.2.1.3.3.1.2			3						4.2.2.2
3.2.1.3.3.1.3			3						4.2.2.2
3.2.1.3.3.2			3						4.2.2.2
3.2.1.3.3.3			3						4.2.2.2
3.2.1.3.3.4			3						4.2.2.2
3.2.1.3.3.5			3						4.2.2.2
3.2.1.3.3.6			3						4.2.2.2
3.2.1.3.3.7			3						4.2.2.2
3.2.1.3.3.8			3						4.2.2.2
3.2.1.3.4	X								
3.2.1.3.4.1			1/3						4.2.2.2, 4.2.2.4

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## REQUIREMENTS FOR VERIFICATION

## VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

## VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.2.1.3.4.2			1/3						4.2.2.2, 4.2.2.4
3.2.1.3.4.3			1						4.2.2.2, 4.2.2.4
3.2.1.3.4.4			1/3						4.2.2.2, 4.2.2.4
3.2.1.3.4.5			3						4.2.2.2
3.2.1.3.4.6			3						4.2.2.2
3.2.1.3.4.6.1			1						4.2.2.4
3.2.1.3.4.6.2			3						4.2.2.2
3.2.1.3.4.6.3			1/3						4.2.2.2, 4.2.2.4
3.2.1.3.4.6.4			3						4.2.2.2
3.2.1.3.4.7			3						4.2.2.2
3.2.1.3.4.7.1			5						4.2.2.3
3.2.1.3.4.7.2			1/3						4.2.2.2, 4.2.2.4
3.2.1.3.4.7.3			1/3						4.2.2.2, 4.2.2.4
3.2.1.3.4.7.4			1/3						4.2.2.2, 4.2.2.4
3.2.1.3.4.8			3/5						4.2.2.2, 4.2.2.3
3.2.1.3.4.9			3						4.2.2.2
3.2.1.3.4.10			3/5						4.2.2.2, 4.2.2.3
3.2.1.4			1/3						4.2.2.2, 4.2.2.4
3.2.1.5	X								
3.2.1.5.1			1/3						4.2.2.2, 4.2.2.4
3.2.1.5.2			1/3						4.2.2.2, 4.2.2.4
3.2.1.5.3			3						4.2.2.2
3.2.1.6	X								

System  <p style="text-align: center;">Log M</p>	VERIFICATION CROSS REFERENCE INDEX	Spec No. <u>CP02930</u> Dated <u>15 December 1971</u> Page <u>63 of 74</u>
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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
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3.2.2.5.1.1			3						4.2.2.2
3.2.2.5.1.2			3						4.2.2.2
3.2.2.5.1.3			3						4.2.2.2
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3.2.2.5.2.1			5						4.2.2.3
3.2.2.5.2			3						4.2.2.2
3.2.2.6	X								
3.2.2.6.1			5						4.2.2.3
3.2.2.6.2			5						4.2.2.3
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

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- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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3.2.6.2.1.2			3						4.2.2.2
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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Log M

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## VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

## VERIFICATION PHASE:

- A. Development
- B. Qualification
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- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

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Design Requirement  
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## Verification Methods

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Verification  
Requirement  
Reference

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
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- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
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- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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3.6.3	X								
3.6.3.1			1						4.2.3.4
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3.6.3.1.2.1			1						4.2.2.4
3.6.3.1.2.2			1						4.2.2.4
3.6.3.1.2.3			1						4.2.2.4
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3.6.3.1.7	X								

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

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- A. Development
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Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
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- 4.4 Test Support Requirements
  - 4.4.1 Facilities and Equipment
    - 4.4.1.1 Test equipment needed to simulate inputs/outputs to subsystems shall be compatible with the onboard checkout and fault isolation system and other interfacing subsystems.
    - 4.4.1.2 All test equipment shall be certified to ensure that no damage or degradation is introduced into the test hardware or that results will not include test equipment error.
    - 4.4.1.3 Special high levels of atmospheric or surface cleanliness shall not be required for verification processes unless necessary to the requirement being verified.
  - 4.4.2 Articles
    - Log M test articles shall consist of and be limited to a Functional Model (FM). Performance and design requirements specified in the following paragraphs shall determine the characteristics of the FM.
    - 4.4.2.1 Functional Model
      - 4.4.2.1.1 FM Capability Requirements
        - 4.4.2.1.1.1 The Log M Functional Model shall provide the capability of being utilized to develop the functional integration of the Log M with ISS subsystems. As a design goal it shall provide design assurance that all equipment shall perform properly when subsequently the flight articles are tested.
        - 4.4.2.1.1.2 The FM shall be capable of providing a Log M simulation in support of computer program development for the ISS.
        - 4.4.2.1.1.3 The FM shall be capable of being used for development of preliminary operations procedures, relative to crew utilization of the ISS control consoles.



4.4.2.1.2 FM Composition

4.4.2.1.2.1 The FM shall functionally represent the entire Log M. This shall be accomplished either by interconnection of flight equipment or by simulation.

4.4.2.1.2.2 All critical functional interfaces shall be simulated, including representative interfaces with the Orbiter and cargo.

4.4.2.1.2.3 As a design goal the entire electrical/electronic function shall be represented by flight hardware. As a minimum, the following shall be included:

- a) The complete data management subsystem including displays and controls.
- b) All automatic redundancy management equipment.
- c) A highly representative portion of the onboard checkout and fault isolation subsystem.
- d) Representative data sensors or data source devices from all subsystems.

4.4.2.1.2.4 Flight equipment shall be composed of a combination of production flight hardware and assemblies or components from the development program which shall be functionally equivalent to production equipment.

4.4.2.1.3 FM Design and Construction Standards

4.4.2.1.3.1 Structural

The FM design shall provide for physical installation of hardware in equipment racks suitable for a laboratory environment.

4.4.2.1.3.2 Functional

The FM design shall provide interconnect of equipment which shall detail cable lengths and arrangements.

4.4.2.1.3.3

Life

The FM shall be designed to be operated for three years.

4.4.2.1.4

FM Configuration Control

The FM design shall accommodate a change control system which shall, as a minimum, provide traceability of interconnect changes and provide the capability to establish, at the FM facility, a specific detailed functional configuration.

IDENTIFICATION ITEM DETAIL SPECIFICATION

PART I OF TWO PARTS

PERFORMANCE, DESIGN AND VERIFICATION REQUIREMENTS

FOR

GROUND SUPPORT EQUIPMENT

(CEI NUMBER CP-02931)

FOR

MODULAR SPACE STATION PROJECT

APPROVED BY J.D. Smith  
(Preparing Activity)

APPROVED BY W.A. Brookholy  
(NASA Office)

DATE 15 December 1971

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1. SCOPE

This part of this specification establishes the requirements of performance, design and verification of one type-model-series of equipment identified as the Modular Space Station Ground Support Equipment.

It constitutes a support system of the Modular Space Station Project of the Modular Space Station Program. Other systems of the Modular Space Station Project include the Initial Space Station (ISS) Module, the integral experiment systems which are accommodated in the ISS, the Logistics Module (Log M) system and the facility systems which support the project from development through mission operations.

The Modular Space Station Project, when integrated with the Research and Application Module (RAM) Project and supported by the Space Shuttle Program forms the Space Station Program, providing a laboratory in Earth orbit to conduct and support scientific and technological experiments for beneficial application and for further development of space exploration capability.

This document is subordinate and constrained by the requirements specified in MSFC Data Procurement Document 235, Data Requirement CM-02 Specification, Space Station Project (Modular).

2. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced, and other detailed contents of this specification, the detailed requirements herein shall be considered superseding.

GROUND SUPPORT EQUIPMENT

SPECIFICATION

Text Reference

Military

MIL-C-91302, C  
Cleaning Compound Solvent

3. 3. 10. 5

Text Reference

Military

MIL-M-8090, Mobility, Towed Aerospace GSE	3. 2. 7. 2
MIL-I-8500, Interchangeability and Replaceability	3. 3. 12
MIL-T-21200, Test Equipment, for Use with Electronic and Fire Control Systems	3. 3. 12
MIL-F-7179, Finishes and Coatings	3. 3. 9. 1
MIL-I-7444, Insulation Sleeving	3. 3. 5. 7
MIL-B-50878(ASG), Bonding, Electrical, and Lighting Protection for Aerospace Systems, 31 August 1970	3. 3. 5. 1
MIL-E-6051D, Electromagnetic Compatibility Requirements, System, 5 July 1968	3. 3. 5. 1
MIL-H-25475A, Hydraulic Systems, Missile, Design, Installation Tests, and Date Requirements, General Require- ments for, 19 January 1961	3. 3. 6. 2
MIL-I-6181D, Interference Control Requirements, Aircraft Equipment, 22 June 1965	3. 3. 5. 1

KSC

KSC-SPEC-Z-0007, Tubing Steel, CRES, Type 304 and 316, Seamless, Specification for	3. 3. 6. 5
KSC-SPEC-Z-0008, Fabrication and Installation of Tube Assemblies and Installation of Fittings and Fitting Assemblies	3. 3. 6. 5
KSC-SPEC-Z-0002, Welding Aluminum Alloy Pipe, Tubing, and Associated Fittings	3. 3. 6. 4
KSC-SPEC-Z-0003, Welding of Stainless Steel, Invar 36 Pipe, Tubing and Associated Fittings	3. 3. 6. 4

Text Reference

MSFC

MSFC-SPEC-250, Protective Finishes for Space Vehicle Structures, February 1964	3.3.9.1
MSFC-SPEC-491, Space Vehicle Ordnance Systems, January 1970	3.3.2.2.2

STANDARDS

Military

MIL-STD-129E, Marking for Shipment and Storage, 20 April 1970	3.3.13
MIL-STD-130C, Identification Marking of U. S. Military Property, 29 September 1967	3.3.13
MIL-STD-143B, Standards and Specifications, Order of Precedence for the Selection of 12 November 1969	3.3.1
MIL-STD-721B, Definition of Effectiveness Terms for Reliability Maintainability, Human Factors, and Safety, 25 August 1966	3.3.12
MIL-STD-810B, Environmental Test Method	3.3.8

MSFC

MSFC-STD-267A, Human Engineering Design Criteria, September 1966	3.2.4.1, 3.2.6.1
MSFC-STD-421A, Electrical Support Equipment, General Design Requirements for	3.3.5.4

KSC

KSC-STD-E-0012, Bonding and Grounding	3.3.5.6
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PROCEDURES

Text Reference

MSFC

MSFC-PROC-195, Cleanliness Level, Gas Bearing Supply, Slosh Measuring System	3. 3. 10. 4
MSFC-PROC-158, Soldering of Electrical Connections, Notice-1 August 1968	3. 3. 5. 3
MSFC-PROC-404, Gases, Drying and Preservation, Cleanliness Level and Inspection Methods	3. 3. 10. 4

DRAWINGS

10M01671, Cleanliness Levels, Inspection Procedures for Support Equipment	3. 3. 10. 4
50M02260, Wiring Board, Printed, Multilayer, Design and Documentation of	3. 3. 5. 5
10M33295, Plate, Calibrated	3. 3. 6. 6
10M33300, Orifice, Flow Restricting	3. 3. 6. 6
10M01801, Marking of GSE, for Handling	3. 3. 13
40M00220, Wiring Electric, GSE, Identification Marking and Color Coding	3. 3. 13

OTHER PUBLICATIONS

Regulations

U. S. Atomic Energy Commission Title 10 Code of Federal Regulations	3. 3. 7
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	<u>Text Reference</u>
<u>Handbooks</u>	
MIL-HDBK-5, Metallic Materials and Elements for Aerospace Vehicle Structures	3. 3. 6
MIL-HDBK-17, Plastics for Flight Vehicles, Part II Transparent Glazing Materials, 14 August 1961	3. 3. 6
MIL-HDBK-23, Structural Sandwich Composites, 30 December 1968	3. 3. 6
Miscellaneous	
KSC-F-124, Fittings (Pressure Connections )Flared Tube	3. 3. 6. 5
KSC-SP-4-38, Acoustics and Vibration Environment and Test Specification Levels GSE LC 39	3. 2. 7. 3
O-E-760, Ethyl Alcohol (Ethanol). Denatured Alcohol and Proprietary Solvent	3. 3. 10. 5
O-M-232, Methanol (Methyl Alcohol)	3. 3. 10. 5
BB-F-1421, Fluorocarbon Refrigerants	3. 3. 10. 5
TT-I-735, Isopropyl Alcohol.	3. 3. 10. 5
ASA-B31, Code for Pressure Piping	3. 3. 6. 4
ASTM-A-182, Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temp Service, Specification for	3. 3. 6. 4
ASTM-A312, Seamless and Welded Austenitic Stainless Steel Pipe, Specification for	3. 3. 6. 4
ASTM-B241, Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube, Specification for	3. 3. 6. 4
ASTM-B361, Factory Made Wrought Aluminum and Aluminum- Alloy Welding Fittings, Specification for	3. 3. 6. 4

3. REQUIREMENTS

3.1 CEI Definition

Modular Space Station Project Ground Support Equipment (GSE) shall be utilized to support the Initial Space Station Modules (Specification No. CP-02929) and Logistics Modules (Specification No. CP-02930) during factory acceptance test, transportation from the factory to the launch site, servicing operation, orbital support operations and, in the case of the Log M, refurbishment between flights.

3.1.1 General Description

Ground Support Equipment will be predicated on maximum utilization of Orbital vehicle capabilities. In particular, the ISS onboard checkout and fault isolation equipment shall be used to a maximum extent possible for all checkout operations. Orbital procedures and computer software shall also be used to the greatest practical extent. Specific types of GSE are described as follows:

3.1.1.1 Space Station Modules

Space Station Modules GSE shall provide the functions described in the following paragraphs relative to the ISS and shall be capable of utilization for ground support of other systems of the product. Unique additions for adopting Space Station Modules GSE to another system shall be identified with that system.

3.1.1.1.1 Integrated checkout equipment shall supplement the capabilities of onboard systems to accomplish system checkout.

3.1.1.1.2 Electrical equipment is required to perform special tests on individual or integrated modules.

3.1.1.1.3 Servicing equipment is required to provide ground services such as cooling, purging, flushing, pressurizing, and filling.

3.1.1.1.4 Access equipment shall provide access for personnel and equipment to the interior and exterior during ground operation.

- 3.1.1.1.5 Handling and protection equipment is required to permit hoisting modules and assemblies during manufacturing, transportation, and assembly operations and to protect the modules and assemblies during transportation and storage.
- 3.1.1.1.6 Transportation equipment shall provide the capability to transport Space Station and Logistics modules over improved roadways and perform as a carrier in transport aircraft.
- 3.1.1.2 Logistics Module  
Logistics Module GSE includes only that additional equipment uniquely required to support Log M development, production and operations. Included also is the equipment required for spares maintenance and handling, and cargo handling. Log M GSE shall serve the same functions described for the Space Station modules, as applicable.
- 3.1.1.3 Integral Experiments  
Experiment GSE is that unique equipment required to support experiments to be integrated into the Initial Space Station modules. It includes checkout, handling, shipping, and servicing equipment.
- 3.1.1.4 Launch Operations  
Launch Operations equipment includes all unique equipment required to supplement Space Station, Logistics Module, and Shuttle GSE during prelaunch and launch operations over and above that required to support the hardware both at the factory and launch site.
- 3.1.1.5 Flight Operations  
Flight operations equipment supports mission operation's functions which provide mission planning, flight operations support, logistics operations support and experiment operations support.

- 3.1.1.6                    Test Article  
                          Test Article GSE is that unique equipment required to support the operations of the Functional Model (FM) and Flight Integration Tool (FIT).
- 3.1.2                     Missions
- 3.1.3                     Operational Concepts
  - 3.1.3.1                 The ISS onboard checkout system shall be used to the maximum extent possible for all ground checkout at the factory and launch site.
  - 3.1.3.2                 GSE shall be used to supplement onboard subsystems with additional functions and services.
  - 3.1.3.3                 The design of ground support provisions shall be compatible with orbital checkout and fault isolation procedures and strengthen if possible.
  - 3.1.3.4                 Multipurpose utilization of GSE shall be optimized.
  - 3.1.3.5                 GSE shall be transportable to allow use at multiple locations.
- 3.1.4                     Organization and Management Relationships (TBD)
  - 3.1.4.1                 The Modular Space Station Project shall ensure the optimization of commonality among GSE designs and operations and of multipurpose utilization of equipment among prime equipment contractors. Furthermore, it shall ensure that each GSE contractor, assigned on the basis of prime equipment original user, satisfactorily accommodates the requirements of subsequent users.
- 3.1.5                     Systems Engineering Requirements (TBD)
- 3.1.6                     Government Furnished Property List  
                          Any existing equipment that can meet the included requirements shall be identified here as GFE.

- 3.1.7 Critical Components (TBD)
- 3.2 Characteristics
  - 3.2.1 Performance
    - 3.2.1.1 Space Station Module GSE
      - 3.2.1.1.1 Integrated Checkout Equipment
        - 3.2.1.1.1.1 A central distribution point for all digital data handled or processed on the ground shall be provided. It shall be designed to provide the following capabilities:
          - 3.2.1.1.1.1.1 Provide external control and monitoring of onboard functions and the data bus during hazardous operations, during launch countdown, and as backup to critical onboard functions during ground operations.
          - 3.2.1.1.1.1.2 Verify data bus operation across the docking interfaces.
          - 3.2.1.1.1.1.3 Verify digital data communications via RF link to the DRSS, ground and Shuttle.
          - 3.2.1.1.1.1.4 Monitor and control the ground servicing and checkout equipment.
          - 3.2.1.1.1.2 Ground control and display is required for both the onboard systems and supplementary ground checkout and servicing. This shall be compatible with the utilization of the portable control and display unit provided for flight use to supplement the integrated checkout equipment.
          - 3.2.1.1.1.3 Test receivers and transmitters capable of radiated and hardline transmission and receiving shall be provided to verify the communications interfaces.
          - 3.2.1.1.1.4 A communications system shall be provided capable of receiving voice, television, digital and ranging data in multiplexed baseband from the receivers.

- 3.2.1.1.1.5           A general-purpose digital computer capable of formatting digitally coded commands and data for transmission via various RF interfaces and the data bus docking port and ground umbilical interfaces shall be provided. Specific requirements are:
- 3.2.1.1.1.5.1        Verify capability of Space Station to receive and process digital commands and/or data transmitted from the ground (direct and via DRSS), from the experiment modules, and from the Shuttle, with data rates to 10 megabits per second (Mbps).
- 3.2.1.1.1.5.2        Verify the capability of the Space Station to transmit digital commands and/or data to the ground (direct and via DRSS), to the experiment modules, and to the Shuttle, with data rates to 10 Mbps.
- 3.2.1.1.1.5.3        Verify data bus interfaces across docking ports.
- 3.2.1.1.1.5.4        Provide ground control of data bus as backup to onboard system during ground operations.
- 3.2.1.1.1.5.5        Provide data management functions during initial system integration and checkout.
- 3.2.1.1.1.5.6        Provide control and monitoring of ground servicing and checkout equipment.
- 3.2.1.1.1.6         Provide electrical power to the Space Station during ground operations where the solar array is neither deployed nor functional.
- 3.2.1.1.1.7         Provide the capability to verify that the Space Station power distribution system can operate at rated electrical loads and can deliver the specified power to the docking interfaces.
- 3.2.1.1.1.8         Provide external recording of test data for engineering analysis and to provide backup to the onboard recording capabilities in the event of an accident or malfunction which results in loss of onboard data.
- 3.2.1.1.1.9         Provisions shall be made for the artificial stimulation and loading of onboard star trackers, star sensors, horizon sensors.

- 3.2.1.1.1.10 A time reference shall be provided to onboard systems capable of generating timing signals.
- 3.2.1.1.1.11 Switching and measurement capability shall be provided for those items of ground servicing and checkout equipment which require remote monitoring and control. Specific functions to be included are as specified in the following paragraphs.
- 3.2.1.1.1.12 Provide remote monitoring and control capability for GSE items located near the vehicle which require continuous monitoring or which must be monitored and controlled during testing hazardous operations such as high-pressure gas transfer, propellant loading, countdown, and launch.
- 3.2.1.1.1.13 Backup external control and monitoring of critical Space Station functions shall be provided to allow safing in the event of an accident or malfunction which renders normal control channels inoperative.
- 3.2.1.1.1.14 A portable metabolic simulator shall be provided for checkout of the ECLS subsystem. It shall be capable of injecting and/or removing H<sub>2</sub>O, O<sub>2</sub> and CO<sub>2</sub> from the atmosphere in test.
- 3.2.1.1.1.15 Provisions shall be made for the distribution of electrical control and monitoring signals and dc power between various items of GSE and between the GSE and station module(s).
- 3.2.1.1.2 Electrical Equipment
- 3.2.1.1.2.1 Steady state and transient interference between electrical/electronic equipment shall be capable of being detected and recorded.
- 3.2.1.1.3 Servicing Equipment
- 3.2.1.1.3.1 The capability shall be provided to remove heat loads generated by onboard electronic/electrical equipment and habital heat loads of the modules during ground operations.
- 3.2.1.1.3.2 Facility-provided gases shall be controlled and regulated for the purpose of leak and functional testing,



purging hazardous gases, and filling onboard pressure vessels. This capability shall be provided for all gases used during ground operations.

- 3.2.1.1.3.3            A 10-100 micron vacuum capability shall be provided.
- 3.2.1.1.3.4            Provisions shall be made for purging, leak-testing, filling and pressurizing radiator circuits, interface heat exchangers, temperature control units, pumps and accumulators.
- 3.2.1.1.3.5            During ground operations, when the module(s) is in a power-down condition, the capability for maintaining a habitable working environment within manned compartments, shall be provided. As a minimum ample control and distribution of filtered, humidity- and temperature-controlled air shall be provided to work areas.
- 3.2.1.1.3.6            The capability to evacuate, pressurize, fill, circulate, and purge potable and coolant water systems shall be provided.
- 3.2.1.1.3.7            Provisions shall be made to maintain insulation at a moisture content below TBD.
- 3.2.1.1.3.8            A hardwire electrical umbilical shall be provided at the ground system/station module interface which includes essential command, control, and monitor functions associated with assessing condition of and safing dynamic systems of the vehicle and with accomplishing checkout functions.
- 3.2.1.1.3.9            The capability of withdrawing up to one gallon of coolants, potable water, and coolant water from service units for clinical analysis prior to use shall be provided.
- 3.2.1.1.3.10           Provisions shall be made for the bulk storage, control and distribution of coolants prior to charging onboard systems. Control shall include quantitative measurement and leak detection.
- 3.2.1.1.4            Access Equipment
- 3.2.1.1.4.1            Provisions shall be made for ground crew access to both internal and external portions of Space Station modules. These access provisions shall be designed to.

- 3.2.1.1.4.1.1 Protect docking port seals from damage by personnel and equipment.
- 3.2.1.1.4.1.2 Protect the Space Station interior from damage by personnel, tools, and carry-on ground equipment.
- 3.2.1.1.4.1.3 Provide internal lighting during periods that normal lighting cannot be used.
- 3.2.1.1.4.2 Provisions for emergency treatment and removal of injured or incapacitated crewmen from the Space Station interior shall be made.
- 3.2.1.1.4.3 Provisions for external access to the modules in both a vertical and horizontal mode shall be made.
- 3.2.1.1.4.4 Provision for internal access to the modules in a horizontal mode shall be made.
- 3.2.1.1.5 Handling and Protection Equipment
  - 3.2.1.1.5.1 Hoisting equipment shall be provided for handling spacecraft equipment external to the modules during assembly and/or repair.
  - 3.2.1.1.5.2 Provisions shall be made for handling equipment which exceeds the weight and size limitation for safe manual handling.
  - 3.2.1.1.5.3 Provisions shall be made to attach hoisting devices to modules during ground handling, weight checks, and transportation. These provisions shall enable placement in assembly areas and movement onto or from transport devices.
  - 3.2.1.1.5.4 All practical methods and procedures to protect special coatings from damage or contamination shall be employed. Additionally, all module external surfaces shall be protected during transportation and storage from excessive dust, moisture, or corrosive atmosphere.
  - 3.2.1.1.5.5 Provisions shall be made to allow the station modules to breathe to ensure that no detrimental pressure .

differential exists because of changes in external temperature or of altitude, and it is required that incoming air be clean and of low humidity to protect against contamination and condensation.

3.2.1.1.6                   Transportation Equipment

3.2.1.1.6.1               Equipment shall be provided to transport the station module, antenna assemblies and any logistics option equipment over the roadway conditions on the itinerary. This equipment shall include provisions to monitor and record the environment to which the item being transported is exposed.

3.2.1.1.7                   Radiator Surface Test/Refurbishment Equipment

3.2.1.1.7.1               A capability shall be provided to measure thermal control surface coating optical properties in order to ascertain the need for refurbishment.

3.2.1.1.7.2               The capability to effect such refurbishment shall be provided.

3.2.1.1.8                   Shuttle Loading Equipment

3.2.1.1.8.1               Equipment shall be provided to hoist and load the Space Station Modules in the cargo bay and to remove modules as required.

3.2.1.1.8.2               Loading equipment shall provide for both horizontal and vertical loading/removal.

3.2.1.2                     Logistics Module GSE

3.2.1.2.1                   System Checkout Equipment

3.2.1.2.1.1               Provide external control and monitoring of the logistics module during hazardous operations, during launch countdown and other ground operations.

3.2.1.2.1.2               Monitor and control ground servicing and checkout equipment.

3.2.1.2.1.3               Provide switching and measurement capability.

3.2.1.2.1.4               Verify data bus interface access to docking ports.

3.2.1.2.2 Servicing Equipment

3.2.1.2.2.1 Facility provided gases shall be controlled and regulated for the purpose of pressure and integrity testing, leak and functional testing, purging hazardous gases and filling onboard pressure vessels. This capability shall be provided for all gases used during ground operations.

3.2.1.2.2.2 A 10-100 mission vacuum capability shall be provided.

3.2.1.2.2.3 During ground operations the capability for maintaining a habitable working environment shall be provided.

3.2.1.2.2.4 A hardwire umbilical shall be provided at the ground system module surface which includes control and monitoring functions associated with ground checkout failures.

3.2.1.2.3 Access Equipment

3.2.1.2.3.1 Provision shall be made for ground crew access to both internal and external portions of the Logistic Module. These access provisions shall be designed to:

3.2.1.2.3.1.1 Protect docking port seals from damage by personnel and equipment

3.2.1.2.3.1.2 Protect the logistics module interior from damage by personnel, tools and carry-on ground equipment.

3.2.1.2.3.1.3 Provide internal lighting during periods that normal lighting cannot be used.

3.2.1.2.3.1.4 Provision for emergency treatment and removal of injured or incapacitated crew from the interior shall be made.

3.2.1.2.3.3 Provision for both internal and external access to modules in both vertical and horizontal mode should be made. The internal access in the horizontal mode shall be limited to the requirement for loading time critical cargo.

- 3.2.1.2.4 Handling and Protection Equipment
- 3.2.1.2.4.1 Hoisting equipment shall be provided for handling module equipment external to the modules during assembly and/or repair.
- 3.2.1.2.4.2 Provision shall be made for handling equipment which exceeds weight and size limitation for manual handling.
- 3.2.1.2.4.3 Provisions shall be made to attach hoisting devices and provide horizontal support points to modules during ground handling, weight and CG checks and transportation. These provisions shall enable placement in assembly areas, loading areas and movement onto or from transport devices.
- 3.2.1.2.4.4 All module external surfaces shall be protected during transportation and storage from excessive moisture or corrosive atmospheres.
- 3.2.1.2.4.5 Provision shall be made to allow the modules to breathe to ensure that no detrimental pressure differential exists because of changes in external temperature or altitude.
- 3.2.1.2.5 Transportation Equipment
- 3.2.1.2.5.1 Equipment shall be provided to transport the logistic module over the roadway conditions on the itinerary. This equipment shall include provisions to monitor and record the environment to which the item being transported is exposed.
- 3.2.1.2.6 Shuttle Loading Equipment
- 3.2.1.2.6.1 Equipment shall be provided to hoist and load the logistic module in the cargo and remove modules as required.
- 3.2.1.2.6.2 Loading equipment shall provide for both horizontal and retreat loading/removal.
- 3.2.1.3 Integral Experiment GSE (TBD)
- 3.2.1.4 Launch Operations GSE
- 3.2.1.4.1 Launch Operations GSE shall be designed to satisfy Space Station Module GSE requirements as follows: (TBD)

- 3.2.1.4.2           The capability to store, transfer and control hydrazine shall be provided at the launch site.
- 3.2.1.4.3           The distribution of electrical control and monitoring signals and dc power between the various items of GSE and Space Station modules shall be provided at the launch site.
- 3.2.1.4.4           Connectors shall be provided for essential command; control and monitor functions, and ground coolant.
- 3.2.1.5             Flight Operations GSE
- 3.2.1.5.1           Real or near-real-time form dynamic data in the form of plots, indicator lights, television, and digital data of inflight station status shall be provided.
- 3.2.1.5.2           Data processing required to support the sustained Space Station operations in areas of systems status monitoring, Space Station systems control, trajectory analysis, mission planning, and experiments quick-look data analysis shall be provided.
- 3.2.1.5.3           A communications system shall provide the capability to receive, process, and distribute all incoming and outgoing data to and from the proper flight operations support area.
- 3.2.1.5.3.1         The system shall be capable of accepting wideband digital data, teletype data, and compressed digital data from the DRSS and the ground network.
- 3.2.1.5.3.2         The system shall be capable of interfacing all incoming and outgoing communications, and shall provide for centralized operational transfer and switching control.
- 3.2.1.5.4           Equipment shall be provided for support of inventory control operations including special loading, protection, conditioning, and handling of resupply cargo.
- 3.2.1.5.5           Provide the capability for experiment operational support and data collection; real-time experiment data pre-processing, storage, and distribution; experiment monitoring, planning and coordination; and experiment data analysis.

- 3.2.1.6 Test Article GSE
  - 3.2.1.6.1 Functional Model (FM)
    - 3.2.1.6.1.1 Selected Space Station module integrated checkout equipment shall be provided to supplement the capabilities of the FM to accomplish subsystem and system development.
    - 3.2.1.6.2 Flight Integration Tool (FIT)
      - 3.2.1.6.2.1 Equipment uniquely required to support the FIT beyond the Space Station integrated checkout equipment shall be provided (TBD).
  - 3.2.2 Physical
    - 3.2.2.1 All GSE shall be designed to operate in the available work envelope.
    - 3.2.2.2 The commonality of GSE usage dictates that it be designed so as to not preclude portability without requiring specific handling equipment for GSE.
  - 3.2.3 Reliability
    - 3.2.3.1 The GSE shall be designed to provide a high probability of functional availability during individual Space Station integration test periods and shall incorporate limiting devices to prevent failures within the GSE from precipitating failures in the Space Station modules.
  - 3.2.4 Maintainability
    - 3.2.4.1 The GSE shall be designed to incorporate features to reduce fault isolation time and to permit ease of maintenance. MSFC-STD-267A, Standard Human Factors Design Criteria, Section 5.8, shall be used as a guide to providing maintainability design features. The primary method of repair shall be by component replacement with individual repair/replacement determinations based on cost/time optimization concepts.

3.2.5 Operational Availability

3.2.5.1 GSE shall be designed and verified to assure a high probability of function when placed in operation. The design shall permit ease of installation and checkout.

3.2.6 Safety

3.2.6.1 The GSE shall be designed to incorporate safety features outlined in MSFC-STD-267A, Standard Human Factors Design Criteria, Section 5.7.3.

3.2.6.2 All pressure systems shall be designed to ICC safety standards for tanks and lines and provided with relief valves that vent discharge in unoccupied areas.

3.2.6.3 Pressure tanks and fuel storage shall be installed remote from checkout and test areas for the Space Station.

3.2.7 Environment

3.2.7.1 GSE shall be designed to withstand natural environment extremes of the location in which it will operate.

3.2.7.2 Transporters and other mobile Ground Support Equipment shall comply with the applicable requirements of Specification MIL-M-008090 for Type I or Type II Mobility, providing that the specified environments therein do not exceed actual operating conditions.

3.2.7.3 Mobile GSE shall function as intended after exposure to the shock "g" load and vibration requirements defined in KSC-SP-4-38D.

3.2.8 Transportability/Transportation

3.2.8.1 GSE shall be designed to be compatible with surface transportation, shipment by an ocean going vessel.



3.2.9 Storage

3.2.9.1 GSE shall be provided with protective coverings to enable its withstanding storage environment and duration without unrepairable degradation.

3.3 Design and Construction Standards

3.3.1 Selection of Specifications and Standards

All materials, parts, and processes shall be defined by standards and specifications. Standards and specifications shall be selected from Government, industry, and contractor specifications and standards in accordance with MIL-STD-143. B Rationale for the selection of contractor specifications and standards over existing higher order or precedence standards and specifications shall be compiled and maintained for historical record. This rationale shall include an identification of each higher order or precedence specification or standard examined and state why each was unacceptable.

For purposes of this order or precedence, commercial materials, parts and processes shall be considered equivalent to contractor standards.

3.3.2 General

3.3.2.1 Design and construction standards for hardware obtained from the Saturn, Apollo, Gemini, or other space programs shall be either in accordance with existing specifications for those items or in accordance with the standards below, as appropriate. New hardware shall be designed and constructed in accordance with standards in the following sections.

3.3.2.2 Dangerous Materials and Components

3.3.2.2.1 Where functional requirements preclude meeting flammability requirements, materials may be isolated from any hazardous environment by fireproof storage compartments, or barrier materials which meet these requirements.

3.3.2.2.2 All ordnance shall conform to the requirements of MSFC-SPEC-491.

3.3.3 Aeronautical

3.3.4 Civil

Federal, state, and local codes shall be observed as necessary for construction, fabrication, transportation, communications, and safety.

3.3.5 Electrical

3.3.5.1 Electromagnetic Interference

The design requirements incorporated to ensure electromagnetic compatibility shall be generally in accordance with MIL-1-6181D.

3.3.5.2 Containers

Electrical systems containers shall be hermetically sealed, purged, pressurized, or encapsulated, where necessary. Solenoids, transducers, squirrel-cage induction motors, and similar hardware having no circuit-switching devices, shall be hermetically sealed, purged, pressurized, or encapsulated with compatible material. Precautions against sparking of metal-to-metal contacts shall be taken for all devices which have moving parts.

3.3.5.3 Soldering Requirements

Soldering of electrical connections shall conform to the requirements of MSFC-PROC-158.

3.3.5.4 ESE Design

Design and construction of electrical ground support equipment shall be in accordance with MSFC-STD-421A.

3.3.5.5 Multilayer Printed Wiring Boards

Multilayer printed wiring boards shall be designed and documented in accordance with 50M02260.

3.3.5.6 All equipment used in hazardous areas, hand tools included, which constitutes a potential fire or explosion hazard shall be electrically bonded and grounded internally to MSFC-SPEC-249 and installed in accordance with KSC-STD-E-0012.

3.3.5.7 Insulation Sleeving, Electrical  
Flexible electrical insulation sleeving shall meet the requirements of MIL-I-7444C (Amendment #1).

3.3.6 Mechanical  
The structural and mechanical systems shall have sufficient strength and rigidity to sustain anticipated loads. These systems shall have sufficient strength and rigidity to withstand the ultimate load without failure and without deformation which would result in premature failure of any safety critical function. Extremes of the environmental effects with appropriate loads shall be considered. Analysis shall be performed to assess the effects of dynamic magnification, shock factors and surge phenomena as applicable. Design data and materials properties shall be obtained from or alternatively from other sources which meet the approval of the procuring agency.

3.3.6.1 Design Safety Factors

3.3.6.1.1 General Safety Factors

Yield factor of safety = 1.10 x Limit Load

Ultimate factor of safety = 1.40 x Limit Load

3.3.6.1.2 Flexible Hose, Tubing, Ducts, and Fittings

Proof Pressure = 2.00 x Limit Pressure

Yield Pressure = 1.10 x Proof Pressure

Burst Pressure = 4.00 x Limit Pressure

3.3.6.1.3 Actuating Cylinders, Valves, and Switches

Proof Pressure = 1.50 x Limit Pressure

Yield Pressure = 1.10 x Proof Pressure

Burst Pressure = 2.50 x Limit Pressure

3.3.6.1.4 Reservoirs

	<u>Liquid</u>	<u>Gas or Liquids and Gases</u>
Proof Pressure	1.50	2.00 x Limit Pressure
Yield Pressure	1.10	1.10 x Proof Pressure
Burst Pressure	2.50	4.00 x Limit Pressure

3.3.6.2 Hydraulic System

Hydraulic system design, installation, test and data requirements shall be in accordance with MIL-H-25475.

3.3.6.3 Pressure Vessels

All vessels shall be designed and fabricated in accordance with the A. S. M. E. Boiler and Pressure Vessel Code, Section VIII, Unified Pressured Vessels. Any vessel which meets all the expressed requirements of the Code will be stamped with the Code symbol. Vessels having requirements of such size and/or pressure such as to be excluded from the specific provisions of the Code will be designed to conform to the Code.

3.3.6.4 Pipe Assemblies

Pipe assemblies shall be fabricated in accordance with KSC-SPEC-Z-0003 for stainless steel and KSC-SPEC-Z-0002 for aluminum.

Installation of pipe and pipe assemblies shall be in accordance with ASA-B31, 1-155 and applicable design drawings. Torque for MC597 bolts shall be in compliance with the manufacturer's recommended values.

All pipe fittings shall be in accordance with the following standards: MC595, MC596, MC597 and MC598. All stainless steel pipe shall be seamless and shall conform to ASTM-A312, TP316 or TP316L. All stainless steel fittings shall conform to ASTM 182, F316, or F316L. All aluminum pipe shall conform to ASTM-B241, Alloy 6061T6.

All aluminum pipe fittings shall conform to ASTM-B361, Alloy WP6061T6.

Code of Unified Pressure Vessels (Sec. VIII) (ASME) (RA-16).

3.3.6.5

Tube Assemblies

Tube assemblies shall be fabricated in accordance with KSC-SPEC-Z-0008. Tube assemblies, fittings, and fitting assemblies shall be installed in accordance with KSC-SPEC-Z-0008.

All tubing shall conform to KSC-SPEC-Z-0007, Condition A, Class III, Grade C, Group 3, Minimum.

All tube fittings shall be procured in accordance with KSC-F-124 and shall conform to the applicable KC fitting specification. Material for fittings, excluding sleeves, shall be per QQ-S-763, 316, Condition A. Sleeves shall be per QQ-S-763, 316, Condition plus single consummable electrode vacuum remelt process, cold finished.

3.3.6.6

Consoles

All purged consoles will utilize calibrated orifices and bleed plates per Drawings 10M33300 and 10M33295, respectively.

3.3.7

Nuclear

Design practice associated with the containment, handling, and safety of nuclear materials and devices shall comply and be subject to AEC policies and practices defined by Title 10 Code of Federal Regulations.

3.3.8

Moisture and Fungus Resistance

Materials which are not nutrients for fungus shall be used whenever possible. The use of materials which are nutrients for fungus shall not be prohibited in hermetically sealed assemblies and other accepted and qualified uses, such as paper capacitors and treated transformers. If it is necessary to use nutrient materials in other

than such qualified applications, these nutrient materials shall be treated by a method which will render the resulting exposed surface fungus resistant. The treated surface must satisfactorily pass the fungus tests in MIL-STD-810.

3.3.9 Corrosion of Metal Parts

3.3.9.1 Metals Parts shall be inherently resistant to the corrosive action of moist sea atmosphere or shall be protected by the methods and materials for cleaning, surface treatment and application of finishes and protective coatings defined in Specification MIL-F-7179.

3.3.9.2 Dissimilar Metals

Dissimilar metals as defined by (TBD) which are subject to electrolytic corrosion, shall not be used in combination unless suitably coated, sealed, or separated by barrier material compatible with both metals. Special consideration will be given to electrical bonding requirements where dissimilar metals are involved.

3.3.9.3 Painting and Coating

Finishes shall be applied to metal parts to ensure environmental protection. Consideration shall be given to weight, thermal emissivity, outgassing and electrical bonding requirements. All exposed, unpainted, machined surfaces which could corrode shall be finished with an inorganic coating such as plating or anodizing. Anodizing shall be used where electrical bonding must be made.

3.3.10 Contamination Control

3.3.10.1 Special cleanliness levels imposed by equipment involving hydraulics, pneumatics, life support and special experimental procedures shall not be imposed on the supporting equipment.

- 3.3.10.2 Special high levels of atmospheric or surface cleanliness shall be minimized for transportation handling, assembly and checkout of prime elements.
- 3.3.10.3 Specific areas of activity or design wherein special cleanliness is mandatory shall have equipment and/or support tooling to maintain local cleanliness during assembly, handling and servicing of such equipment. As a goal, extensive cleanroom facilities should be avoided.
- 3.3.10.4 The cleanliness requirements for the ground equipment shall be as defined herein as applicable:
- a. Assemblies and components used in oxygen, fuel and pneumatic systems shall meet the requirements of MSFC Drawing 10M01671, Level 4.
  - b. Assemblies, components, fluids and cleaning methods utilized in hydraulic systems shall meet the requirements of MSFC-PROC-166.
  - c. Gas bearing gas supply and slosh measuring system shall meet the requirements of MSFC-PROC-195.
  - d. Cleanliness level and inspection methods for drying and preservation gases shall meet MSFC-PROC-404.
- 3.3.10.5 Fluid Commodity Specifications
- The GSE shall be designed to transfer, condition, store, or dilute fluids conforming to the following specifications.
- O-E-760, Ethyl Alcohol (Ethanol). Denatured. Alcohol and Proprietary Solvent
  - O-M-232, Methanol (Methyl Alcohol)
  - BB-F-1421, Fluorocarbon Refrigerants
  - TT-I-735, Isopropyl Alcohol
  - MIL-C-81302, Cleaning Compound Solvent

3.3.11 Coordinate Systems (N/A)

3.3.12 Interchangeability and Replaceability

Mechanical and electrical interchangeability shall exist between replacement parts, assemblies and sub-assemblies, regardless of manufacturer or suppliers. All parts having the same part number, regardless of source, shall be functionally and dimensionally interchangeable as defined in MIL-STD-721.

Support equipment items shall be interchangeable functionally in accordance with the requirements of MIL-I-8500. The electronic test equipment shall be interchangeable to the extent specified in MIL-T-21200.

3.3.13 Identification and Marking

Nameplates and markings shall be made and affixed in accordance with MIL-STD-130, and MIL-STD-129, or equivalent. All configuration identification information on these nameplates and markings shall be taken from and agree with production or construction drawings and/or their engineering release records.

Equipment shall be marked for handling in accordance with 10M01801.

Electrical wiring for support equipment shall be marked according to the requirements of 40M00220.

3.3.14 Workmanship

Ground Support Equipment, including all parts and accessories shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be paid to neatness and thoroughness of soldering, wiring, impregnation of coils, markings of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.15 Human Performance/Human Engineering

The criteria specified in MIL-STD-803 shall be met as a minimum in the design of GSE hardware.



- 3.4                    Logistics (TBD)
  
- 3.5                    Personnel and Training  
                      Personnel and training requirements shall be as  
                      specified in Section 3.5 of Space Station Project  
Specification RS-02927.
  
- 3.6                    Interface Requirements
  
- 3.6.1                 Interprogram  
                      Reference RS02928, Project Level Interface and  
                      Support Requirements—Modular Space Station Project/  
Orbiter Project.
  
- 3.6.2                 Intraprogram (TBD)
  
- 3.6.3                 N/A

4. VERIFICATION

4.1 General

Each applicable design/performance requirement stated in Section 3 shall be verified by assessment and/or test. Section 4.2 contains the requirements which must be met for verification for each item as well as the system. The relationship of these requirements to Section 3 and the methods to be used in verification are identified in Section 4.3. The requirements specified herein are limited to the responsibility for verification, the methods to be used in verification and the requirements on verification operations to constrain activities for verification of GSE performance. These requirements do not address the specific uses of individual pieces of GSE or detailed testing requirements.

4.1.1 Responsibility for Verification

Unless otherwise specified, the contractor responsible for specific equipment (reference 3.1.4.1) shall be responsible for the verification of Section 3 requirements. Verification shall be performed as specified herein with NASA review and approval of verification completion.

4.1.1.1 Development

Development shall be conducted by the contractor, when necessary, to verify design feasibility and to provide confidence in the design. Although the extent and definition of development shall be left to the contractor's discretion, it shall be reviewed by NASA for compatibility with system requirements and project effectiveness goals.

4.1.1.2 Qualification

Qualification shall be performed on the actual GSE to verify that the design requirements have been met and the equipment performs as is intended. The contractor shall conduct this verification at his first opportunity to monitor functional performance. There is no requirement for system qualification. Qualification shall be performed by the responsible contractor on the specific equipment.

- 4.1.1.3                    Acceptance  
Acceptance of individual GSE items shall be performed by the manufacturing contractor at the site of qualification. Acceptance of the GSE System as defined by Section 3 shall be verified by NASA by means of analytical evaluation of individual acceptance data.
- 4.1.2                    Verification Method Selection  
Section 3 requirements shall be verified by the method identified in Section 4.3 and to the corresponding requirements of Section 4.2. The methods chosen for verification shall be based upon the requirements of Table I.
- 4.1.3                    Relationship to Management Reviews  
NASA shall confirm through regularly scheduled management reviews that the requirements for verification specified in Section 4.2 and the methods and phases identified in the Verification Matrix, Section 4.3, are appropriate and provide NASA the assurance of meeting the specified requirements in the most cost effective manner. The following requirements pertain to each GSE contractor and shall be satisfied at the respective review for his prime equipment.
- 4.1.3.1                    Preliminary Requirements Review (PRR)
- 4.1.3.1.1                    Each System Manager shall support PRR by presenting verification concepts for review and assurance of overall project compatibility. Development tests required to select or substantiate design approaches shall be of special concern in establishing this baseline.
- 4.1.3.1.2                    The Program/Project specification shall be approved at the PRR.
- 4.1.3.2                    Preliminary Design Review (PDR)
- 4.1.3.2.1                    PDR for the structure shall occur sufficiently early in Phase C to provide for the design and fabrication of test article hardware to ensure meaningful integration of GSE with ISS modules.

Table I  
 GSE VERIFICATION METHOD REQUIREMENTS

		Verification Phases											
		Development			Qualification					Acceptance			
Hardware General Level	Verification Method	Analysis	Demonstration	Test	Similarity	Analysis	Inspection	Demonstration	Test	Analysis	Inspection	Demonstration	Test
		Component		X	X	X	X	X	X	X	X		
Assembly/Subsystem		X	X	X	X	X	X	X	X				
System										X	X	X	X

4. 1. 3. 2. 2 PDR, a formal technical review of the basic design approach, shall include a technical review of the basic verification approach of ground support equipment.

4. 1. 3. 2. 3 Verification participation in PDR shall include identification of requirements for development testing; preliminary criteria for receiving inspection/test, in-process inspection/test, end-item test and acceptance inspection; and preliminary development and qualification plans which include the methodology for verifying the design and performance requirements of Section 3.

4. 1. 3. 2. 4 Sufficient analyses and/or testing shall be conducted to provide confidence in the design approach and its producibility.

4. 1. 3. 2. 5 The Part I CEI specifications listing performance/design requirements and verification methods for all systems shall be approved at the PDR.

- 4.1.3.3                   Critical Design Review (CDR)
- 4.1.3.3.1                The formal technical review of CEI design performed at CDR shall be supported by development verification data.
- 4.1.3.3.2                As a goal, all development data shall be available by completion of CDR.
- 4.1.3.3.3                Test review at CDR shall cover analysis of available development test data, preliminary end-item test plans, sampling plans, and detailed inspection plans.
- 4.1.3.3.4                Processing and manufacturing methods specified by the design which have not been previously used shall be substantiated prior to release drawings.
- 4.1.3.3.5                The Part II CEI specification indicating design solutions and verification requirements shall be presented at the CDR.
- 4.1.3.4                   Configuration Inspection (CI)
- The Configuration Inspection is a formal technical review to determine if the end-item hardware has been built and verified in accordance with the Part II CEI Specification which is presented at the CI for approval. The CI establishes that verification was performed and that the as-built hardware did in fact comply with the requirement of the Part I CEI Specification. The verification documentation and hardware presented at CI shall verify the applicable portion of Section 4.2 of this specification.
- 4.1.3.5                   Post-CI Reviews
- The status of verification shall be reviewed at each major milestone and documented prior to initiation of the next activity. Management reviews shall be utilized to perform these reviews. As a minimum these reviews shall occur at completion of ISS module integrated systems verification and initiation of prelaunch checkout. Specific requirements for these reviews shall be stated herein by completion of PRR.

- 4.1.4 Test/Equipment Failure
  - 4.1.4.1 Failure/Criteria
    - 4.1.4.1.1 Prior to the performance of any verification, the criteria of failure must be objectively established in procedural documentation.
    - 4.1.4.1.2 Subsequent to each failure, but prior to reverification, an evaluation shall be made to determine whether partial requirements have been met prior to failure or can be met by other means. If either is true, total reverification shall not be performed.
- 4.2 Phased Verification Requirements
  - 4.2.1 Development
    - 4.2.1.1 Development assessment and tests are performed to verify the feasibility of the design approach prior to committing to the production of flight hardware.
      - 4.2.1.1.1 Analysis
        - 4.2.1.1.1.1 Design and analytical algorithms shall be employed, where possible, to reduce the need for exhaustive and redundant testing.
        - 4.2.1.1.1.2 Development analysis shall consist of common accepted systems engineering and mathematical methods. The findings of these analyses shall be documented to provide traceability at PDR.
      - 4.2.1.1.2 Demonstration
        - 4.2.1.1.2.1 Development demonstrations shall be substantiated at PDR.
      - 4.2.1.1.3 Test
        - 4.2.1.1.3.1 Development tests are conducted to determine optimum design margins, stress effects, failure modes under varied combinations and sequences of environmental stresses, safety parameters, applicability of processes, etc.

- 4.2.1.3.2                   Development hardware shall be representative, but not necessarily identical to, flight hardware or operational GSE.
- 4.2.2                        Qualification  
Qualification is performed on the actual GSE to verify that design and performance specifications have been met.
- 4.2.2.1                    Similarity
- 4.2.2.1.1                 Hardware characteristics (all or partially) qualified for use on a previous program may be verified for Space Station use by similarity if the following requirements are met:
- (a) The manufacturer and fabrication/assembly processes are the same.
  - (b) The environments and/or operating conditions for which it was qualified are equivalent to those required of the Space Station.
  - (c) Any dissimilarities between performance and Space Station requirements can be demonstrated to have a negligible effect on qualification.
- 4.2.2.1.2                 Similarity shall be substantiated by manufacturer attestations, specifications and product inspection reports and approved by NASA.
- 4.2.2.2                    Analysis
- 4.2.2.2.1                 Analysis shall not be the sole basis of qualification.
- 4.2.2.2.2                 All analyses used for qualification shall be documented as to methods used and results obtained.
- 4.2.2.3                    Demonstration
- 4.2.2.3.1                 GSE configurations used in demonstrations shall not be simulated and the procedures followed must be prepared prior to the demonstration and controlled throughout the activity.

- 4.2.2.3.2                   Qualification demonstrations shall be witnessed by the NASA, or its appointed designee, and documented in the manner designated for qualification tests.
- 4.2.2.4                    Test
- 4.2.2.4.1                  GSE computer programs will be qualified by functional performance test.
- 4.2.2.4.2                  The 10-year life requirement shall be verified by test and analysis.
- 4.2.2.4.3                  Tests shall be conducted to verify:
- (a) The performance of the hardware to perform its intended mission in the anticipated environment.
  - (b) Electromagnetic compatibility
- 4.2.2.4.4                  Qualification testing shall be restricted to the functional operation of GSE in the operating environment.
- 4.2.2.4.5                  Qualification testing shall be restricted to the functional operation of GSE in the operating environment.
- 4.2.3                    Acceptance
- Acceptance verifies that GSE has been manufactured to the qualified design, meets the design intent and will properly perform during the mission as designed. All acceptance verification shall be conducted against released engineering.
- 4.2.3.1                  Analysis
- 4.2.3.1.1                 Factory acceptance of end-items shall restrict the use of analysis to those features which need be verified by other methods.
- 4.2.3.1.2                 Lower level test data shall be analyzed using standard mathematical methodology to assess structural integrity.
- 4.2.3.1.3                 Acceptance data for each item of GSE shall be analyzed for compliance with system requirements.



4.2.3.2 Inspection

4.2.3.2.1 Receiving inspections shall be performed on flight hardware to verify that shipping or transportation damage has not occurred.

4.2.3.2.2 In-process inspections shall verify that prescribed methods and materials are used in the manufacturing processes.

4.2.3.3 Demonstration  
None identified.

4.2.3.4 Test  
None identified.

4.3 Verification Matrix

The one-for-one cross reference identifies each verification requirement for each Section 3 requirement and identifies the method by which each requirement is to be verified.

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REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

VERIFICATION PHASE:

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.	X								
3.1	X								
3.1.1	X								
3.1.1.1	X								
3.1.1.1.1	X								
3.1.1.1.2	X								
3.1.1.1.3	X								
3.1.1.1.4	X								
3.1.1.1.5	X								
3.1.1.1.6	X								
3.1.1.2	X								
3.1.1.3	X								
3.1.1.4	X								
3.1.1.5	X								
3.1.1.6	X								
3.1.2	X								
3.1.3	X								
3.1.3.1				3					4.2.3.1.3
3.1.3.2				3					4.2.3.1.3
3.1.3.3				3					4.2.3.1.3
3.1.3.4				3					4.2.3.1.3
3.1.3.5				3					4.2.3.1.3
3.1.4	X								

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirement Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
3.1.5	X								4.2.3.1.3
3.1.6				3					
3.1.7	X								
3.2	X								
3.2.1	X								
3.2.1.1	X								
3.2.1.1.1				3				4.2.3.1	
3.2.1.1.2				3				4.2.3.1	
3.2.1.1.3				3				4.2.3.1	
3.2.1.1.4				3				4.2.3.1	
3.2.1.1.5				3				4.2.3.1	
3.2.1.1.6				3				4.2.3.1	
3.2.1.1.7				3				4.2.3.1	
3.2.1.1.8				3				4.2.3.1	
3.2.1.2	X								
3.2.1.2.1				3				4.2.3.1	
3.2.1.2.2				3				4.2.3.1	
3.2.1.2.3				3				4.2.3.1	
3.2.1.2.4				3				4.2.3.1	
3.2.1.2.5				3				4.2.3.1	
3.2.1.2.6				3				4.2.3.1	
3.2.1.3									
3.2.1.4				3				4.2.3.1	

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**REQUIREMENTS FOR VERIFICATION**

**VERIFICATION METHOD:**

1. Test
2. Similarity
3. Analysis
4. Inspection
5. Demonstration

N/A - Not Applicable

**VERIFICATION PHASE:**

- A. Development
- B. Qualification
- C. Acceptance
- D. Integrated Systems
- E. Prelaunch Checkout
- F. Flight/Mission Operations
- G. Postflight

Section 3.0 Performance/ Design Requirement Reference	Verification Methods							Section 4.0 Verification Requirement Reference	
	N/A	A	B	C	D	E	F		G
3.2.1.5				3					4.2.3.1
3.2.1.6	X								
3.2.1.7				3					4.2.3.1
3.2.1.8				3					4.2.3.1
3.2.2				3					4.2.3.1
3.2.3				3					4.2.3.1
3.2.4				3					4.2.3.1
3.2.5				3					4.2.3.1
3.2.6				3					4.2.3.1
3.2.7				3					4.2.3.1
3.2.8				3					4.2.3.1
3.2.9				3					4.2.3.1
3.3				3					4.2.3.1
3.4									
3.5									
3.6									

4.4

Test Support Requirements

None identified.

Specification No. CP-02932

Date 15 December 1971

FACILITIES DETAIL SPECIFICATION  
PERFORMANCE, DESIGN AND VERIFICATION  
REQUIREMENTS  
(CEI NUMBER CP-2932)  
FOR  
MODULAR SPACE STATION PROJECT

APPROVED BY J.D. Smith  
(Preparing Activity)

APPROVED BY W.A. Brinkley  
(NASA Office)

DATE 15 December 1971

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1. SCOPE

This specification establishes the requirements and basic restraints/constraints imposed upon the development of a design for engineering, manufacturing, test, prelaunch and mission operations facilities in support of the Modular Space Station Project. Requirements for facilities to be provided by the Space Shuttle Program and/or RAM Project in support of the Modular Space Station Project are contained in the appropriate Interface and Support Requirements (I&SR) documents.

2. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced, and other detailed contents of this specification, the detailed requirements specified herein shall be considered superceding.

SPECIFICATIONS

None identified.

Standards

None identified.

Other Publications

None identified.

3. REQUIREMENTS

3.1 Facility Definition

Modular Space Station facilities shall be utilized for the engineering, manufacturing, test, prelaunch checkout, logistics support and mission support of the Initial Space Station Modules (Specification No. CP-02929) and Logistics Modules (Specification No. CP-02930). Modular Space Station facilities shall be provided in a cost effective manner by making a maximum effort to use existing facilities, by making minimum cost modifications, and by providing facilities for many purposes.



### Engineering

Engineering facilities are those buildings, office areas, computers and equipment, normally provided to support design and develop the end item. The areas in which mockups are contained shall also be considered an engineering facility.

### Manufacturing

Manufacturing facilities are those suitable facilities and equipment required for the fabrication, subassembly, and assembly of Space Station modules. Included is an office clean area for the final assembly, test and preparation for shipment activities.

### Test

Test facilities are those facilities, areas, test equipment (vibration tables, vacuum chambers, etc.), computers and support equipment required to conduct development, qualification, acceptance and integrated systems testing. Included in this category are the areas and equipment required to support the test articles (Functional Module and Flight Integration Tool).

### Prelaunch Checkout

Prelaunch checkout facilities are those located at the launch site to receive, inspect, and checkout modules prior to integration with the shuttle; and those required for the refurbishment of returning modules. Included in this category are a landing strip near the launch site, a low bay area for module inspection and flight servicing, and access roadways to the area of shuttle integration.

### Logistics Support

Logistics facilities include those which support the planning of and providing of sustaining materials and services for the Space Station through its 10-year orbital life. The primary function of these facilities will be to provide the inventory and procurement support of the station, including the loading and unloading of logistic modules. The RAM modules and support hardware will be accounted and handled by this function.

### Mission Support

Mission support facilities include those which support management activities of orbital flight operations, mission analysis and planning, direct real-time logistics planning and direct real-time support for experiment operations.

3.1.1 Facility Siting and Layout (TBD)

3.1.2 Government Furnished Property List

3.1.2.1 The launch site shall provide the following major facilities to the Modular Space Station Project.

a) A landing strip adjacent to the launch site for module air transport.

b) An area for the receipt, inspection, checkout, and refurbishment of modules prior to integration with the Orbiter.

c) Transportation between the area of receipt inspection checkout and refurbishment of module and the Orbiter integration site.

d) Suitable facilities near the orbiter integration sites for logistics support operations

3.1.2.2 Suitable facilities and equipment shall be provided for performance of Space Station Project mission support operations.

3.2 Characteristics  
(TBD)

3.3 Interface Requirements  
None identified.

4. Verification

4.1 General

Each applicable requirement stated in Section 3 shall be verified by assessment and/or test in accordance with the requirements of Section 4.2 established herein. The requirements specified herein are limited to the responsibility for verification, the methods to be used in verification, and the requirements for verification. These requirements do not address the detailed testing requirements.

- 4.1.1                    Responsibility for Verification  
Unless otherwise specified herein, the providing contractor shall be responsible for the verification of Section 3 requirements. NASA shall review and approve verification completion for those facilities which are constructed or modified under government contract.
- 4.1.2                    Verification Method Selection  
Section 3 requirements shall be verified by the method identified in Section 4.3 and to the corresponding requirements of Section 4.2. The contract shall verify these requirements by means of analysis, inspection, demonstration or test.
- 4.1.3                    Relationship to Management Reviews  
NASA will confirm through regularly scheduled management reviews that the requirement for verification contracted facilities are appropriate and provide NASA the assurance of meeting the specified requirements in the most cost effective manner.
- 4.2                      Phased Verification Requirements  
(TBD)
- 4.3                      Verification Matrix  
(TBD)
- 4.4                      Test Support Requirements  
(TBD)
5.                        PREPARATION FOR DELIVERY (N/A)
6.                        NOTES
10.                      APPENDIX