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SD 71-217-5

MODULAR space station

PHASE B EXTENSION

PRELIMINARY SYSTEM DESIGN

Volume V: Configuration Analyses



PREPARED BY PROGRAM ENGINEERING
JANUARY 1972

Space Division
North American Rockwell

12214 Lakewood Boulevard, Downey, California 90241

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ABSTRACT

DESCRIBES THE INITIAL AND GROWTH MODULAR SPACE STATION CONFIGURATIONS AND A DETAILED DESCRIPTION OF EACH MODULE. THE EVOLUTIONARY STEPS ARRIVING AT THE FINAL CONFIGURATION IS DESCRIBED. SUPPORTING TRADE STUDIES AND SUPPORTING ANALYSIS SUCH AS STRESS, RADIATION DOSAGE, MICROMETEOROID AND THERMAL PROTECTION IS DESCRIBED.

FOREWORD

This document is one of a series required by Contract NAS9-9953, Exhibit C, Statement of Work for Phase B Extension-Modular Space Station Program Definition. It has been prepared by the Space Division, North American Rockwell Corporation, and is submitted to the National Aeronautics and Space Administration's Manned Spacecraft Center, Houston, Texas, in accordance with the requirements of Data Requirements List (DRL) MSC-T-575, Line Item 68.

Total documentation products of the extension period are listed in the following chart in categories that indicate their purpose and relationship to the program.

ADMINISTRATIVE REPORTS	TECHNICAL REPORTS	STUDY PROGRAMMATIC REPORTS	DOCUMENTATION FOR PHASES C AND D	
			SPECIFICATIONS	PLANNING DATA
EXTENSION PERIOD STUDY PLAN DRL-62 DRD MA-207T SD 71-201	MSS PRELIMINARY SYSTEM DESIGN DRL-68 DRD SE-371T SD 71-217	EXTENSION PERIOD EXECUTIVE SUMMARY DRL-65 DRD MA-012 SD 71-214	MSS PRELIMINARY PERFORMANCE SPECIFICATIONS DRL-66 DRD SE-369T SD 71-215	MSS PROGRAM MASTER PLAN DRL-76 DRD MA-209T SD 71-225
QUARTERLY PROGRESS REPORTS DRL-64 DRD MA-208T SD 71-213, -235, -576	MSS DRAWINGS DRL-67 DRD SE-370T SD 71-216			MSS PROGRAM COST AND SCHEDULE ESTIMATES DRL-77 DRD MA-013(REV. A) SD 71-226
FINANCIAL MANAGEMENT REPORTS DRL-63 DRD MF-004	MSS MASS PROPERTIES DRL-69 DRD SE-372T SD 71-218, -219			MSS PROGRAM OPERATIONS PLAN DRL-74 DRD SE-377T SD 71-223
	MSS MOCKUP REVIEW AND EVALUATION DRL-70 DRD SE-373T SD 71-220			
	MSS INTEGRATED GROUND OPERATIONS DRL-73 DRD SE-376T SD 71-222			
	MSS KSC LAUNCH SITE SUPPORT DEFINITION DRL-61 DRD AL-005T SD 71-211			
	MSS SHUTTLE INTERFACE REQUIREMENTS DRL-71 DRD SE-374T SD 71-221			
	INFORMATION MANAGEMENT ADVANCED DEVELOPMENT DRL-72 DRD SE-375T SD 72-11			
	MSS SAFETY ANALYSIS DRL-75 DRD SA-032T SD 71-224			

This document is Volume V of the Modular Space Station Preliminary System Design Report, which has been prepared in the following seven volumes:

I	Summary	SD 71-217-1
II	Operations and Crew Analysis	SD 71-217-2
III	Experiment Analyses	SD 71-217-3
IV	Subsystem Analyses	SD 71-217-4
V	Configuration Analyses	SD 71-217-5
VI	Trades and Analyses	SD 71-217-6
VII	Ancillary Studies	SD 71-217-7

CONTENTS

Section			Page
1	CONFIGURATION DESIGN		1-1
	1.1	INTRODUCTION	1-1
	1.2	EXTERNAL CONFIGURATION	1-5
		1.2.1 Configuration Requirements	1-5
		1.2.2 Station Assembly	1-6
		1.2.3 Shuttle Interface	1-11
		1.2.4 Structural Arrangement	1-11
		1.2.5 Crewman Access	1-21
		1.2.6 Dual Egress	1-21
		1.2.7 Hatches	1-23
		1.2.8 Auxiliary Passage	1-26
		1.2.9 Windows	1-27
		1.2.10 Communications	1-27
		1.2.11 Experiment Airlock	1-31
		1.2.12 Environmental	1-31
		1.2.13 Radiators	1-34
	1.3	INTERNAL CONFIGURATION	1-37
		1.3.1 Configuration Requirements	1-37
		1.3.2 Module Floor Structural Arrangement	1-40
		1.3.3 Utilities Distribution	1-44
		1.3.4 Maintenance	1-47
	1.4	GROWTH STATION CONFIGURATION	1-51
		1.4.1 Growth Requirements	1-51
		1.4.2 Growth Accommodations	1-51
		1.4.3 Structural Arrangement	1-53
	1.5	PRELIMINARY DESIGN DESCRIPTION OF MODULES	1-55
		1.5.1 Core Module 1	1-56
		1.5.2 Power Module	1-67
		1.5.3 Station Module Common Structure	1-71
		1.5.4 Station Modules 1 and 4	1-75
		1.5.5 Station Modules 2 and 3	1-89
		1.5.6 Berthing Port Design	1-100
		1.5.7 Antenna Package	1-110

Section			Page
	1.5.8	Experiment Airlock Package	1-117
	1.5.9	Berthing Adapter	1-119
	1.5.10	Manufacturing Assembly	1-123
	1.6	GROWTH STATION MODULES DESIGN DESCRIPTION	1-129
	1.6.1	Core Module 2	1-130
	1.6.2	Power Module Assembly	1-135
	1.6.3	Station Modules 5 and 6	1-138
2	ALTERNATIVE CONFIGURATION ANALYSIS		2-1
	2.1	STUDY CONFIGURATION 1	2-7
	2.1.1	Manipulator and Berthing Mode	2-7
	2.1.2	Reconfiguring Station Modules	2-7
	2.1.3	Core Module	2-11
	2.2	STUDY CONFIGURATION 2	2-15
	2.2.1	Lower Volume Utilization	2-15
	2.2.2	Module	2-17
	2.3	STUDY CONFIGURATION 3	2-23
	2.4	STUDY CONFIGURATION 4	2-29
	2.4.1	Manipulator - Berthing or Direct Mode	2-29
	2.4.2	Core Module Overweight	2-31
	2.5	STUDY CONFIGURATION 5	2-33
	2.5.1	Subsystem Selection	2-33
	2.5.2	Module Replacement	2-36
	2.6	STUDY CONFIGURATION 6	2-39
	2.6.1	High-Pressure Tanks Relocation	2-39
	2.6.2	Relocated Control Centers	2-39
	2.7	STUDY CONFIGURATION 7	2-43
	2.7.1	Split-Level Crew Quarters	2-43
	2.7.2	Equipment Relocation	2-46
	2.8	STUDY CONFIGURATION 8	2-53
APPENDIXES			
	A.	SUPPORTING TRADES	A-1
	B.	SUPPORTING ANALYSIS	B-1

ILLUSTRATIONS

Figure		Page
1-1	Initial Station Configuration	1-2
1-2	Growth Station Configuration	1-3
1-3	Typical Module Berthing	1-7
1-4	Berthing Port Arrangement	1-7
1-5	Berthing Port Location	1-9
1-6	Shuttle Manipulator Reach Envelope	1-10
1-7	Turret Rotation	1-10
1-8	Payload Retention System	1-12
1-9	Manipulator/Payload Attachment	1-12
1-10	Station/Shuttle Berthing Adapter	1-13
1-11	Station Module Structural Arrangement	1-17
1-12	Berthing Load vs. Closing Velocity	1-19
1-13	Core Module Structural Arrangement	1-19
1-14	Power Module Structural Arrangement	1-20
1-15	Access Routes	1-22
1-16	Module Access Paths	1-22
1-17	Common Hatch	1-24
1-18	Module Hatch Arrangement	1-25
1-19	Auxiliary Passage Activation	1-26
1-20	Cross Sectional View of MSC Window Assembly	1-28
1-21	Window Cover Deployment	1-29
1-22	Station Communication Arrangements	1-30
1-23	Airlock Capabilities	1-31
1-24	Environmental Shield Sections	1-33
1-25	Radiator Installation	1-35
1-26	Station Module Radiator Installation	1-35
1-27	Module Functional Allocation Arrangement	1-39
1-28	Station Module Floor Arrangement	1-41
1-29	Longitudinal Floor Attachment	1-42
1-30	Basic Floor Attachment	1-42
1-31	Split Level Floor Attachment	1-43
1-32	Typical Module Equipment Attachment Arrangement	1-43
1-33	Longitudinal Floor Characteristics	1-44
1-34	Utilities Distribution Routing	1-45
1-35	Air Circulation Ducting	1-46
1-36	Core Module Utilities Distribution Arrangement	1-46
1-37	Power Module Utilities Distribution Arrangement	1-48
1-38	RCS Engine Maintenance	1-48
1-39	Typical Exterior Light Installations	1-49
1-40	Antenna Package Installation	1-49
1-41	Growth Station Functional Allocations	1-52
1-42	Growth Galley and Dining Arrangement	1-52
1-43	Core Module Interior Arrangement	1-57

Figure		Page
1-44	Core Module Exterior Arrangement	1-58
1-45	External Diameter Configuration	1-61
1-46	CMG/RCS Engine Interface	1-65
1-47	Power Module Installation	1-67
1-48	Power Module	1-68
1-49	Environmental Shield Installation	1-69
1-50	Power Module Tank Locations	1-70
1-51	Common Module Structural Arrangement	1-71
1-52	Radiator/Environmental Shield Assembly	1-73
1-53	Typical Radiator Arrangement	1-73
1-54	Auxiliary Passage Activation	1-74
1-55	Station Module 1	1-78
1-56	Station Module 4	1-79
1-57	Station Module 1 Internal Arrangement	1-81
1-58	Station Module 4 Internal Arrangement	1-82
1-59	Floor Arrangement	1-83
1-60	Control Center Installation for Maintenance Provisions	1-84
1-61	Crew Staterooms	1-87
1-62	Station Module 2	1-92
1-63	Station Module 3	1-93
1-64	Floor Arrangement	1-94
1-65	Station Module Utility Run Areas	1-96
1-66	Station Module 2 Internal Arrangement	1-97
1-67	Station Module 3 Internal Arrangement	1-99
1-68	Berthing Modes	1-100
1-69	Passive Berthing Port Assemblies	1-103
1-70	Active Berthing Port Assemblies	1-104
1-71	Berthing Port Utilities Arrangement	1-106
1-72	Berthing Alignment Concept	1-107
1-73	Berthing Port Hatch	1-109
1-74	Direct Docking Adapter	1-111
1-75	Antenna Coverage	1-112
1-76	Antenna Location	1-114
1-77	K-band Antenna Arrangement	1-115
1-78	S-band and VHF Antenna Arrangement	1-115
1-79	Structure Arrangement	1-116
1-80	Experiment Airlock Location	1-118
1-81	Experiment Airlock Arrangement	1-118
1-82	Outer Hatch Configuration	1-120
1-83	Pressure Shell and Environmental Shield	1-120
1-84	Station/Shuttle Berthing Adapter	1-121
1-85	Shuttle/Station Berthed Orientation	1-122
1-86	Core Module Manufacturing Assembly Sequence	1-124
1-87	Power Boom Manufacturing Assembly Sequence	1-125
1-88	Station Module Manufacturing Assembly Sequence	1-126
1-89	Growth Station Configuration	1-129
1-90	Core Module 2 External Configuration	1-131
1-91	Core Module 2 Internal Configuration	1-132

Figure		Page
1-92	Power Module Configuration	1-135
1-93	Solar Array Replacement Aids	1-137
1-94	Solar Array/Turret Replacement	1-139
1-95	Station Module 5	1-142
1-96	Station Module 6	1-143
2-1	Reference Configuration (Starting Point)	2-5
2-2	Crew Quarters Modules 1 and 2	2-8
2-3	Module Arrangements	2-9
2-4	Galley Module	2-10
2-5	Medical/Exercise Module	2-11
2-6	Split Core Module Concept	2-11
2-7	Study Configuration - Concept 1	2-12
2-8	Stypical Module Cross Section	2-16
2-9	Control Center and Medical Module	2-16
2-10	Control Center and Laboratory Module	2-17
2-11	Module Diameters Evaluated (9- and 10-Foot)	2-19
2-12	Module Diameters Evaluated (11- and 12-Foot)	2-19
2-13	Module Diameters Evaluated (13- and 14-Foot)	2-20
2-14	Module Diameters Evaluated (15-Foot) and Module Diameter Summary	2-20
2-15	Station Configuration - Study No. 2	2-21
2-16	Module Arrangements	2-26
2-17	Module Arrangements	2-26
2-18	Station Configuration - Study 3	2-27
2-19	Docking and Berthing	2-29
2-20	Station Configuration 4	2-31
2-21	Integrated Subsystem Concept	2-33
2-22	Modular Space Station Subsystems	2-34
2-23	Module Replacement Impact on Facility/Hardware Allocations	2-36
2-24	Study Configuration 5	2-38
2-25	Power Boom - Initial Station (Study 6)	2-40
2-26	Core Module 1 (Study 6)	2-40
2-27	Core Module 2 (Study 6)	2-41
2-28	Study Configuration 6	2-41
2-29	Arrangement Concepts	2-44
2-30	Split Level Staterooms	2-45
2-31	Station Module 1	2-47
2-32	Station Module 4	2-47
2-33	Station Module 2	2-48
2-34	Station Module 3	2-49
2-35	Power Boom Concept	2-49
2-36	Core Module	2-51
2-37	Selected Configuration - Initial Station	2-51

TABLES

Table		Page
1-1	Module Classification	1-6
1-2	Shuttle Orbiter Loads	1-14
1-3	Shuttle Orbiter and MSS Berthing Criteria	1-15
1-4	Factors of Safety for Space Station Structural Design	1-15
1-5	Radiation Protection.	1-34
1-6	Station Module Functional Allocation Requirements	1-38
1-7	Special Module Functional Allocation Requirements	1-40
1-8	Module Classification	1-53
1-9	Preliminary Design Drawing Tree	1-55
1-10	Core Module Design Requirements	1-59
1-11	Station Modules 1 and 4 Design Requirements	1-76
1-12	Station Modules 2 and 3 Design Requirements	1-90
1-13	Berthing Port Utilities Interfaces.	1-102
1-14	Core Module 2 Design Requirements	1-133
1-15	Station Modules 5 and 6 Design Requirements	1-141
2-1	Configuration Drivers and Alternatives.	2-2
2-2	Reference Configuration (Common Modules Underweight).	2-7
2-3	Module Comparison Matrix.	2-18
2-4	Preliminary Facility Sizing (Initial Station)	2-24
2-5	Candidate Facility Grouping, Study 3.	2-25
2-6	Mode Selection Considerations Summary	2-30
2-7	Space Station Functional Allocation Comparison.	2-45
2-8	Configuration Drivers and Selected Alternatives	2-54

1. CONFIGURATION DESIGN

1.1 INTRODUCTION

The space station configuration described in this section is the initial 6-man station as illustrated in Figure 1-1 and the growth 12-man station as illustrated in Figure 1-2. Preliminary design drawings of the initial station modules are found in SD 71-216, Modular Space Station Drawings. Sketches of the growth configuration modules are included in the design description of each module.

The station configurations, as shown in the previous figures, represent an evolution from the recommended configuration of the Phase A modular space station contract and from the trades performed under this Phase B contract reported in Appendix A of this document and in Volume VI, SD 71-217-6.

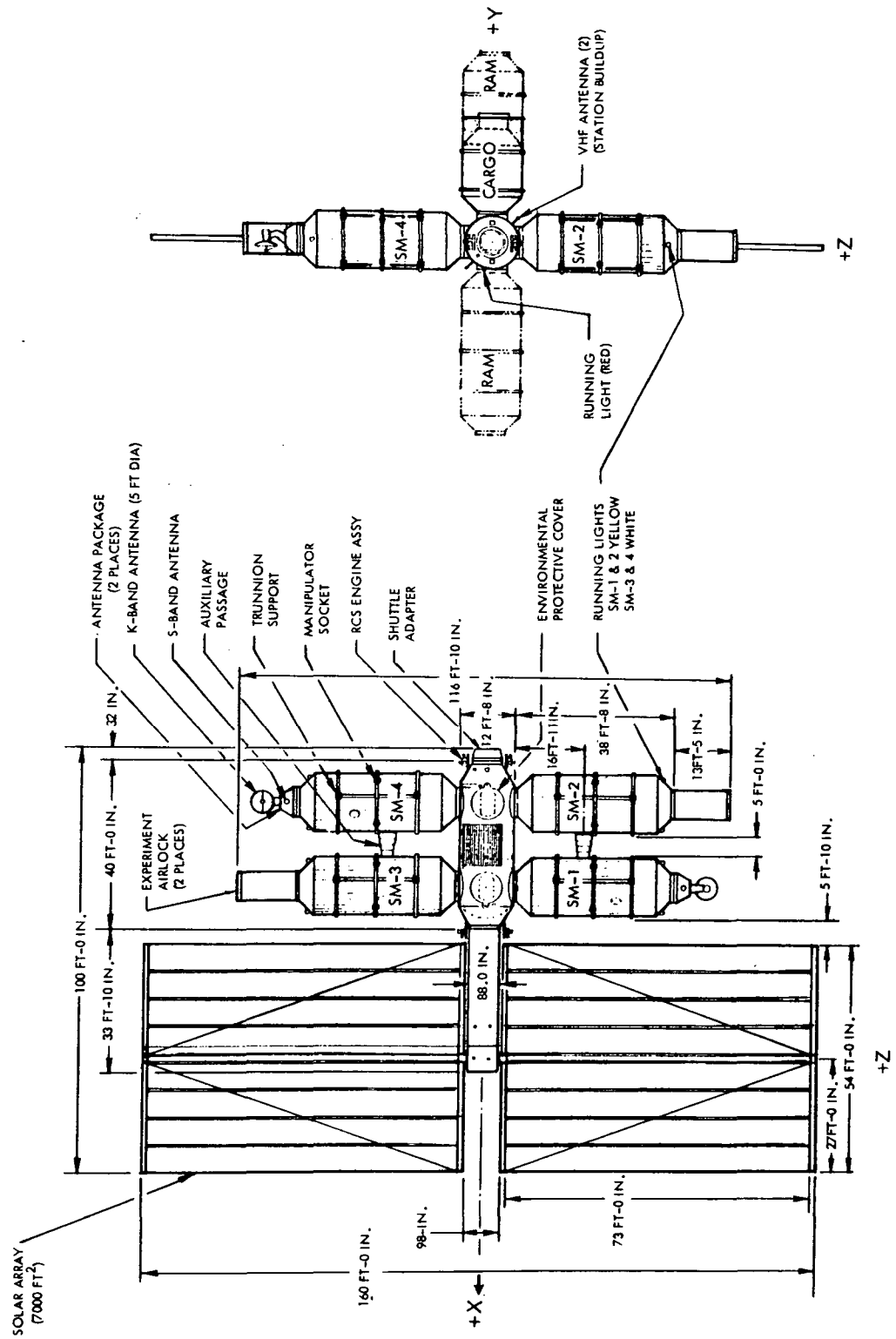


Figure 1-1. Initial Station Configuration

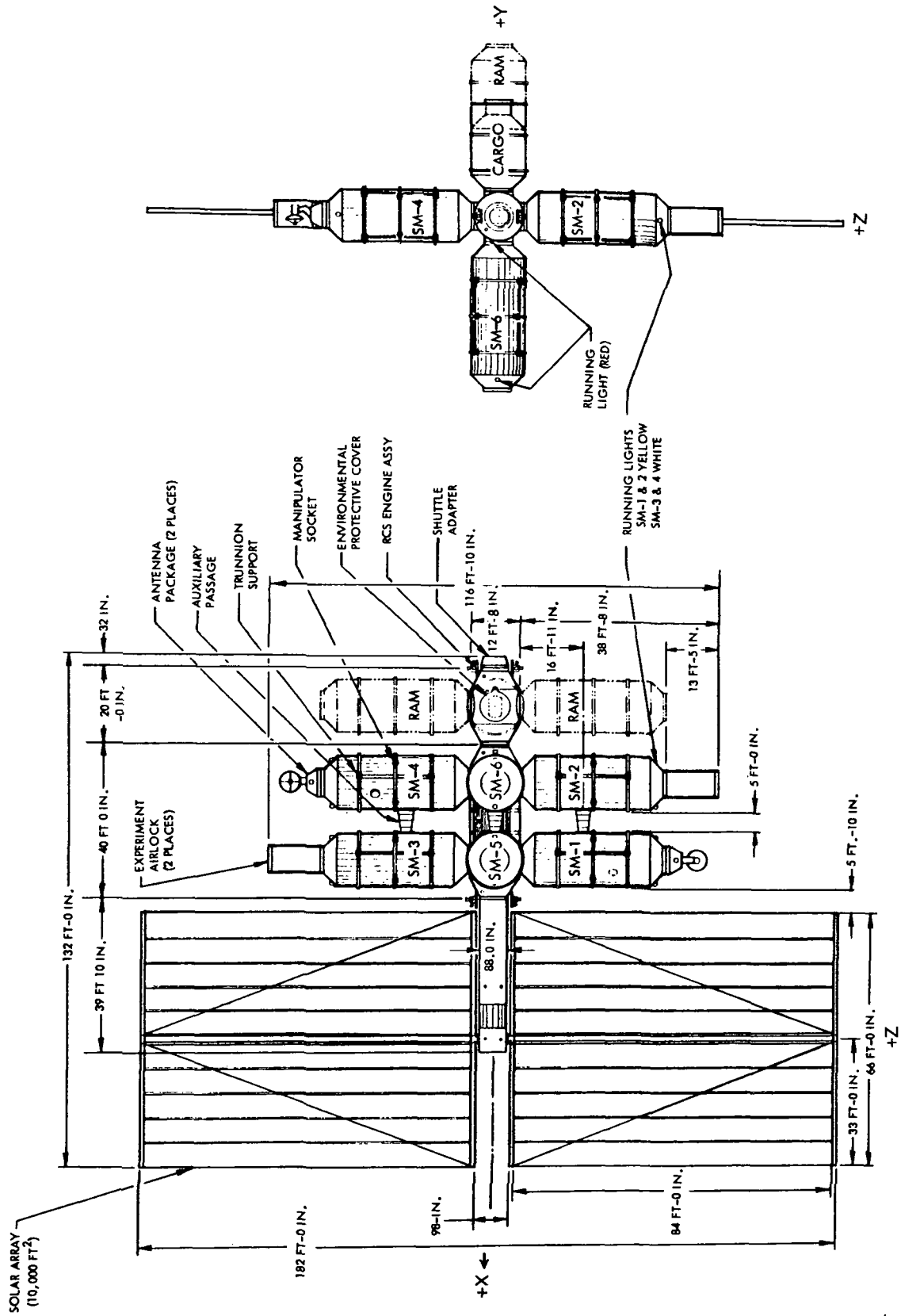


Figure 1-2. Growth Station Configuration

1.2 EXTERNAL CONFIGURATION

The major objective of this study is to define a space station that is composed of individual modules that can be transported into earth orbit via the space shuttle vehicle.

1.2.1 CONFIGURATION REQUIREMENTS

The station is to be assembled on-orbit into an initial configuration that provides accommodations for six crewmen and general purpose laboratory facilities that will provide a base for scientific investigations. This initial configuration will also have the capability for expansion to a growth configuration that will accommodate 12 crewmen and increased experiment facilities that are equivalent to the 33-foot-diameter space station. The initial station will be operable during the first 5 to 6 years with the growth station being operable for an additional 5 years.

In addition to the major general configuration requirements previously described, other general configuration drivers that affect the external configuration of the station assembly are listed as follows:

Berthing provisions for two RAM's

Berthing provisions for one cargo module

Module external dimensions:

- 14-foot diameter by 58 feet long
- 15-foot diameter by 60 feet long envelope for local protrusions

20,000-lb design-to weight (25,000-lb maximum)

No artificial gravity experiment accommodations for the initial station

Two separate pressurized habitable volumes

Nominal 5-foot-diameter berthing ports

Two access routes from every compartment

Minimize EVA repair and replacement

In order to accommodate the major objectives of the program, certain subsystem functional criteria also produced significant impacts to the external configuration. These criteria were the results of trade studies and are described in Appendix A of this volume and in Volume VI, SD 71-217-6, and are listed as follows:

7000-square-foot solar array

Experiment airlocks - nadir and zenith pointing

Communications antennas

RCS engines - shirtsleeve maintainable

Shuttle berthing adapter

5-foot module separation

Station assembly by shuttle manipulator

1.2.2 STATION ASSEMBLY

The modules that make up the initial space station configuration are arranged in a cruciform shape. The seven modules that make up the initial station are of two classifications: common modules and special modules. Units smaller in size than the basic modules are classified as packages. Table 1-1 categorizes these modules.

Table 1-1. Module Classification

Common Modules	Special Modules	Packages
Station Modules	Core Module 1	Antenna
SM-1	Power Module	Experiment Airlock
SM-2	Power Boom	Shuttle Adapter
SM-3	Solar Array Assembly	
SM-4	Initial	
RAM		
Cargo		

The station is assembled by utilizing the shuttle manipulator. The rationale for this mode of assembly is documented in the docking/berthing trade study in Appendix A of this document. A typical module berthing operation is shown on Figure 1-3.

All modules and packages are equipped with the standard neuter berthing port. A detailed description of this concept is made later in this section under "Berthing Port Design." A passive and an active type of port constitute this concept. The passive port provides alignment ramps, a latching ring, and a sealing surface, while the active port contains the alignment wedges, latches, and seals. The normal berthing operation joins an active and a passive port; however, the capability to berth an active port to an active port is also provided, and shown on Figure 1-4.

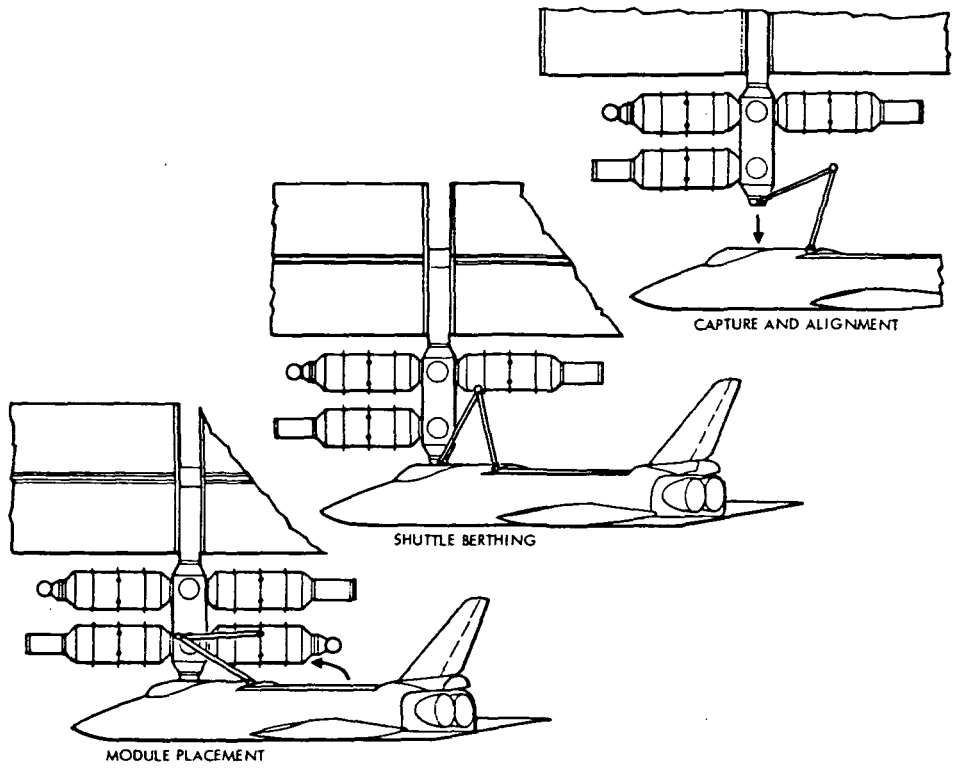


Figure 1-3. Typical Module Berthing

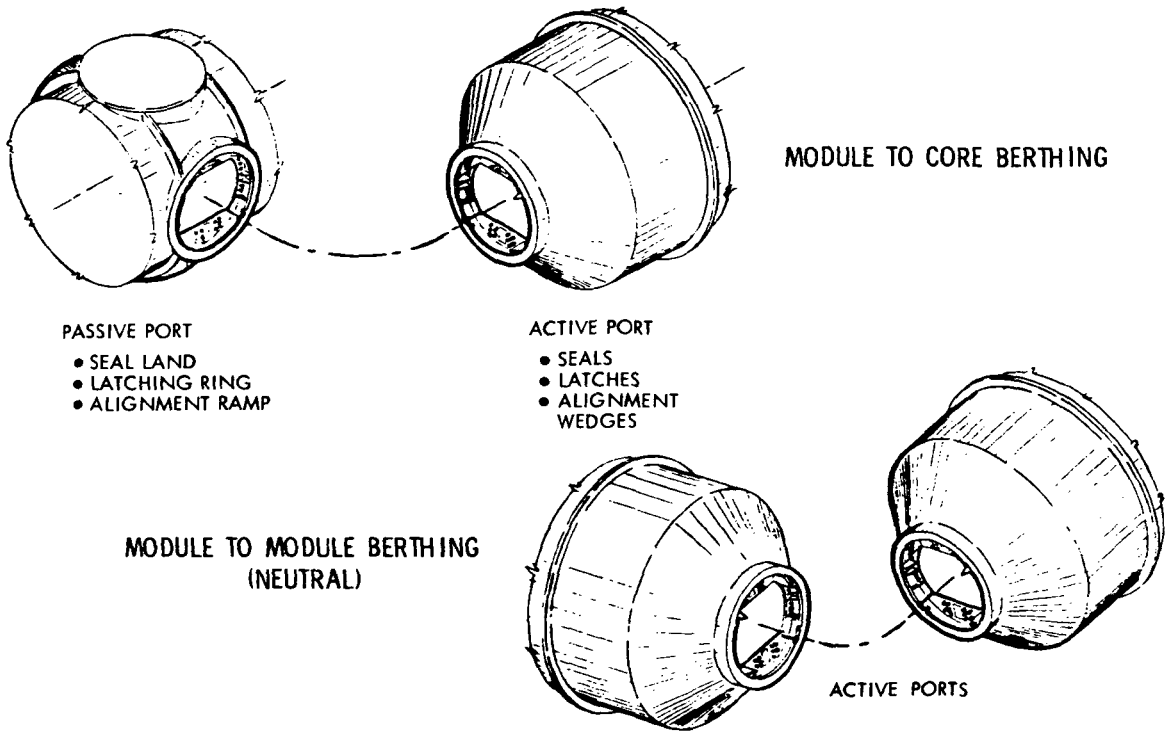


Figure 1-4. Berthing Port Arrangement

The station modules have a 5-foot separation distance between the 15-foot-diameter station envelopes. This separation distance provides the capability for a direct docking operation for station assembly. It also allows the thermal control radiators to be placed completely around the modules. A 5-foot 10-inch clearance is provided between the solar arrays and the station modules. The 10-inch additional separation is required for adequate clearance between the RCS engine assembly and the solar array.

The core module provides 10 passive ports to which the modules containing the active port attach. Each of the station modules contain an active port and a passive port. The power boom and solar array assembly each contain an active and a passive port. The antenna and experiment airlock packages contain only an active port since the other end of the package is required for functional operations. The shuttle adapter contains the active berthing port assembly on the end that attaches to the core module, while the other end has a special active arrangement that matches the shuttle interface. The alignment wedges and latches are identical to those of the neuter berthing port; however, the diameter of the mounting ring is only 60 inches while the neuter berthing ring is 80 inches in diameter. Figure 1-5 defines the berthing port locations.

The thermal control requirements of the station determined the location of the station modules. These modules are placed in the Z-plane pointing in the nadir and zenith directions. This orientation is the preferred orientation for the thermal control of the station.

The cargo module is located in the Y-plane on either side of the core module. The ports adjacent to the solar arrays are assigned to this function. The two ports provide the capability to berth and check out a cargo module before removing the depleted module for return to earth. Utilization of these ports, adjacent to the solar arrays, provides the RAM's with the greatest separation from the solar array. This separation is preferred to minimize interference effects on the experiments conducted from the RAM's. Consequently, the two remaining Y-plane ports are assigned for RAM activities. This assignment of ports provides an additional capability to accept a third RAM by utilizing the one unoccupied cargo module port.

The -X-port of the core module is dedicated to shuttle orbiter berthing; therefore, the shuttle adapter is berthed to this port. The shuttle manipulator is capable of reaching all of the modules from this position. Figure 1-6 illustrates the shuttle manipulator reach envelope from this berthed location.

The power module is berthed to the +X-port of the core module. Since the solar array assembly (solar array panels and orientation drive and power transfer turret) only is replaced, the power boom assembly remains attached to the core module. The orientation drive and power transfer turret provides 2 degrees of rotation to the solar arrays as illustrated in Figure 1-7.

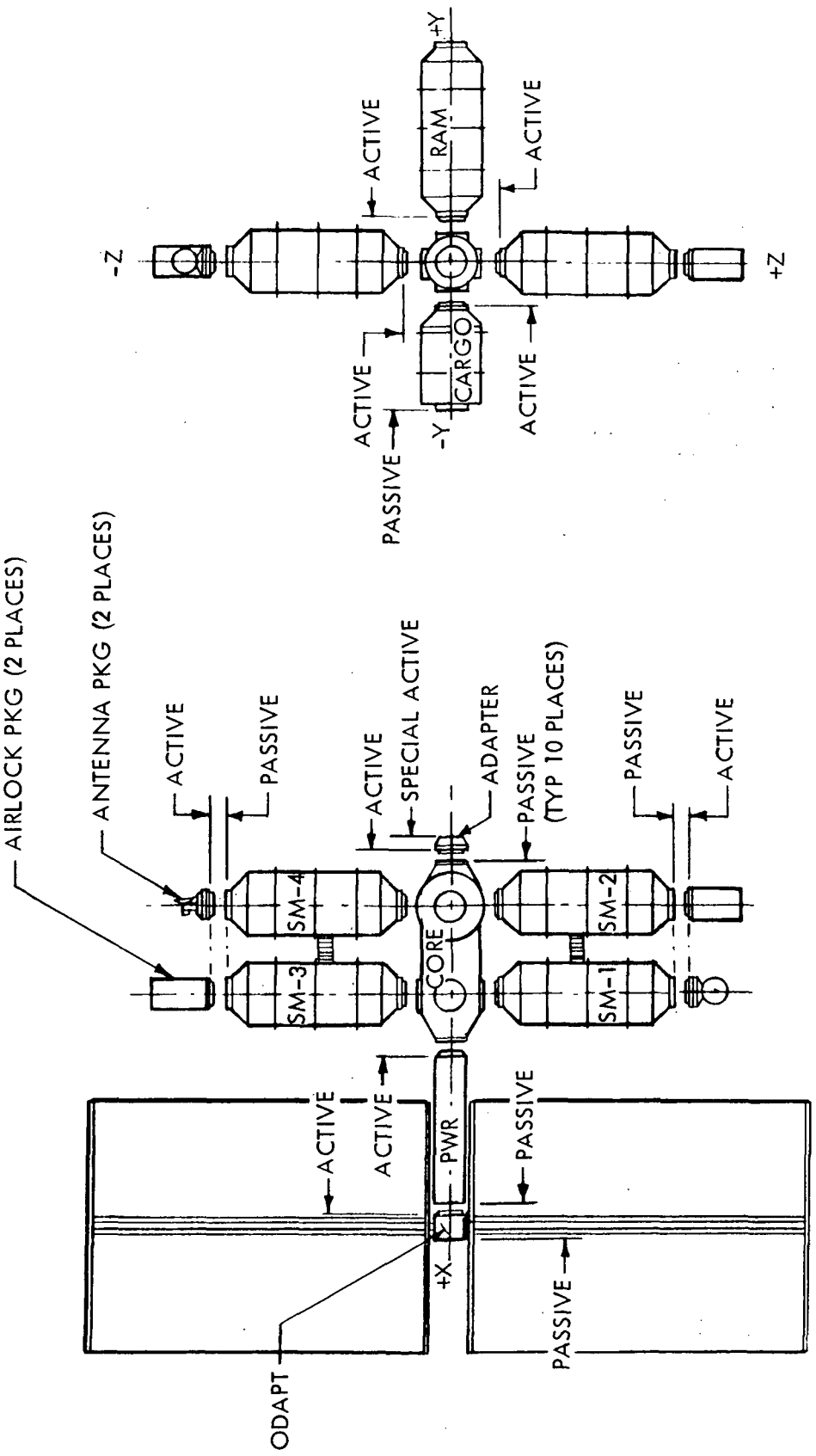


Figure 1-5. Berthing Port Location

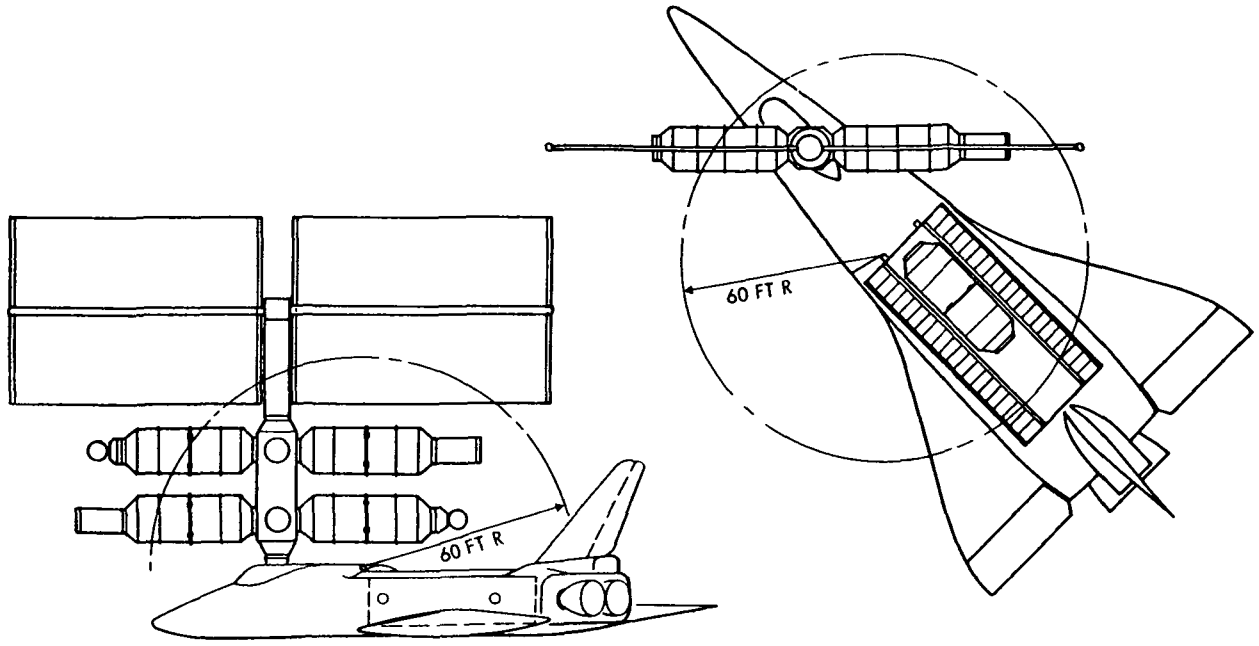


Figure 1-6. Shuttle Manipulator Reach Envelope

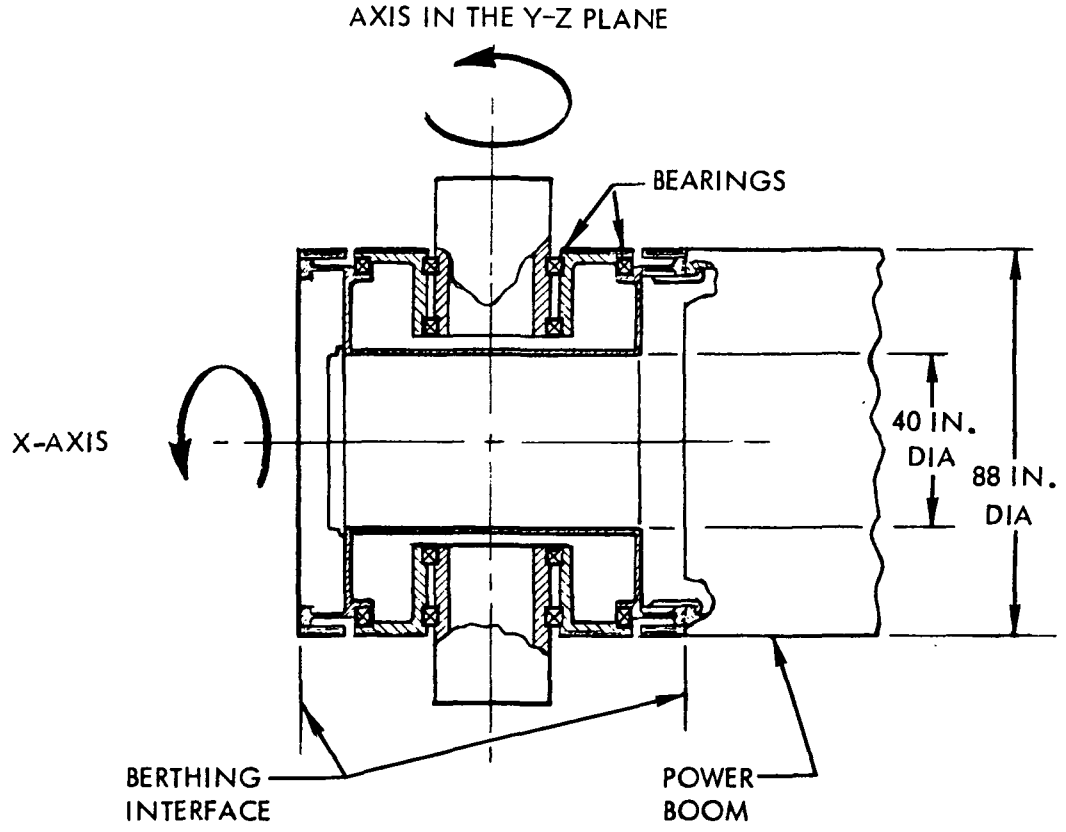


Figure 1-7. Turret Rotation

1.2.3 SHUTTLE INTERFACE

There are three physical interfaces between the modular space station (MSS) and the shuttle orbiter: the orbiter cargo (modules) retention system, manipulator fittings, and the berthing adapter.

The retention system supports the MSS modules in the orbiter cargo bay and reacts flight and landing loads. The major loads occurring in the X- and Z-directions are reacted in an axial and tangential direction. The less significant lateral loads in the Y-direction are reacted normal to the shell. The payload retention system is shown on Figure 1-8.

The method of manipulator attachment to the MSS modules is shown on Figure 1-9. Four equally spaced attachment points are located on a circumference near the module midpoints.

Figure 1-10 shows the adapter required to interface the 80-inch-diameter MSS berthing port with the shuttle orbiter 60-inch-diameter berthing port. The 32-inch adapter length is primarily required to accept the shuttle orbiter door which opens externally. The adapter includes necessary gas, fluid, and electrical lines to support the MSS during buildup.

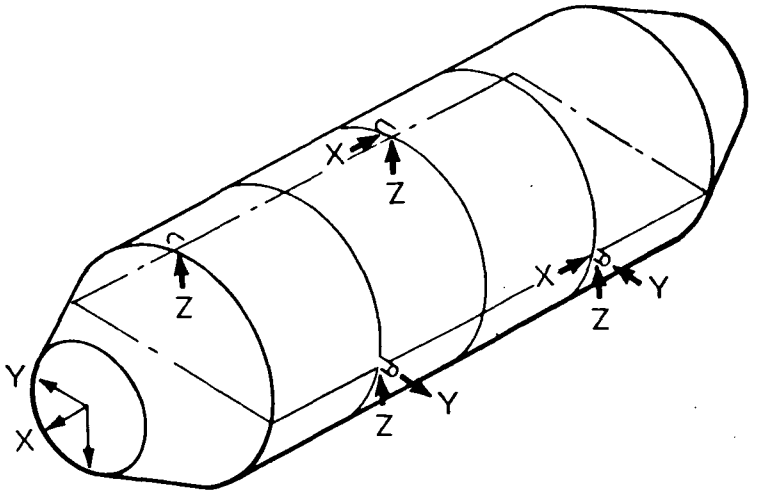
1.2.4 STRUCTURAL ARRANGEMENT

The structural and mechanical subsystem provides the space station pressure enclosure as well as the living and working quarters contained within the structure. It provides for the mounting of associated subsystem components, general purpose laboratory provisions, and storage facilities. The structure provides berthing ports and mechanisms for station assembly and crew and equipment transfer.

Three modular construction arrangements are utilized in the modular space station preliminary design. The station modules utilize the monocoque common module arrangement; the core module utilizes a seimonocoque skin and stringer arrangement; and the power boom utilizes a semimonocoque skin and stringer arrangement; and the power boom utilizes a monocoque construction similar to the station modules. Generally, structural components that are subject to long-term loadings, such as the pressure shell or require welded joints, are constructed from either 2219-T87 or 5052-H34 aluminum alloys. Components that do not require welding and are not subjected to long-term loadings are constructed from 7075-T6 aluminum alloy.

Structural Requirements

The structure will possess sufficient strength and rigidity to survive the shuttle orbiter transport loads (Table 1-2), the berthing velocities (Table 1-3), and the on-orbit operational conditions and will demonstrate the factors of safety as summarized in Table 1-4.



MODULAR SPACE STATION

Figure 1-8. Payload Retention System

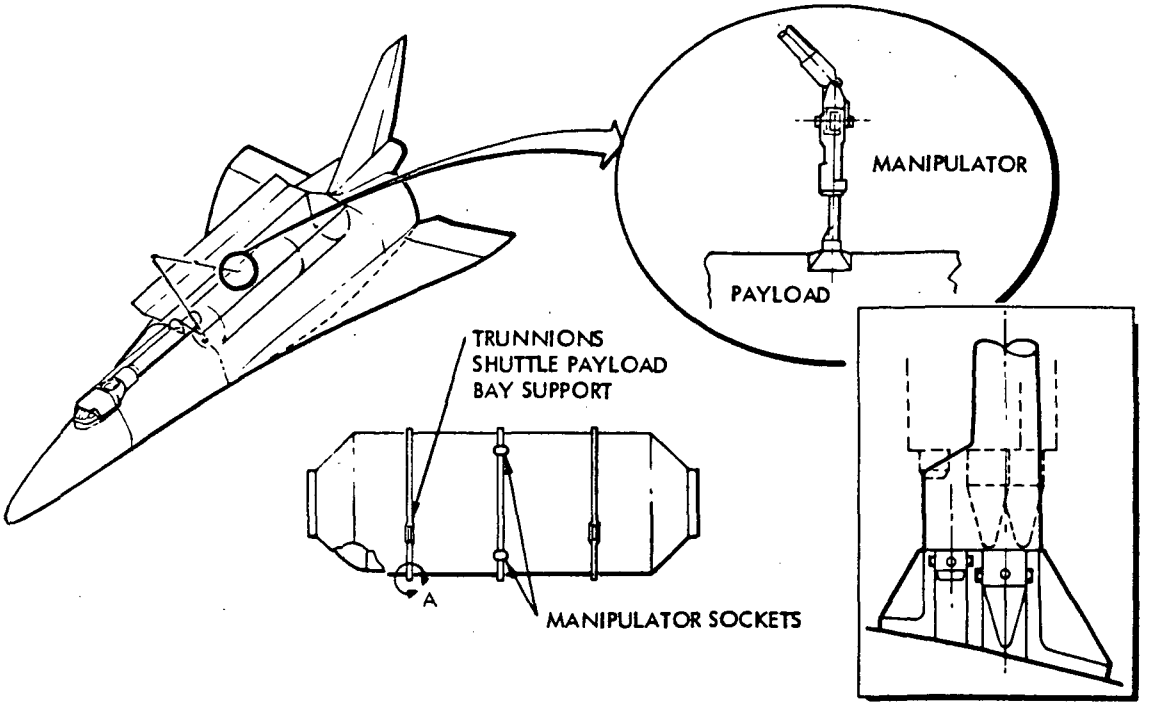


Figure 1-9. Manipulator/Payload Attachment

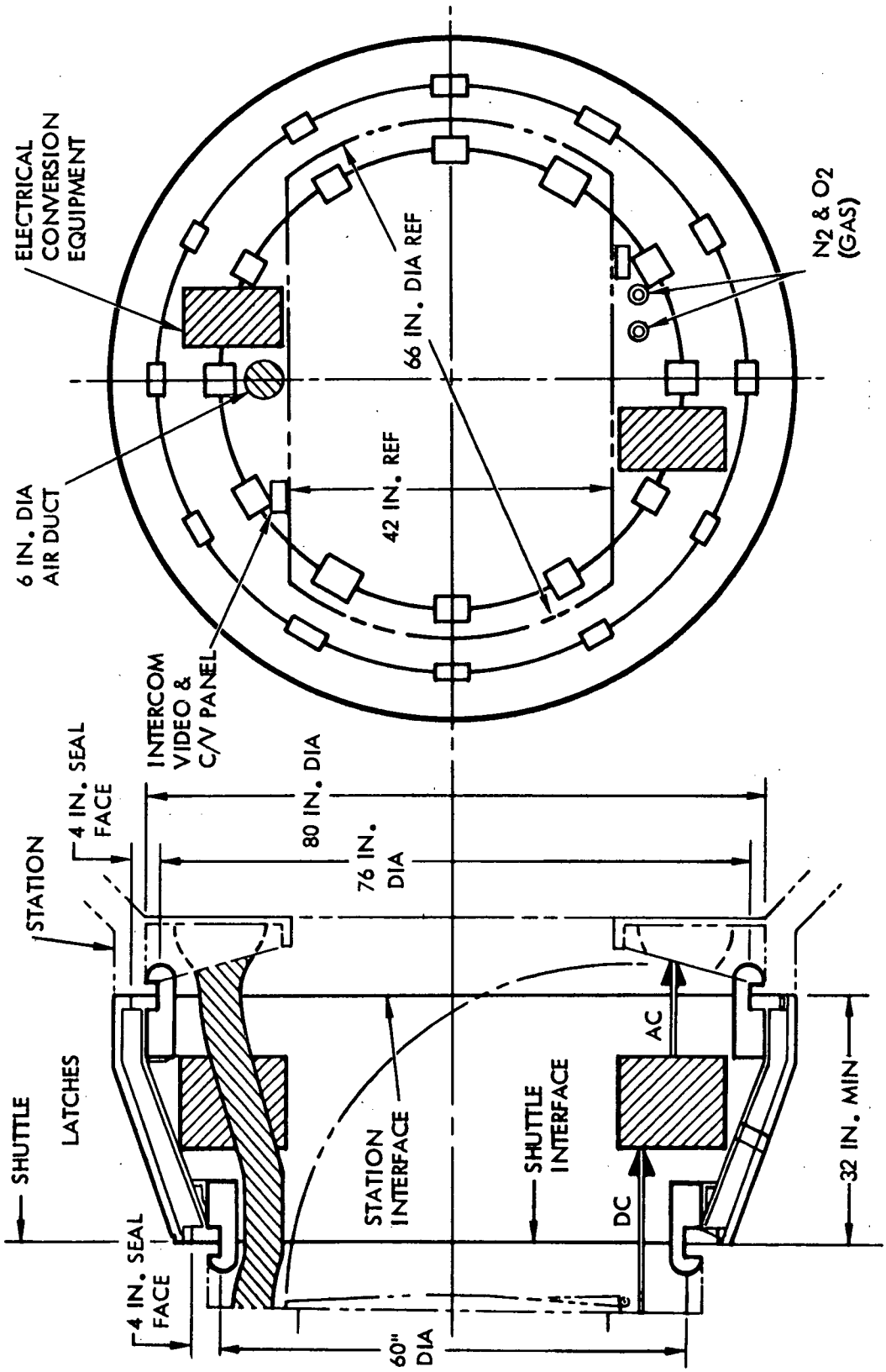


Figure 1-10. Station/Shuttle Berthing Adapter

Stiffness Requirements

Space station structure must provide adequate stiffness to maintain satisfactory vehicle stability and control characteristics in both launch and orbital configurations; to satisfy pointing accuracy requirements of solar arrays, antennas, and on-board or attached experiments; and to provide for proper operation of docking systems, hatches, covers, and other kinematic elements. As a goal, the fundamental bending/torsional natural frequency mode of the space station configuration shall be greater than one hertz.

Table 1-2. Shuttle Orbiter Loads

Condition	Acceleration (g's)		
	X	Y	Z
Liftoff	1.4	±0.8	±0.8
High Q boost	2.1	±0.42	+0.6 -0.84
Booster end burn	3.3	±0.11	-0.55
Staging			
Orbiter end burn	3.3	±0.11	-0.55
OMS operation	0.2	±0.1	0.1
ACPS operation	±0.1	±0.1	±0.1
Entry	±0.25	±0.6	-3.0
Fly-back	±0.25	±0.6	+1.2 -3.0
Landing and braking	+0.96 -1.2	+0.6	-3.0
Crash (cargo and equipment)*	-8.0 +1.5	±1.5	-4.5 +2.0

*Crash load factors are ultimate. All others are limit. These accelerations not separately and shall be used in design of structure whose failure could result in injury to personnel during a crash or prevent egress from a crashed vehicle. The longitudinal (X) acceleration may act within a cone about the X-axis with semivertex angle of 20 degrees.

Table 1-3. Shuttle Orbiter and MSS Berthing Criteria

Parameter	Berthing*
Centerline miss distance (inches)	±2.0
Miss angle (degrees)	±1.0
Longitudinal velocity (maximum) (ft/sec)	0.05
Lateral velocity (maximum) (ft/sec)	0.05
Angular velocity (maximum) (deg/sec)	0.10
*Berthing is defined as employing a manipulator to bring the elements together slowly and thus requires no attenuation.	

Table 1-4. Factors of Safety for Space Station Structural Design

Condition			Factor of Safety	
			Ultimate	Yield
Ground operations	Personnel not present		1.50	1.20
	Personnel present	Unpressurized	3.0	2.0
		Pressurized	4.0	2.0
Launch/Boost (Unmanned)			1.50	1.20
Orbital operations (manned)	Long-term sustained loads		2.0	1.50
	Short-term or transient loads		1.75	1.30

Life Requirement

The space station structure must be designed to maintain structural integrity and full operational capability over a 10-year-orbital service life, under normal operating conditions without requiring replacement or extensive refurbishment of primary structure.

Internal Pressure

Habitable areas of the space station must be pressurized to a nominal level of 14.7 psia for orbital operations. An allowance for pressure-control-

system tolerance must be made to this nominal pressure to establish maximum and minimum limit pressure levels for structural design.

The space station must be divided into at least two separate pressure compartments in a manner that permits isolation of any single compartment should it be damaged or rendered untenable. This requirement is accomplished for the selected design configuration by either of the IVA/EVA airlock pressure bulkheads located in the core module. These bulkheads are designed to withstand full compartment pressure loading acting in either direction.

Space station compartments that are normally pressurized during orbital operations are to be sealed prior to launch, and the corresponding compartment absolute pressure is to be considered in structural design for shuttle transport conditions.

The floor structure is considered to be secondary structure and shall be designed to carry the conventional loads of the architectural design and the equipment installed on them. It shall not be part of the primary structure.

Equipment and equipment support shall be arranged or mounted such that as a goal the entire inside surface of the pressure shell can be exposed for leak detection and repair. The equipment and supports shall also be capable of reacting pushoff and crew impact loads.

Station Modules

Figure 1-11 illustrates the structural concept utilized for the station module.

The common module is 33 feet 8 inches long. Its cylindrical (164-inch diameter) sidewall and cone-knuckle end bulkheads are of pure monocoque construction 0.145-inch-thick 5052-H34 aluminum alloy. The cylindrical section is faired into the conical section by a Cassinian curve. The Cassinian curvature of the pressure shell skin eliminates the requirement of a pressure kick frame. The 0.145-inch shell thickness together with the 0.030-inch-thick aluminum meteoroid bumper is required to meet radiation shielding requirements. Longitudinal drag members incorporated in the pressure shell to distribute the concentrated longitudinal shuttle trunnion support loads and longitudinal floor loads into the cylindrical shell are constructed from 2219-T87 aluminum. Three equally spaced ring frames made from 7075-T6 aluminum alloy are bonded to the exterior of the cylindrical pressure shell. The frames are employed to stabilize the pressure shell and distribute transverse concentrated shuttle support loads and manipulator fitting loads.

In addition to providing the required radiation shielding, the monocoque construction has several other definite advantages over other methods of construction.

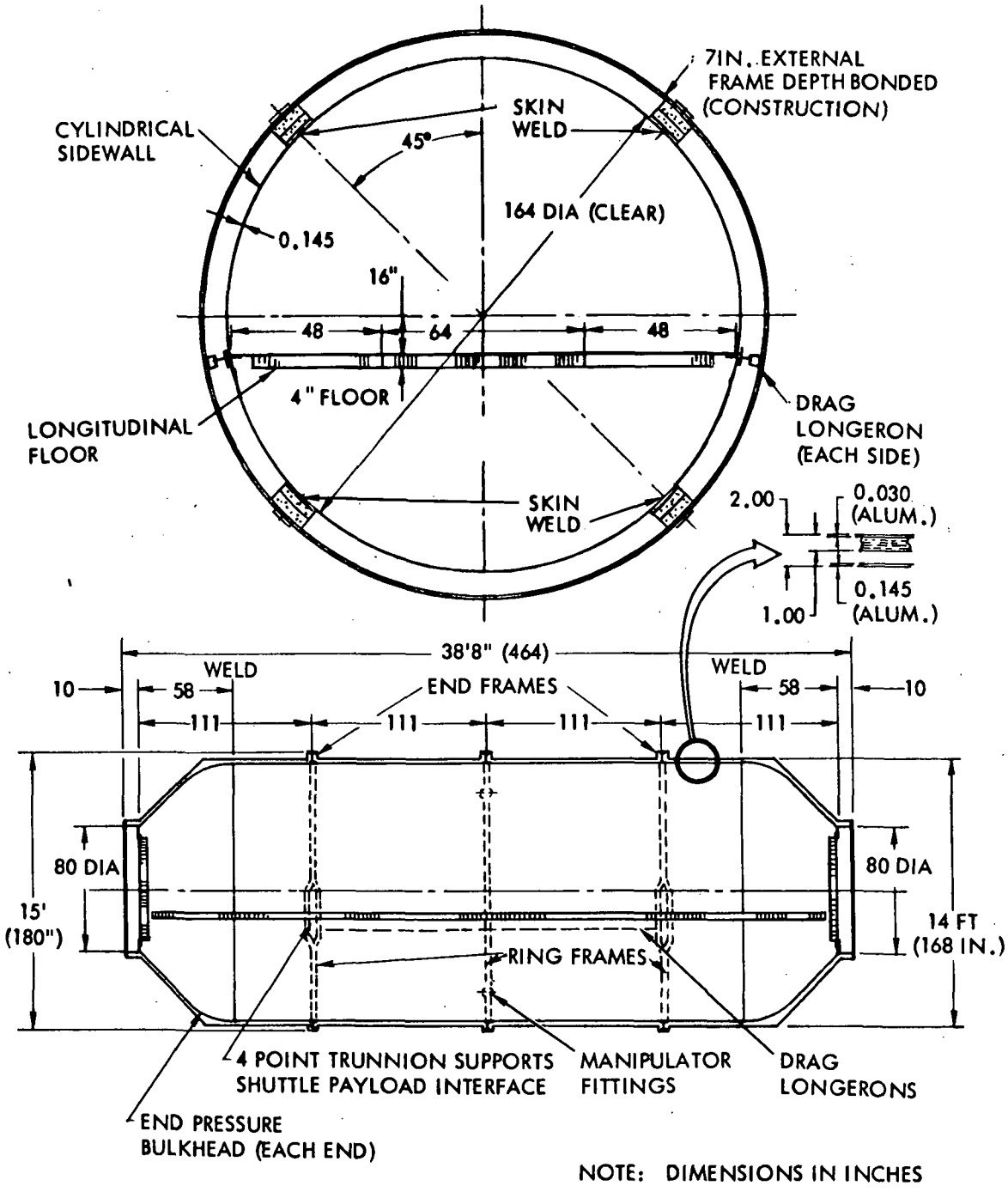


Figure 1-11. Station Module Structural Arrangement

1. Increasing the skin thickness allowed a lower strength aluminum to be used. 5052-H34 was chosen because of its ease of manufacture, low cost, and high-elongation properties. Manufacturing costs of the monocoque shell are approximately 60 percent of the cost of the foam-stiffened or integral skin-stringer consturctions.

2. Increased station stiffness resulting from the thicker monocoque shell raises the lowest mode natural frequencies of the station configuration.

3. Ground handling restrictions are less severe for the monocoque shell compared to the other constructions due to the inherent damage resistance of the thicker aluminum skin.

4. Maintainability and repair are much easier for the monocoque than for the skin-stringer type of construction.

The common modules are designed to facilitate the use of floors either parallel or normal to the module longitudinal axis. The floors are a honeycomb sandwich construction with 7075-T6 aluminum facing sheets and 5056-H38 aluminum core. The structural shell is required to withstand loads introduced at the end berthing ports due to station/orbiter berthing operation. The closing velocity of berthing a module to module or station is 0.05 foot per second. Berthing interface load as a function of closing velocity is shown on Figure 1-12, and is estimated using the axial stiffness characteristics of the structural shells. The capability to withstand berthing loads without buckling failure of the structural shell is shown for pressurized and unpressurized conditions. Since the minimum structural allowable of 0.095 foot per second exceeds the closing velocity criteria of 0.05 foot per second, no active attenuation is required.

Core Module

Figure 1-13 illustrates the structural design arrangement of the core module.

The core module is 40 feet long and has an integral skin-stringer construction outer shell which is composed of a 12-foot-diameter cylindrical section and cone-knuckle end bulkheads. Because of the relatively short time that the core module is inhabited, its radiation protection requirements are not as stringent as for the common modules. Therefore, the core module outer shell employs an integral skin-stringer construction made from 2219-T87 aluminum alloy to emphasize weight efficiency. Four bulkheads transverse to the module longitudinal axis are located immediately adjacent to the docking ports. These bulkheads serve the dual function of supporting internal equipment and providing stiffness between core module and berthed common modules. Two transverse pressure bulkheads are located centrally to the core module for the purpose of providing IVA/EVA capability and pressure compartment redundancy. Drag longerons are provided in the same manner as for the common modules.

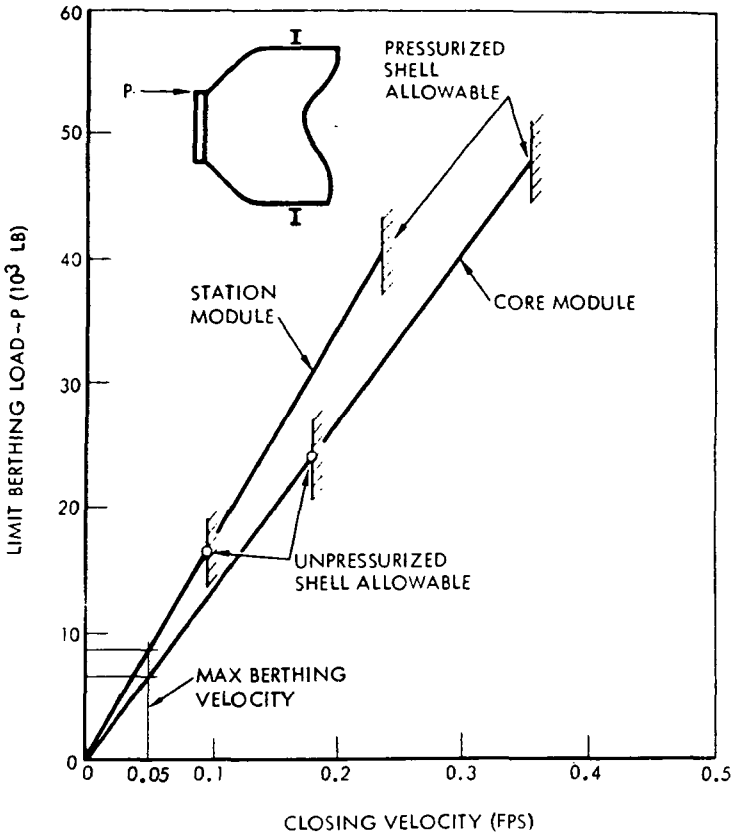


Figure 1-12. Berthing Load Vs Closing Velocity

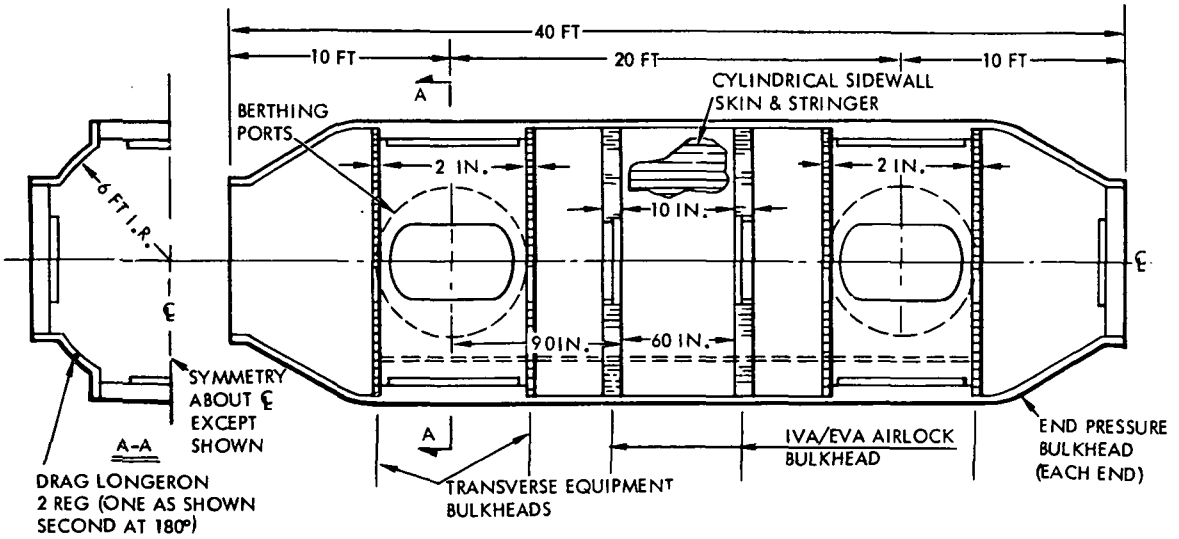


Figure 1-13. Core Module Structural Arrangement

Power Boom

Figure 1-14 illustrates the structural design arrangement of the power boom assembly of the power module. The solar array assembly is being developed by a direct NASA contract; therefore, no preliminary design effort was accomplished on this unit.

The 80-inch-diameter cylindrical power module structural shell utilizes a ring-stiffened monocoque construction. The 0.145-inch thickness used for the 5052-H34 aluminum monocoque shell is not required for strength purposes, but was incorporated to furnish torsional stiffness to increase the station minimum natural frequency. The external circumferential rings serve the dual purpose of supporting the shell against buckling failure and of reinforcing the shell to withstand concentrated loads from the supporting members for the pressurized gas tanks located inside the power module. Longitudinal drag members are provided similar to those provided for the core and common modules.

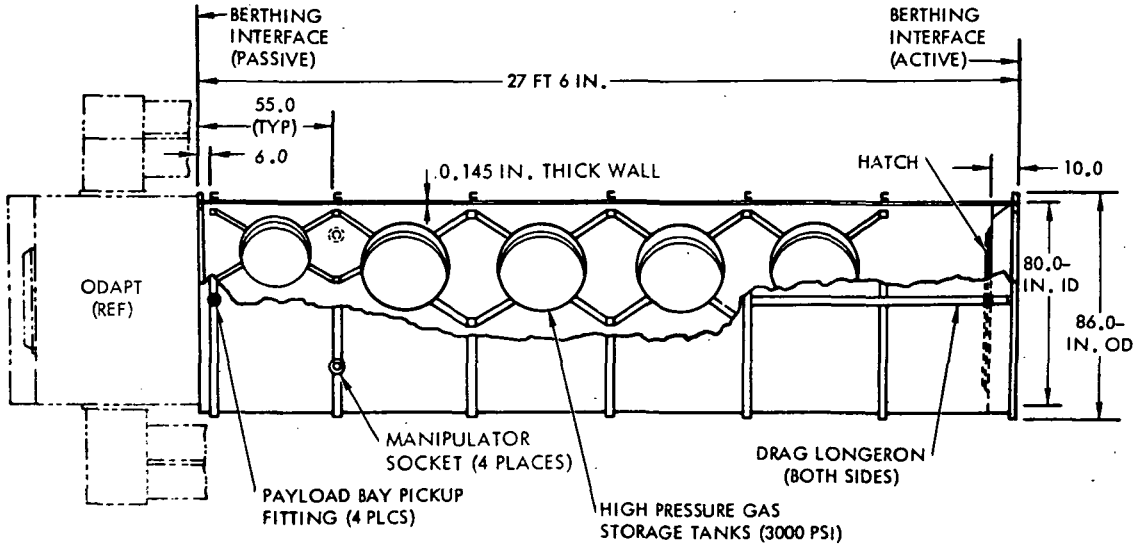


Figure 1-14. Power Module Structural Arrangement

1.2.5 CREWMAN ACCESS

The normal crewman passage between modules is via the core module which acts as a central passageway for the station. Access from the shuttle when berthed to the station is via the -X end of the station to which the shuttle adapter is mounted. EVA activities are accomplished via the EVA/IVA airlock located in the center of the core module. Hatches on either end of the airlock permit access from either Volume 1 or Volume 2 of the station. EVA is accomplished by utilizing a hatch with a 40-inch-diameter clear opening located in the core module airlock at 45 degrees from the Y-axis. Access to the experment airlocks is via the common hatch opening on the outboard ends of modules 2 and 3. Maintenance access to the antenna packages is also achieved via the outboard hatches of station modules 1 and 4. Maintenance to the power boom and solar array turret assembly is provided via the hatch in the +X end of the core.

1.2.6 DUAL EGRESS

A second means of egress from the modules is provided by the auxiliary passage. Hatches are provided on both sides of the passage, which permits isolation of any one module. This passage may be normally pressurized or not, as desired.

A second means of EVA is provided by the experiment airlocks and the power module end port. EVA can also be accomplished by utilizing the V_2 end of the core module with the hatches to the modules and airlock closed. Figure 1-15 illustrates the various access paths described above.

The access paths within each station module are illustrated in Figure 1-16. Access to the upper deck or lower deck is provided through the 48-inch-square opening in the floor adjacent to the core module.

The lower deck passageway provides a clear 42-inch-wide aisle which will accommodate the 40- by 40- by 50-inch maximum package size. Access to the auxiliary passages is accomplished from the upper deck in modules 2 and 4 and from the lower deck in modules 1 and 3. A removable panel is provided in the floor of the modules in line with the auxiliary passageways. These panels provide access to the auxiliary passageways from the lower deck of modules 2 and 4, and from the upper deck of modules 1 and 3. This path also provides the second means of egress from the lower deck.

A second means of egress from the crew staterooms is through the floor separating the crew and commander/executive staterooms. Knock-out panels are provided in the compartmented areas of the station such as the hygiene facility, photo lab, and medical intensive care facility. Removable floor panels in the GPL areas, adjacent to the airlock, provide the second means of access for these areas.

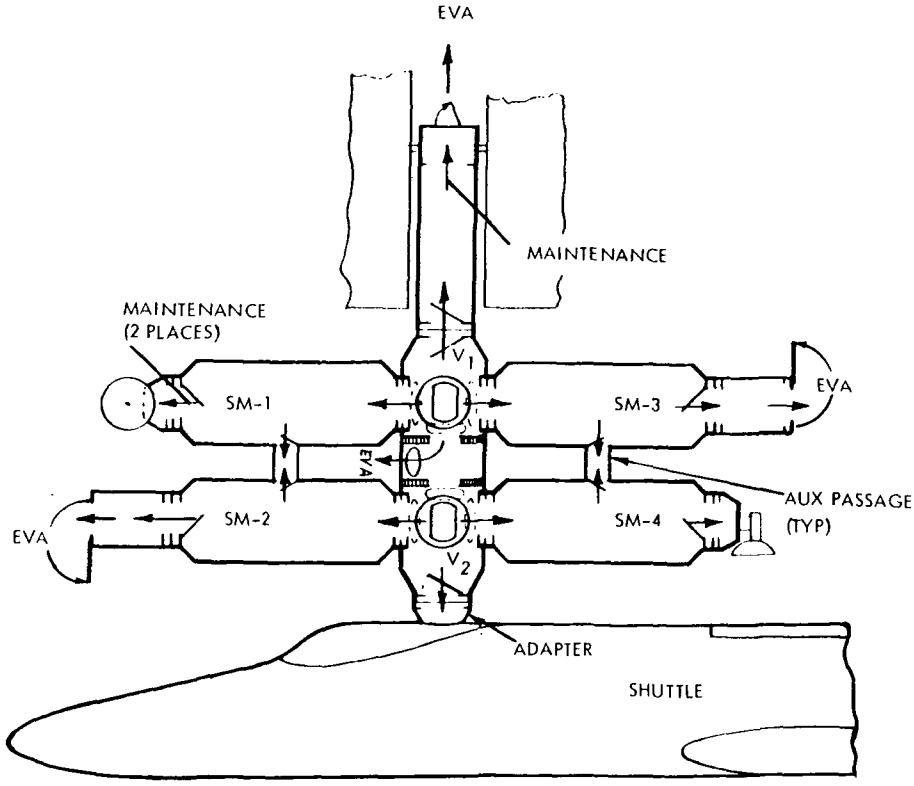


Figure 1-15. Access Routes

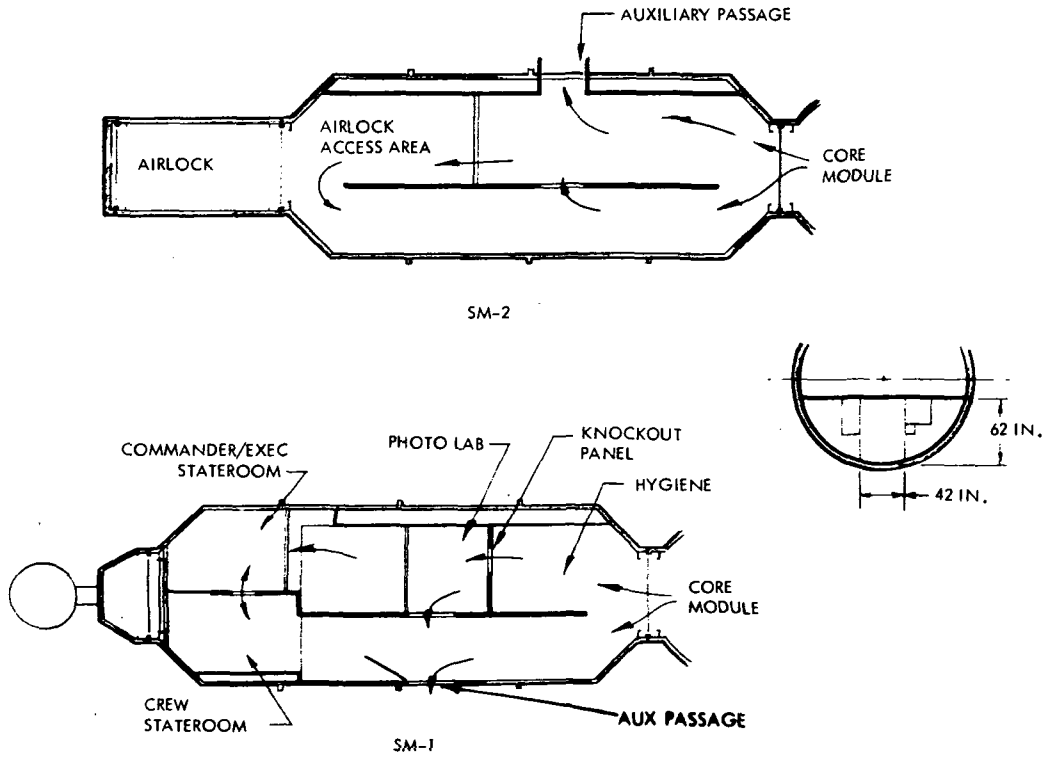


Figure 1-16. Module Access Paths

1.2.7 HATCHES

A common hatch, as shown on Figure 1-17, is located on the end of every module with the exception of the power module. The power module utilizes the common hatch at the interface to the core module, but provides only a 44-inch-diameter hatch on the end of the solar array turret. This hatch is utilized for personnel exit only, and each of the berthing ports contains the common hatch. Consequently, all of the modules provide a completely enclosed configuration for the launch into orbit. This concept, therefore, provides the modules with a habitable atmosphere on arrival into earth orbit, eliminating the necessity for immediate pressurization.

Figure 1-18 illustrates the hatch arrangements of each of the initial station modules. The common hatches all opening inward permit the module pressure to assist the sealing.

The station module hatches at the core module interface are returned to earth after berthing because of space and access limitations. The core module hatches, therefore, will provide the means of closing off the individual modules if required to isolate the volume or if required when removing a module.

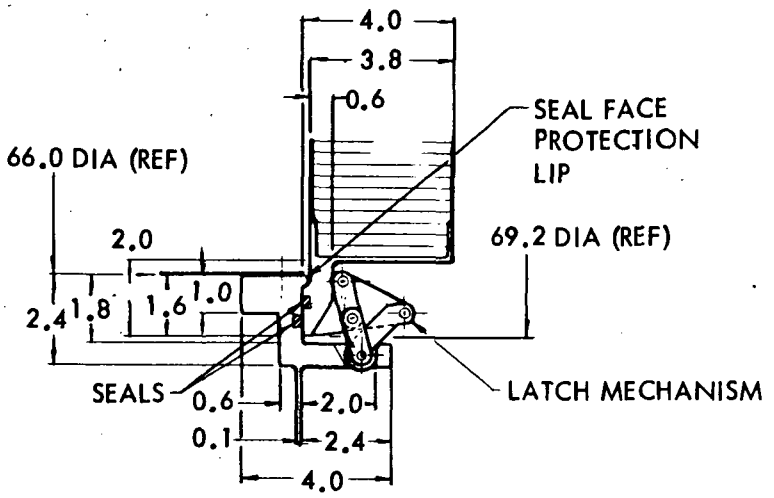
The EVA/IVA airlock located in the core module also utilizes the common hatch for the pressure bulkhead closures. A round 44-inch-diameter hatch is utilized for the EVA egress and opens outward, providing a 40-inch-diameter clear opening. The identical hatch is also utilized on the end of the solar array turret and also opens outward.

Another group of hatches 40 inches in diameter is provided to close off the auxiliary passages which provide the second means of access from each of the station modules.

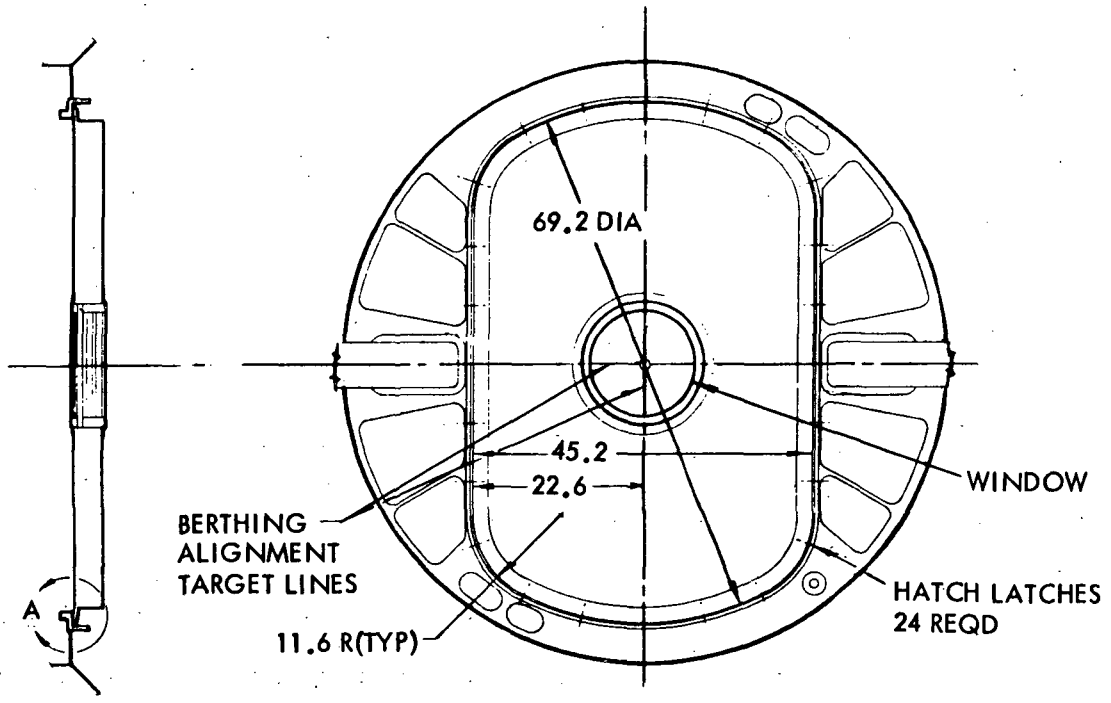
The experiment airlock package has its own special hatch that opens outward exposing the total area to the ambient environment. The station module common hatch provides the inboard closure for the airlock.

The antenna package does not contain any hatches. The station module outboard hatch provides the closure for this package which is normally unpressurized, but has the capability to be pressurized. The station module hatch provides the ingress to the package for shirtsleeve maintenance.

Each common hatch contains a standard 14-inch-diameter clear window. These windows are utilized by the berthing alignment TV to view a berthing target on the window of the approaching module. These windows are also utilized for observation of the solar arrays, and observation of an EVA crewman when there are no modules covering the port. This same window, without the alignment markings, is in the common hatches of the EVA/IVA airlock and also in the EVA hatch of the airlock. The windows in the EVA/IVA airlock also provide observation of the crewman activities inside the airlock.

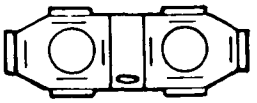
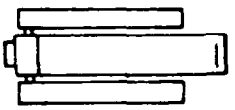
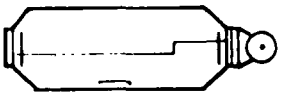
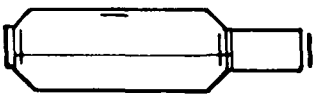
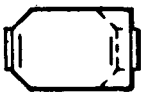


DETAIL A



ALL MEASUREMENTS ARE IN INCHES

Figure 1-17. Common Hatch

MODULE	ARRANGEMENT	HATCHES			
		COMMON (46 X 70)	AUX - PASSAGE (40 DIA)	AIRLOCK EVA (44 DIA)	AIRLOCK LAB (88 DIA)
CORE MODULE		12	-	1	-
POWER MODULE		1	-	1	-
STATION MODULES SM-1		2	1	-	-
SM-2		2	1	-	1
SM-3		2	1	-	1
SM-4		2	1	-	-
CARGO MODULE		2	-	-	-

ALL MEASUREMENTS ARE IN INCHES

Figure 1-18. Module Hatch Arrangement

Each of the auxiliary passage hatches contain a 4-inch-diameter clear window. This window is utilized for observation when the auxiliary passage is being used.

The 44-inch-diameter hatch on the end of the power module is the only hatch that does not have a window. No requirements was established for a window in this hatch.

The large experiment airlock hatches also contain a standard 14-inch-diameter window. This window is required for EVA observation.

1.2.8 AUXILIARY PASSAGE

The auxiliary passage between the station modules provides the second means of egress from the modules. This passage is located approximately 17 feet from the primary exit of the station module to core module interface, which complies with the safety requirement "that the two paths shall be at least 10 feet apart." The auxiliary passage is provided between the station modules only. No auxiliary passage is required between RAM's and cargo modules because of the limited periods of crew occupancy. These passages are connected between modules after the modules have been berthed to the core and declared safe for crew occupancy. Station modules 2 and 4 contain the active assembly of the passageways. The passageway is a rigid aluminum tube with a 36-inch clear opening stowed within the module during launch and berthing and is extended using station pressure to the adjacent module which contains the mating ring. Telescoping environmental protection panels cover the exterior of the tube. Provisions are made in both the extendible tube and the mating ring to allow for misalignments. Figure 1-19 illustrates the auxiliary passage activation procedure.

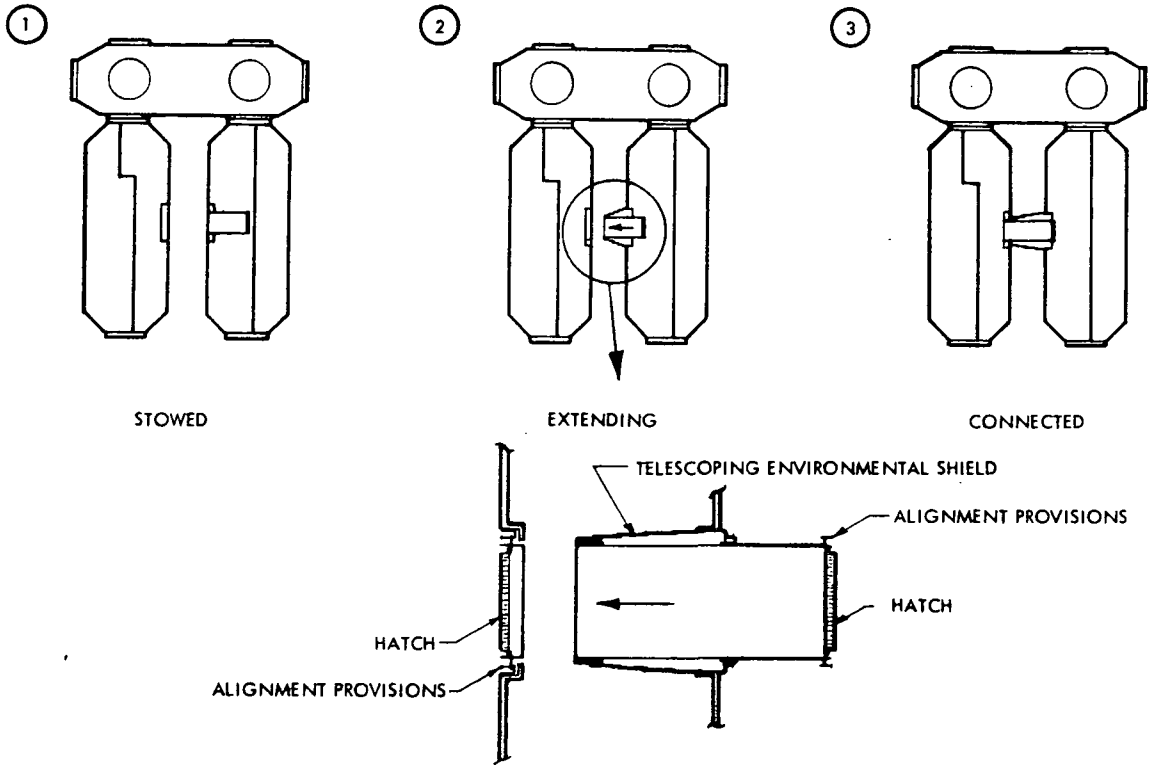


Figure 1-19. Auxiliary Passage Activation

1.2.9 WINDOWS

The space station has been designed to have adequate windows arranged to allow the crew to control the attitude of the vehicle by reference to the external scene, to enable visual contact with the shuttle or free-flying modules during rendezvous, to provide earth and celestial viewing in the main assembly area, to allow visual contact with an EVA astronaut, and to observe the motion of the solar array panels. The standard 14-inch-diameter clear viewing window is used in all of the hatches except the auxiliary access hatch where a 4-inch-diameter window is provided. There are three habitability windows in the station module pressure shell. All habitability window centerlines are located 51 inches from the longitudinal floor. Station modules 1 and 4 have a standard window in the control console area and station module 3 has a standard window in the dining and recreation area. There is a total of 25 standard 14-inch-diameter windows and four 4-inch-diameter auxiliary access windows on the initial station configuration. The standard 14-inch-diameter clear window is shown on Figure 1-20.

The windows are provided protection against thermal and micrometeoroid environment by movable environmental covers. The cover assembly normally remains closed and is only opened when in use. The window shield subassembly consists of the exterior environmental shield and a pressure cover. It is displaced from or returned over the window by a manually operated handle and a displacement mechanism, which pushes the shield outboard before it is rotated out of the way. The window shield, when returned over the window, can be latched in place by manually operated locks spaced about the periphery of the window. The window shield is locked and sealed (dual seals) in place. The window assembly can then be removed by removing the attachment bolts about the window frame. The entire operation is done manually by a crewman in a shirt-sleeve environment. The individual manual locks minimize the lock mechanism installation as compared to a possible remotely driven exterior-mounted mechanism. Figure 1-21 illustrates the cover arrangement concept.

1.2.10 COMMUNICATIONS

Communications for the buildup operations and for the normal station operations are provided by VHF and S-band antennas located on the -X end of the core module. This location provides coverage during the gravity gradient orientation mode of the module in the early stages of station assembly. The antenna packages located on station modules 1 and 4 provide S-band, VHF, and K-band coverage. When station module 1 is assembled to the core module, this buildup configuration has station module 1 in a nadir pointing orientation and, therefore, becomes the primary communications link. The additional coverage required for the initial station configuration is provided by the antenna package located on station module 4 which has a zenith orientation. Figure 1-22 illustrates the communications arrangements during the various stages of station buildup.

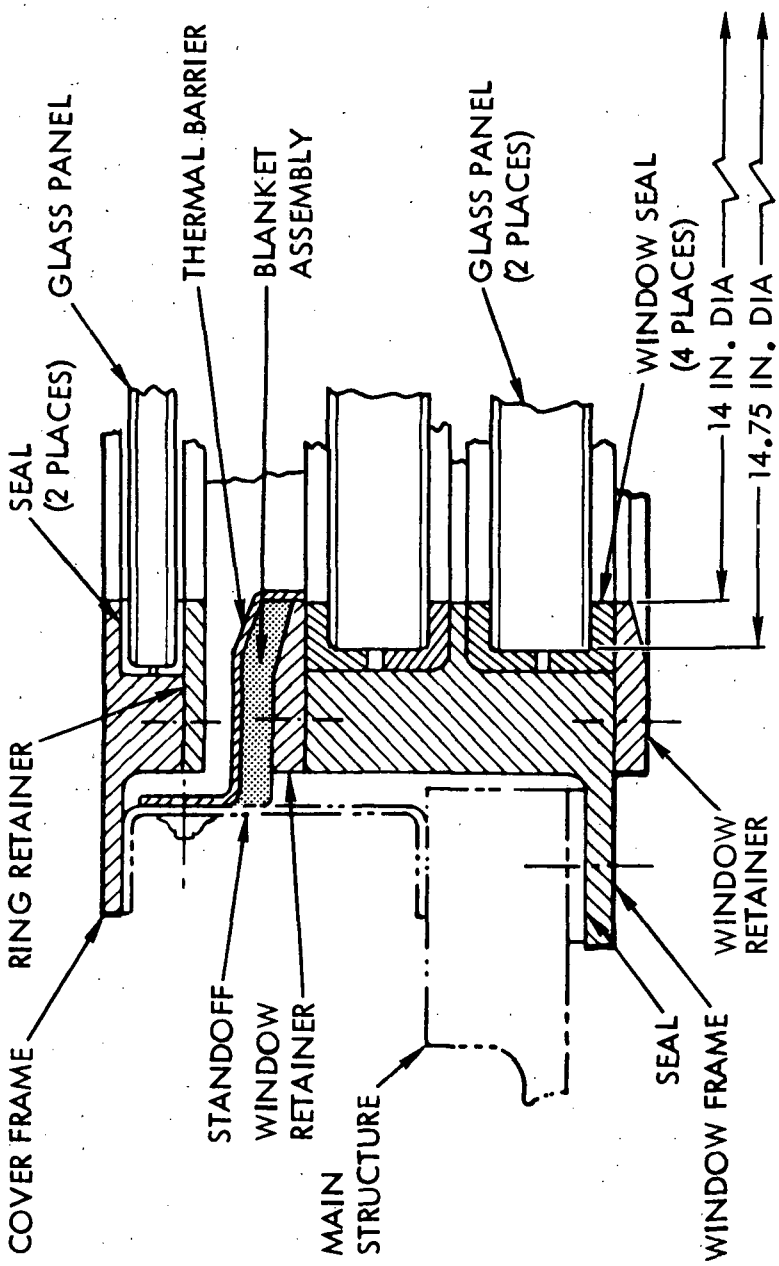


Figure 1-20. Cross Sectional View of MSC Window Assembly

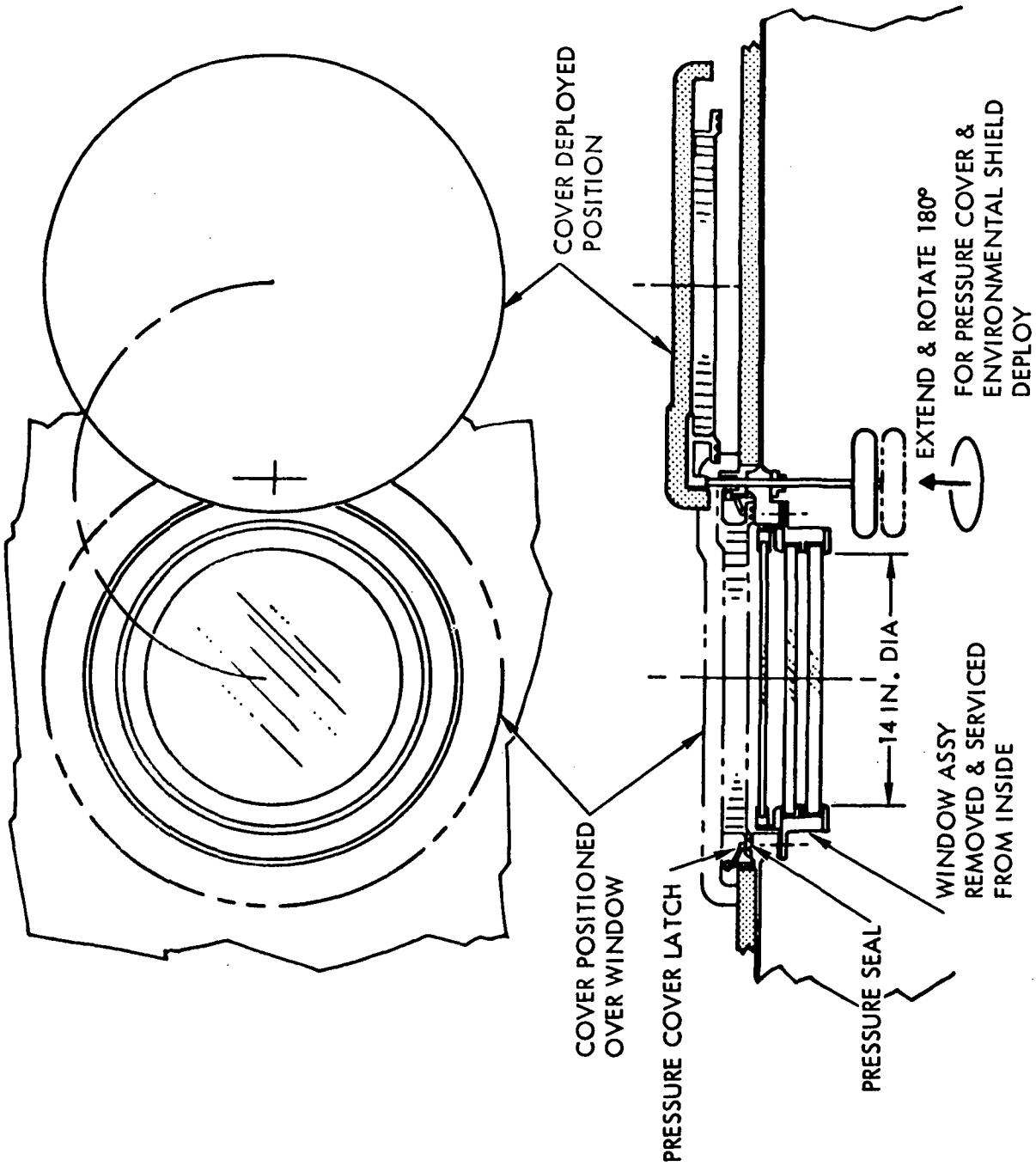


Figure 1-21. Window Cover Deployment

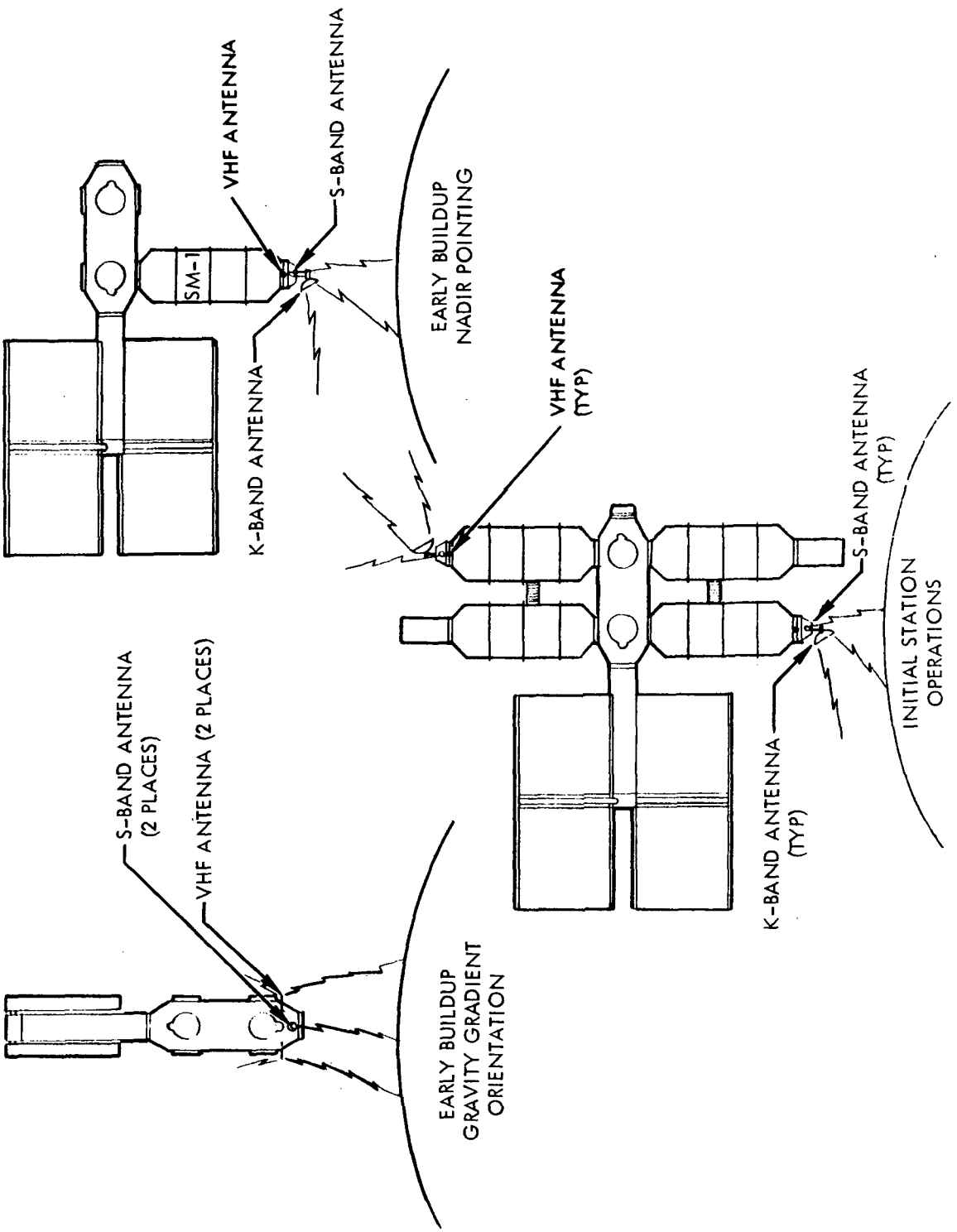


Figure 1-22. Station Communication Arrangements

1.2.11 EXPERIMENT AIRLOCK

Nadir pointing and zenith pointing experiment airlocks are provided on the initial station. Large hatches on the ends of the airlock expose the total volume to ambient atmosphere when required. Experiment sensors may be mounted on the hatches for exposure and/or viewing. A track arrangement within the airlock provides the capability to extend experiment packages or sensors. Figure 1-23 illustrates these capabilities.

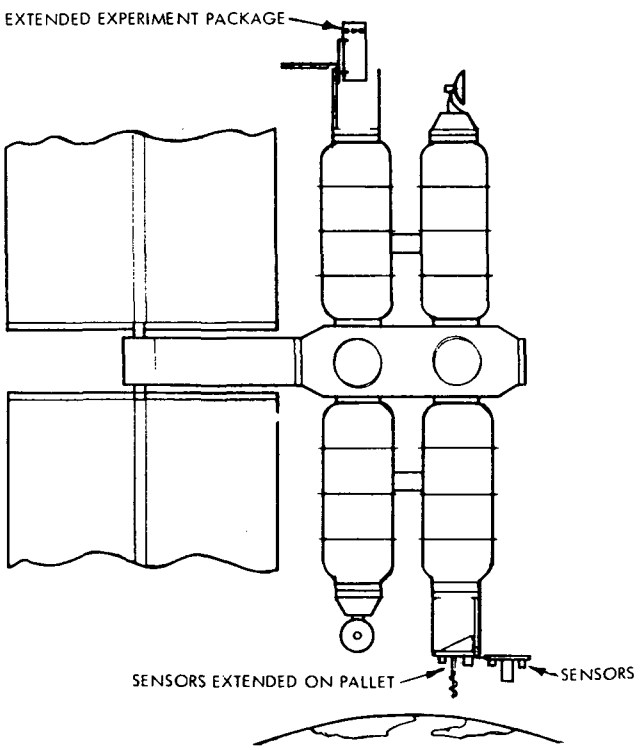


Figure 1-23. Airlock Capabilities

1.2.12 ENVIRONMENTAL PROTECTION

The environmental protection subsystem provides three basic functions: thermal protection, meteoroid protections, and radiation protection. Protection for the subsystem assemblies exposed to the external environment must be

included for all phases of the mission operations. The primary purposes of the thermal protection system are to establish thermal independence of attitude, to preclude condensate formation on interior surfaces, and to prevent excessive limit external environment heat loads to the station and losses from the station. The major considerations in insulation design are installation and mounting provisions, structural heat shorts, and insulation venting provisions. Long-term protection from meteoroids is required for all external structures. The meteoroid bumper is supported with nonmetallic fasteners for thermal isolation. A double-bumper configuration offers maximum efficiency for meteoroid protection. The outer bumper is a structural element to attach the insulation, and the second bumper is incorporated as a protective inner covering for the high-performance insulation. The protection of the crew from radiation includes evaluation of the natural sources, earth trapped, cosmic-galactic, and solar flare radiation. The radiation shield utilizes the primary bumper and the mass of the structure and furnishings for protection of the crew from the natural radiation environment. Figure 1-24 shows cross sections of the environmental shield for the power module, core module, and station modules.

The thermal protection assemblies consist of environmental shield panels that cover the end domes and cylindrical surfaces of the modules. The outer surface provides the carrier panel to mount the insulation and provides strength and stiffness to withstand acoustic pressures inside the shuttle cargo bay. The outer surface is 0.030-inch-thick fiberglass laminate for the power and core modules and is 0.030-inch-thick aluminum for the station modules. This outer surface is the primary meteoroid bumper. An insulation assembly or thermal insulation blanket is the inside layer of the shield assembly. The insulation blanket consists of approximately 60 layers of aluminized Mylar and is supported from the outer surface panel with venting provisions designed for boost and orbital conditions. The insulation assembly is enclosed in a 10-mil-thick Kapton film that protects the insulation from handling damage and permeation of cabin atmosphere leakage. This film also serves as a secondary meteoroid bumper. The edges of the panels are closed out by fiberglass laminate members that serve as support beams and permit widely spaced attachments to the primary structure. The attachments are designed to minimize the heat conduction to the structural wall and also accommodate the thermal expansion of the environmental shield panel. Protective covers that incorporate the same general features are incorporated on four core module berthing ports. These covers are rotated out of the way to allow operation of the protected item. Protective covers are also provided for the three standard windows in station modules 1, 3, and 4 and for the window in the EVA airlock. The environmental shield incorporates dual bumpers to fragment the meteoroid particles and reduce their capability to penetrate the structural pressure shell. Results of an analysis of meteoroid penetration verified a probability of 0.902 of no penetration of the crew or systems compartment over the 10-year service life of the space station. The complete analysis is documented in Appendix B of this report.

The inherent shielding due to mass of structure, furnishings, and equipment is utilized for protection of the crew from natural radiation environment. Evaluation of the radiation doses and dose rates to station crewmen was

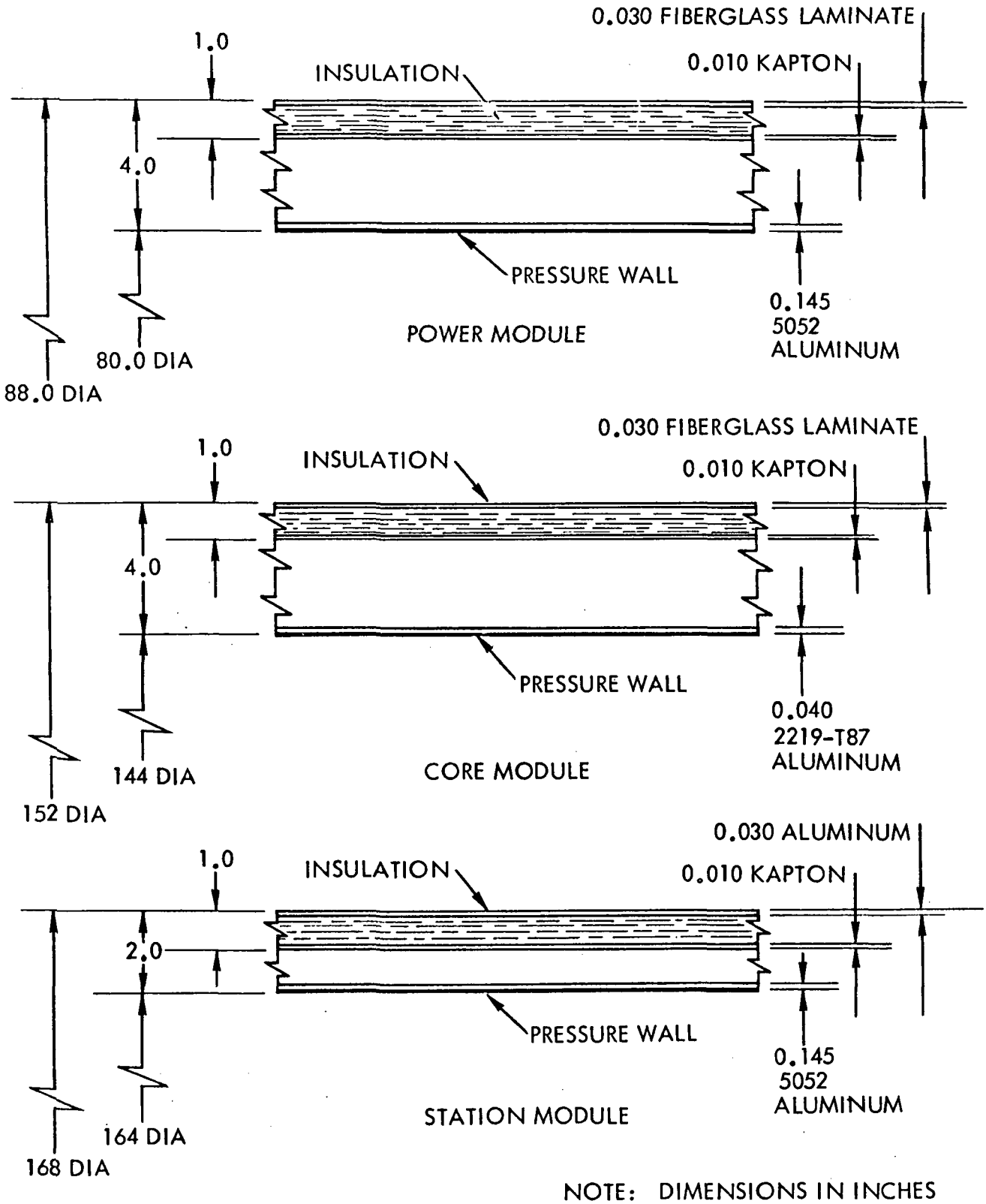


Figure 1-24. Environmental Shield Sections

performed for the final preliminary design configuration. The complete radiation analysis is documented in Appendix B of this report. The analyses considered the three primary sources of natural radiation flux (earth-trapped, galactic cosmic, solar flare event) in an orbit of 55 degrees and an altitude of between 240 and 270 nautical miles.

Results of these analyses show that radiation dose from continuous sources (earth-trapped, galactic cosmic) does not exceed allowable values and does not constrain the crew stay-time. The radiation dose to the eyes is very nearly that received by the skin. Shielding in addition to that provided by the structure is required to meet the quarterly eye dose of 52 rem. It was determined that use of protective goggles during periods of significant solar flare radiation will lower the quarterly eye dose to an acceptable level. Table 1-5 summarizes the radiation dose results of the analysis.

Table 1-5. Radiation Protection

Rem Dose Allowables (90-day exposure)		Dose Rate (270° n mi/55° orbit 0.175 aluminum equiv)
Skin	105 rem	75.2 rem
Eye	52 rem	98.6 rem--goggles required during solar flare event
Marrow	35 rem	10.5 rem

1.2.13 RADIATORS

Radiators are provided as part of the environmental control/life support subsystem. Each radiatior panel assembly is redundant and consists of a radiator system A, radiator system B, and an environmental (thermal and meteoroid) shield assembly. Separate manifolds and interconnects are provided for each system. The two systems provide the necessary redundancy for safety. A number of radiator design concepts were evaluated prior to selecting a configuration. All the concepts evaluated are described under the paragraph Radiator Concept Trades in the Manufacturing Trades section in Appendix A of this report. See Figure 1-25 for a typical radiator section.

Two 92.5-square-foot radiator assemblies are located on core module 1 and are utilized for heat rejection during the station buildup period only. Radiator assemblies of 12-hundred square feet are provided on SM-1, SM-2, SM-3, and SM-4. These radiator assemblies extend the entire length and encompass the full diameter of the cylindrical section of each module. These radiators are utilized for heat rejection during normal station operations.

The core module radiators are independent assemblies, supported but thermally isolated from the modules primary structure. These radiator assemblies may be manufactured from a series of smaller assemblies to aid manufacturing, handling, and transport.

The station module (SM-1, SM-2, SM-3, and SM-4) radiators, like those of the core module, are independent assemblies supported but thermally isolated from the module's primary structure. The radiator consists of 12 primary panel areas. These are divided by manifolds on the upper and lower centerlines, three ring frames, and longerons located between the ring frames at the deck plane. Each of these panels are further divided into panels approximately 3-feet-wide to aid manufacturing, handling, and transport. Figure 1-26 defines a typical station module radiator installation.

The additional radiator area required for the growth station is accommodated by the radiators of SM-5 and SM-6. The radiator areas and installation of these modules is the same as for SM-1, SM-2, SM-3, and SM-4.

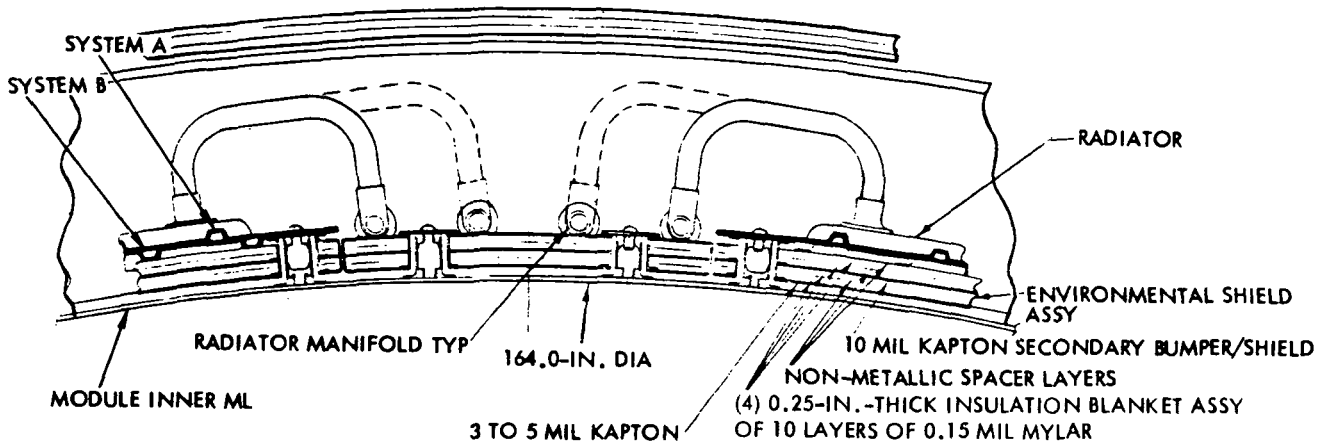


Figure 1-25. Typical Radiator Installation

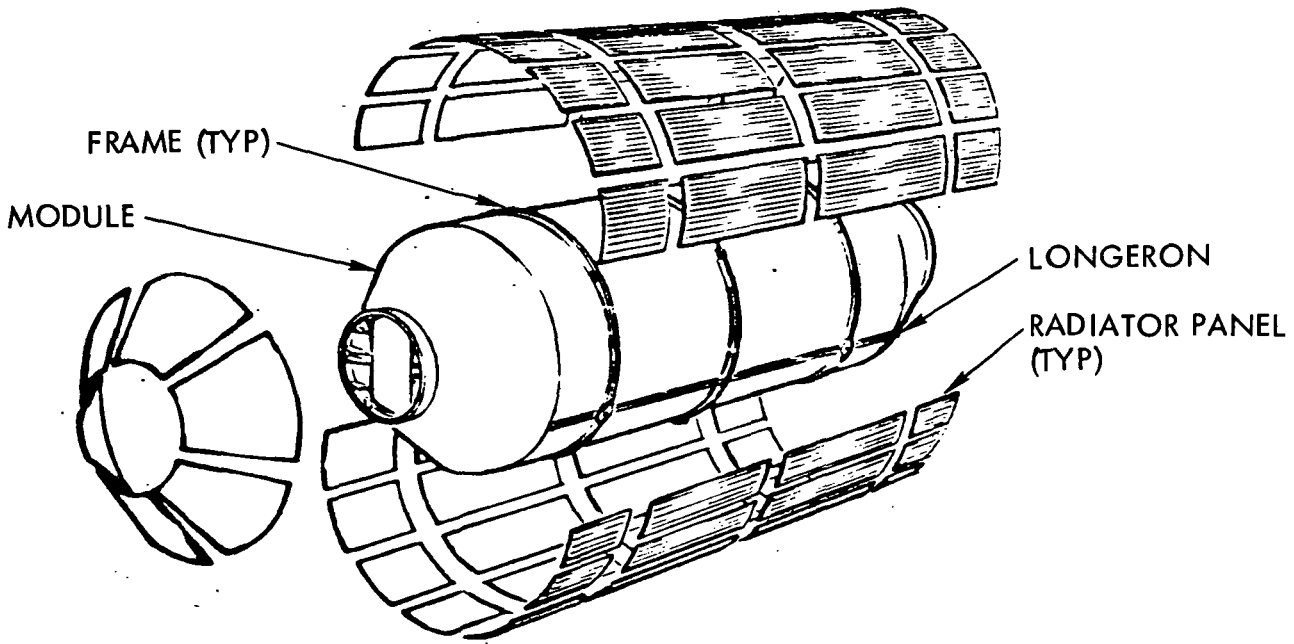


Figure 1-26. Station Module Radiator Installation

1.3 INTERNAL CONFIGURATIONS

The space station interior provides comfortable, efficient, and attractive living and work spaces. The selected functions to be performed in the initial space station, their area allocations and equipment lists, and the station operational equipment and habitability requirements were combined into the four station modules, a core module, and a power module. The functional allocations as defined for the preliminary design are shown in Table 1-6 for station modules and Table 1-7 for special modules.

1.3.1 CONFIGURATION REQUIREMENTS

The rationale for the selection of this allocation is contained in the functional allocation trade study in Appendix A of this volume and is also described in the alternative configuration analysis of Section 2 of this volume. Certain crew and habitability arrangement preferences were defined as follows:

1. Active recreation area should be away from passive recreation area.
2. Private areas (e.g., staterooms) should be away from high traffic/noise areas (e.g., aisles, dining, recreation).
3. Flexports should enter into public areas.
4. Galley and dining adjacent facilities.
5. Personal hygiene should be near staterooms.
6. Control centers should be near staterooms.
7. Dimensional criteria (ceiling height 82-in. main deck general mobility areas).

Other major interior arrangement drivers are listed as follows:

Figure 1-27 schematically illustrates the initial station configuration and the functional allocation arrangement in each of the station modules, the core module, the power module, and the cargo module. A description of the preliminary design arrangement of each module is presented in the detailed description section of this volume.

1. Commonality of installations
2. On-board shirtsleeve maintenance
3. Double occupancy of staterooms for relief and emergency

Table 1-6. Station Module Functional Allocation Requirements

Pressure Volume 1 (V1) — Station Module 1 (SM-1)			
Functional Facility	Location/Qty: Above Deck	Location/Qty: Below Deck	Area (Ft^2)
Commanders stateroom	1		90
Crew stateroom		2	50
Personal hygiene 1	1		54
Data analysis lab	1		95
Control center 1	1		50
Photo processing	1		33
Backup medical/exercise	1		51
Thermal control		1	--
Water management		1	--
EPS electrolysis		1	--
PGA & support		2	

Pressure Volume 2 (V2) — Station Module 2 (SM-2)			
Functional Facility	Location/Qty: Above Deck	Location/Qty: Below Deck	Area (Ft^2)
GPL (mech, elect, optical)	1		232
Experiment ops. (nadir)	1		168
Air revitalization		1	--
Experiment storage		1	--
Backup galley	1		15
Experiment airlock	1		--

Station Module 3 (SM-3)			
Functional Facility	Location/Qty: Above Deck	Location/Qty: Below Deck	Area (Ft^2)
Primary galley	1		85
Dining / Recreation	1		160
GPL (physics)	1		34
GPL (medical/biological)	1		34
Experiment ops. (zenith)	1		100
Experiment airlock	1		--
Air revitalization		1	--
Experiment storage		1	-

Station Module 4 (SM-4)			
Functional Facility	Location/Qty: Above Deck	Location/Qty: Below Deck	Area (Ft^2)
Executive stateroom	1		90
Crew stateroom		2	50
Personal hygiene 2	1		38
Control center 2	1		50
Primary medical/exercise	1		190
Thermal control		1	--
Water management		1	--
EPS electrolysis		1	--
PGA & support		2	--

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North American Rockwell

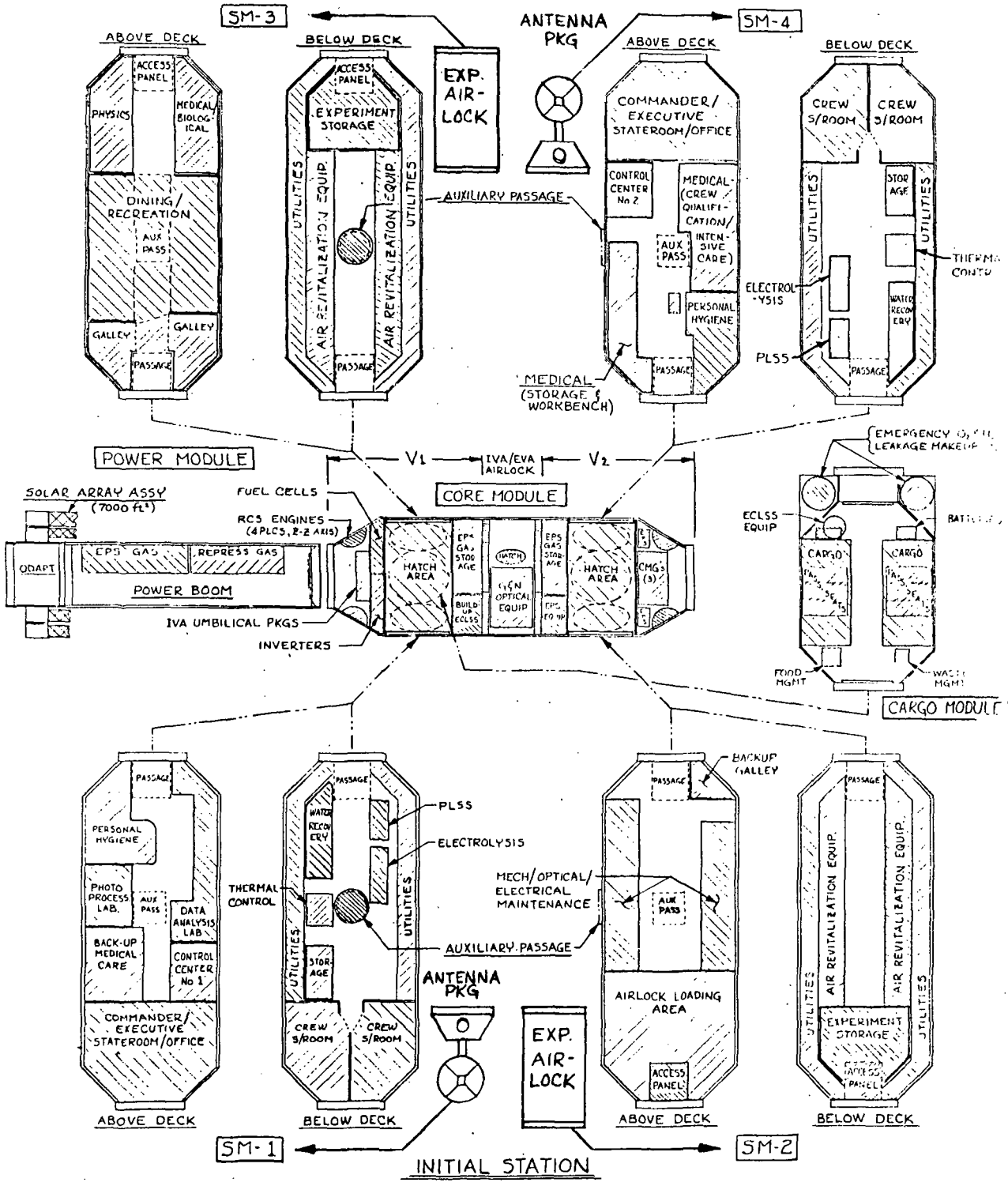


Figure 1-27. Module Functional Allocation Arrangement

4. Private crew staterooms

5. Three crewman staterooms in V_1 and three crewman staterooms in V_2

6. EVA airlock to accommodate two suited crewmen

7. Ports and hatches nominal 5-foot diameter

8. Primary access routes to accommodate 40- by 40- by 50-inch packages

9. Secondary access routes to accommodate 22- by 22- by 50-inch packages

10. Commander's stateroom in same volume as primary control

11. Personnel escape routes - alternate routes not terminating in a common module area

12. Two or more entry-access paths from every compartment

13. High pressure vessels located remotely from living and working quarters

14. Walls, bulkheads readily accessible for inspection and repair in pressurized suit as a goal

Table 1-7. Special Module Functional Allocation Requirements

Core Module			Power Module	
Functional Facility	Area (Ft^2)	Qty	Functional Facility	Qty
EVA/IVA airlock	35	1	EPS gas storage	1
Guidance & control	--	1	Repressurization gas	1
Reaction control	--	1	Solar arrays	1
Information	--	1		

1.3.2 MODULE FLOOR STRUCTURAL ARRANGEMENT

The station module internal structure provides the living and working quarters for the crew, storage, and mounting of equipment components. These structures are riveted, bolted, and bonded to the primary structure and are utilized to support and distribute the weight of the subsystem equipment.

Partitions are used as interior dividing walls to provide private areas and to separate different functional areas.

Two longitudinal floor concepts are developed to accommodate the equipment, and to provide efficient and habitable arrangements. A single-level floor was utilized in developing the arrangements for station modules 2 and 3 while a split-level floor provided the arrangements for station modules 1 and 4. The basic longitudinal floor is located 16 inches below the module centerline, and the split-level floor section is located 4 inches above the module centerline. Figure 1-28 illustrates these floor arrangements.

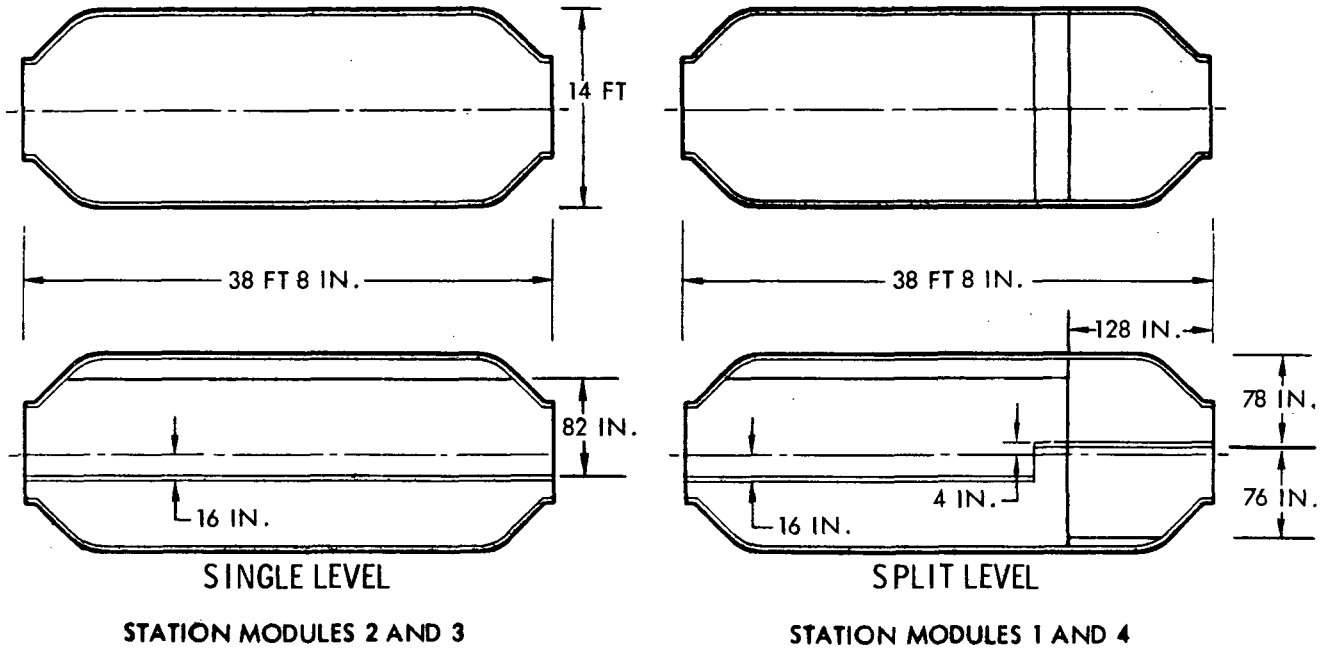


Figure 1-28. Station Modules Floor Arrangement

The floors are designed by the vertical inertia load factor (Nz) defined for the shuttle crash landing case. The single-level floor is bonded honeycomb construction 4 inches deep with 0.030-inch 7075-T6 aluminum face sheets. The split-level floor section is bonded honeycomb construction 2 inches deep with 0.025-inch 7075-T6 aluminum face sheets. The floors are attached to the primary structure allowing, however, for differential deflections in both the longitudinal and transverse directions, as illustrated on Figure 1-29. The primary structure drag longeron acts as the load distribution member since the floor attaching member is bolted directly into the longeron. Figure 1-30 illustrates the basic attaching arrangement. The split-level floor is attached to the structure with a bonded "T" as shown on Figure 1-31. This floor is also isolated from the primary structure deflections as illustrated on Figure 1-29.

The longitudinal floor provides the structure to which all of the subsystem equipment, GPL equipment, crew care, and crew furnishings are attached. Only storage cabinets and brackets for supporting utility runs are attached to the primary structural shell. Figure 1-32 is a typical cross section of a module and illustrates this arrangement. Equipment located both above and

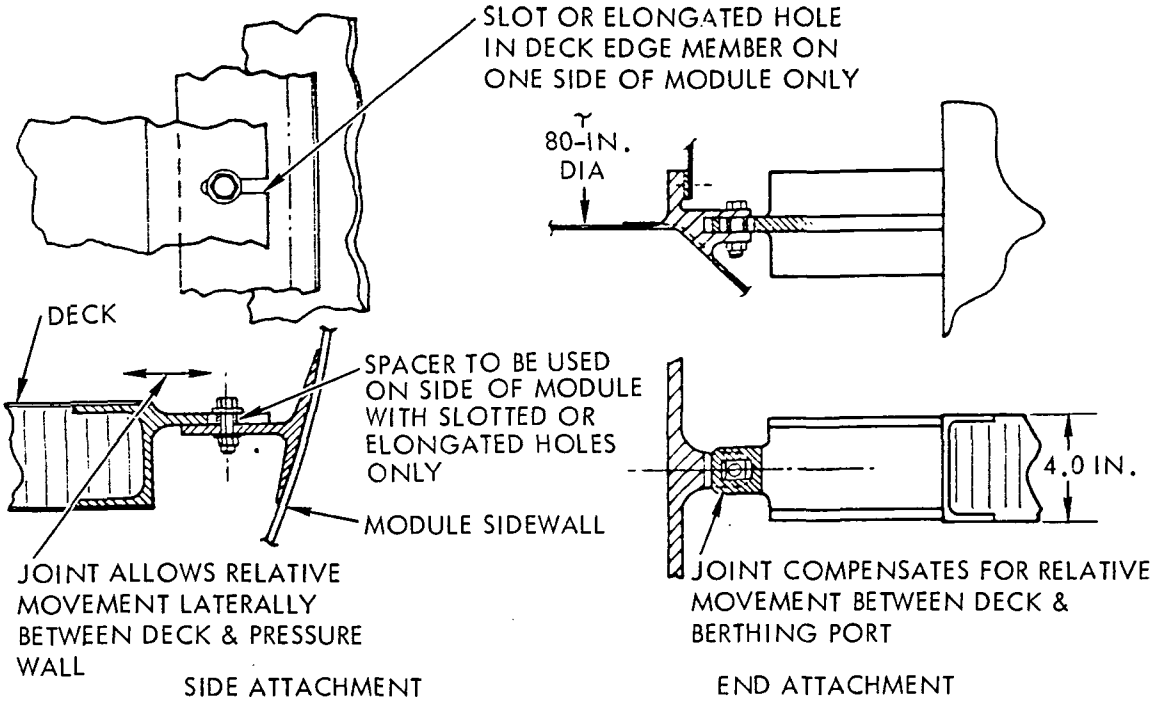


Figure 1-29. Longitudinal Floor Attachment

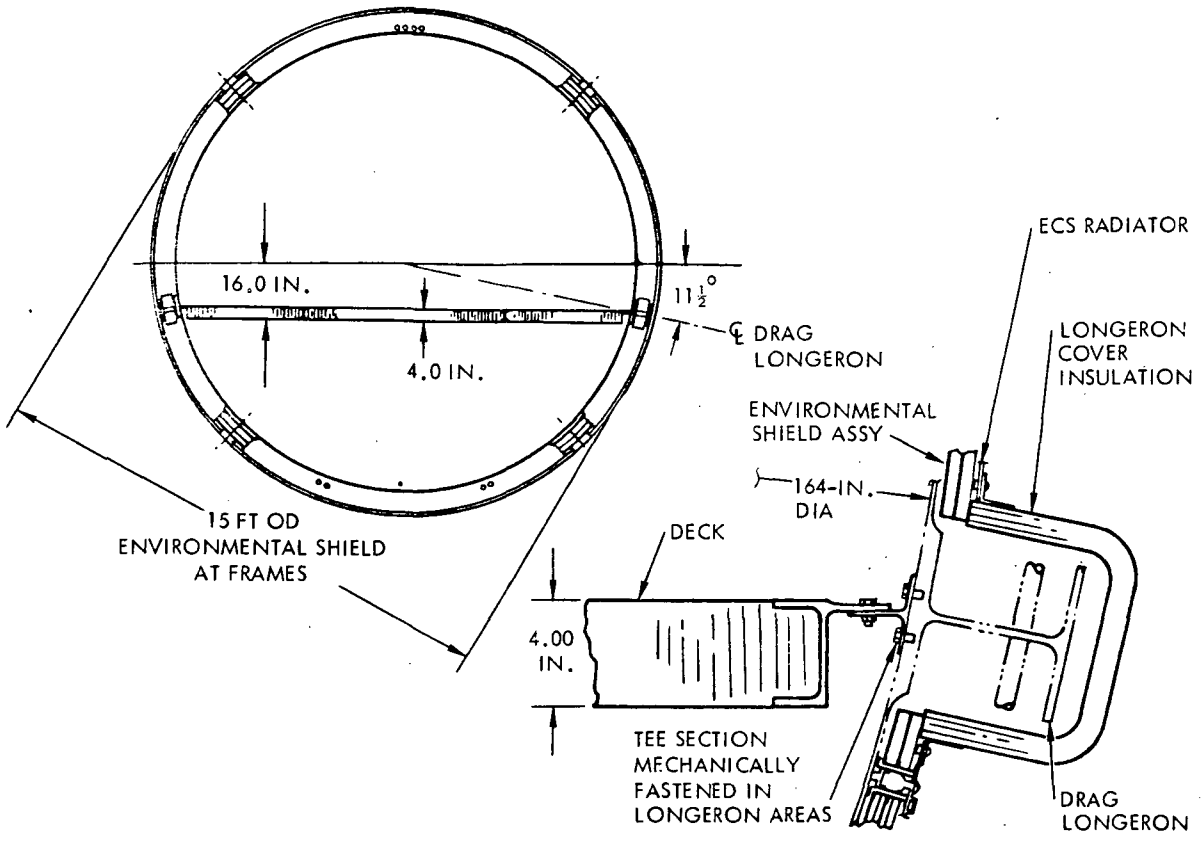


Figure 1-30. Basic Floor Attachment

below the floor utilizes the floor structure for support. This arrangement greatly simplifies the manufacturing installation and design details. The longitudinal orientation also simplifies other ground operations of module assembly, checkout, and shuttle installation (Figure 1-33).

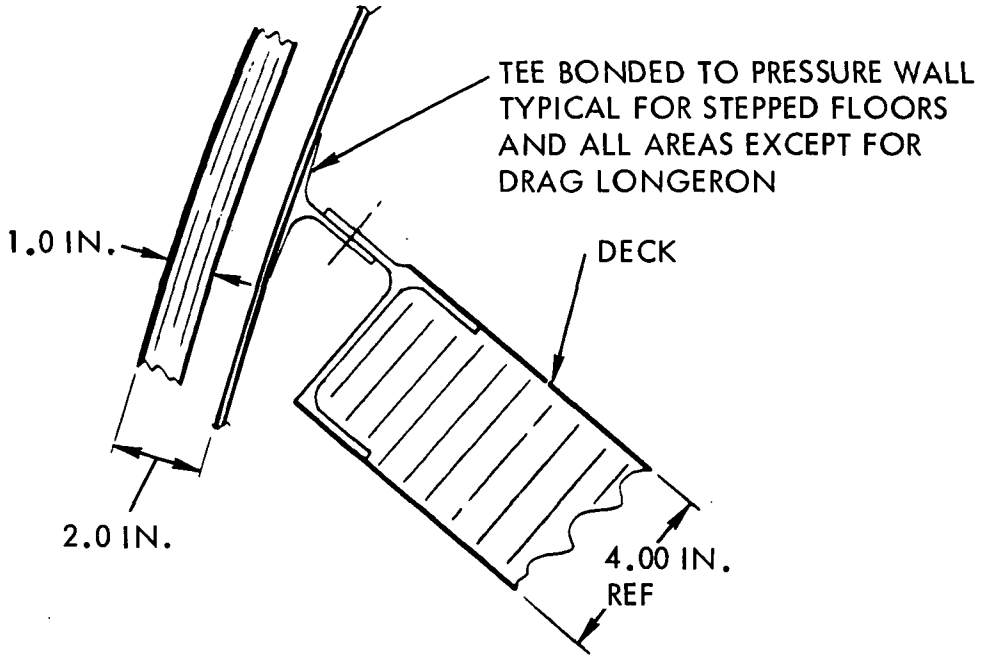


Figure 1-31. Split Level Floor Attachment

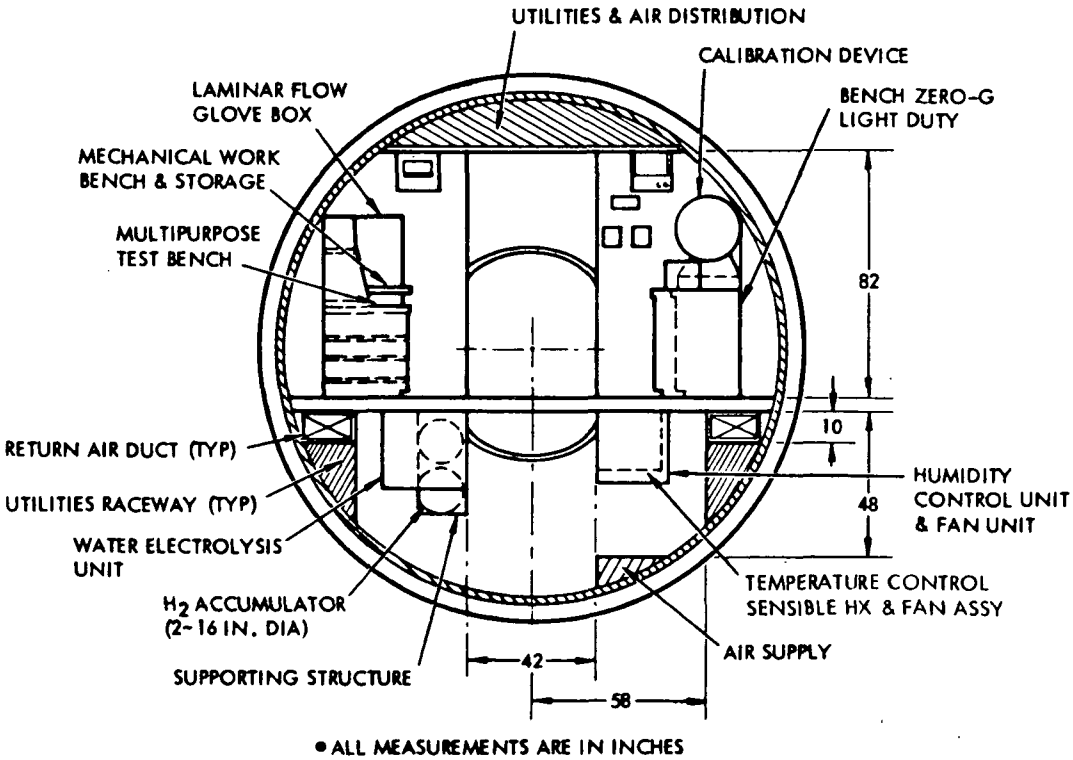


Figure 1-32. Typical Module Equipment Attachment Arrangement

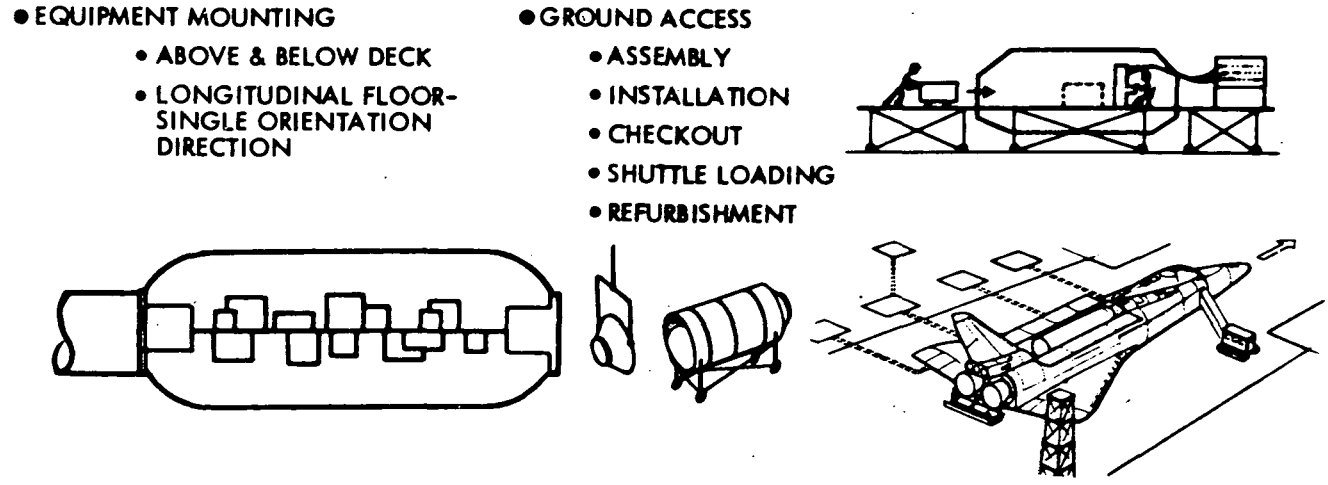


Figure 1-33. Longitudinal Floor Characteristics

1.3.3 UTILITIES DISTRIBUTION

All of the utilities in the station modules--air distribution, electrical power, data buses, fluid and gas lines--interface with the core module through the berthing port. These lines are then distributed to the appropriate equipment through the utility raceways. A 10-inch-deep ring is provided inside the module at the berthing ring to distribute the lines to the false ceiling area and to the raceways below the floor. Figure 1-34 illustrates the utilities raceways routing in a station module. The false ceiling provides a plenum chamber from which the air is disbursed into the upper deck area. Utility lines are also distributed through this area which service the equipment on the upper deck. Air distribution to the lower deck area is provided by a duct located below the subsystem equipment adjacent to the lower deck corridor. The air return system for both the upper and lower decks is routed through ducts under the floor within the utilities raceway area.

The utility raceways under the floor are located on each side of the module behind the subsystem equipment. This equipment is serviced from these raceways.

The location of the raceways in the false ceiling and under the floor provides the shortest line lengths to the equipment and also provides separation for redundancy. Access to the lines is available in both the lower deck runs and the upper deck false ceiling area. Clearance between the subsystem equipment is provided for maintenance of the equipment and also provides access to the utility runs to the equipment as well as to the total raceway.

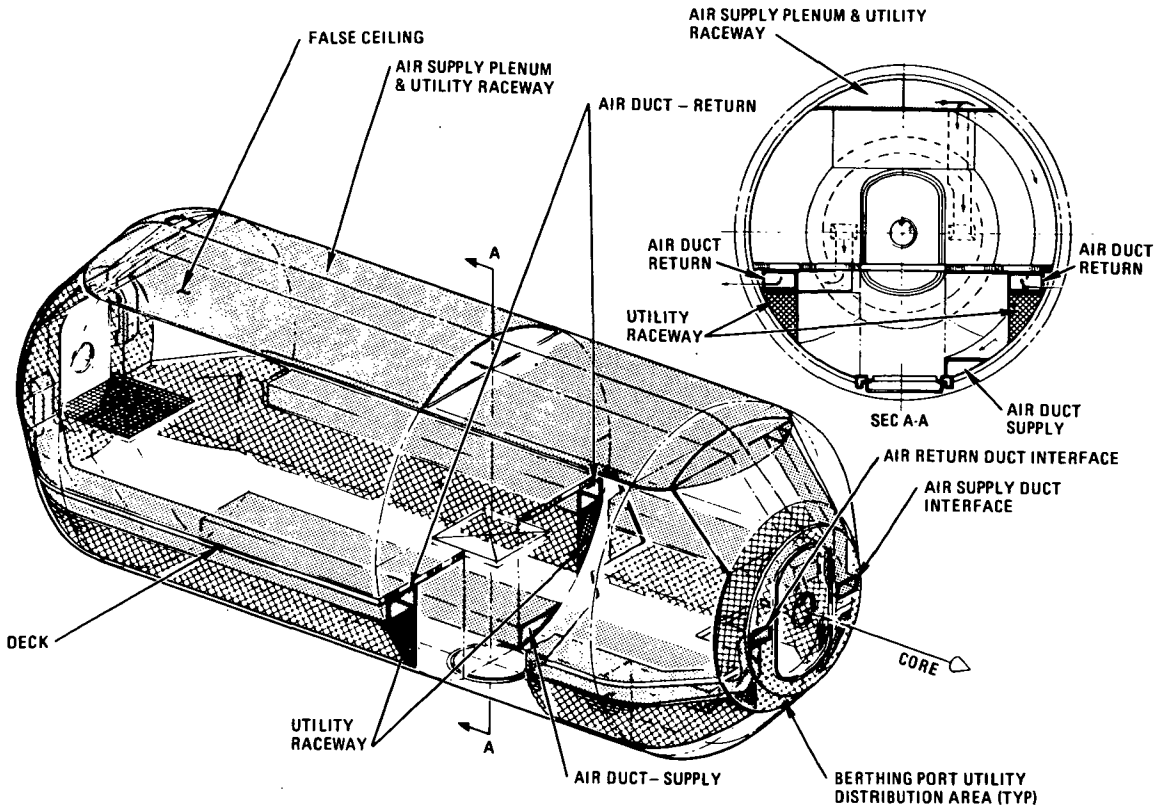


Figure 1-34. Utilities Distribution Routing

Two separated utility raceways are provided in the core module. The utilities from the berthing port interface are routed to the two major raceways via a 10-inch-deep ring around the berthing ports. The air distribution system consists of four ducts running the length of the module. The air supply and return ducting requires 15-inch-diameter ducts. The humidity control ducting system also utilizes 15-inch-diameter ducting within the core module but reduces to 9-inch diameter across the module interfaces. Figure 1-35 shows a schematic diagram of the air circulation ducting system. Figure 1-36 illustrates the utility raceway arrangement within the core module. These raceways provide the service to the subsystem equipment that is mounted on the transverse stiffening and equipment mounting bulkheads as well as providing the utilities distribution between modules attached to the core module.

The power module has two utilities raceways along the sides of the power boom with an area between the storage tanks allocated for the plumbing lines connecting these tanks. A single air distribution duct provides the thermal control for this module. Figure 1-37 illustrates the utilities distribution arrangement in the power module.

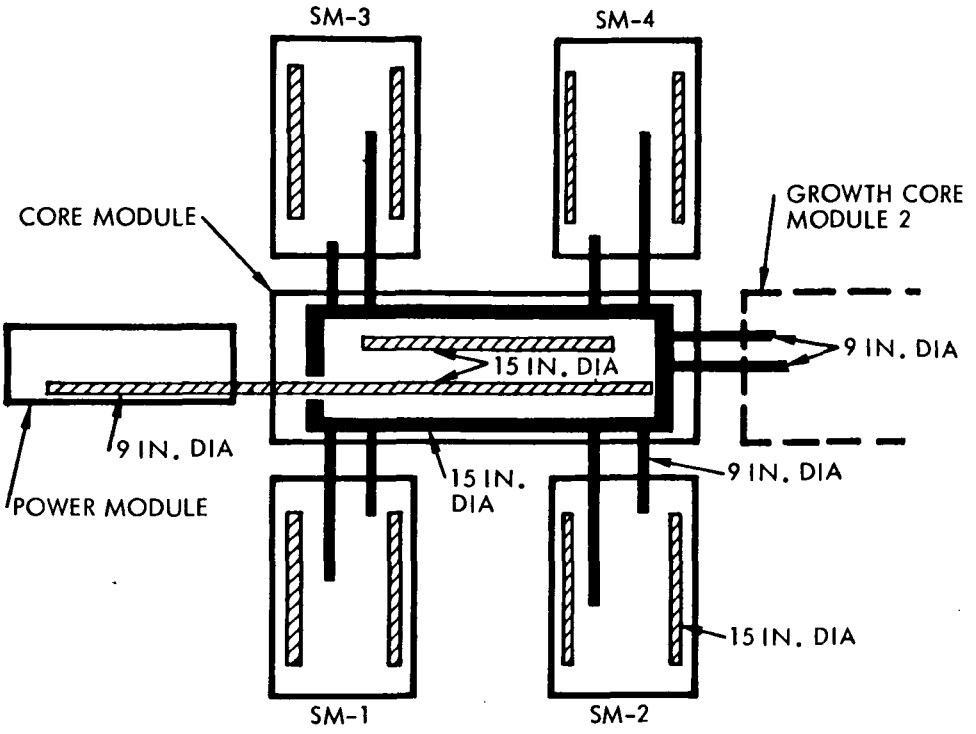


Figure 1-35. Air Circulation Ducting

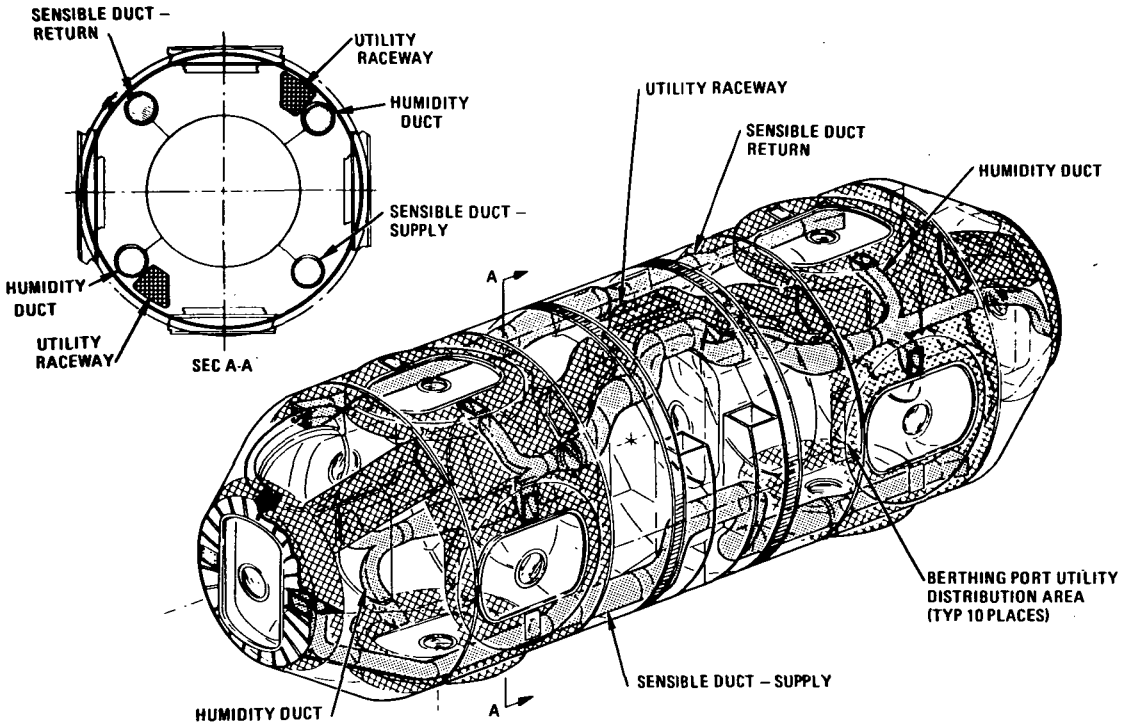


Figure 1-36. Core Module Utilities Distribution Arrangement

1.3.4 MAINTENANCE

The subsystem equipment, GPL equipment, all mechanisms, etc., are designed for shirtsleeve maintenance on-board the space station. The subsystem equipment in the lower deck area of the station modules is installed with three faces of the equipment accessible for maintenance and repair. All electronic equipment has provisions for maintenance from both the front and rear sides of the equipment and to the utilities servicing the equipment. A 42-inch-wide corridor in the lower deck area of the station modules provides the capability to remove and replace a complete equipment unit. The 42-inch-wide clearance between partitions and equipment in the upper deck areas also permits the replacement of any of the components located there. The 42-inch-wide passageway also exists through the core module. The power boom, however, does not have a 42-inch-wide passage. There is adequate clear area, however, to remove and replace the largest tank (34-inch diameter) and to also allow a crewman in a pressure suit to traverse the module.

The RCS engines located on the core module are provided with shirtsleeve access by rotating the engine into a pressure-tight dome. The engine-mounting structure also provides a pressure-tight seal when the engines are retracted. Removal of the pressure dome provides access to the engines which have been rotated into the habitable area of the core module. Figure 1-38 illustrates this arrangement.

Running lights, acquisition lights, and communication antenna that are used only during buildup operations are not maintainable. However, these items that are required for the initial station operations do have the capability for shirtsleeve maintenance. Both the running lights and acquisition lights have their lenses pressure-sealed to the primary structure.

The bulb units are exposed to the habitable atmosphere and can, therefore, be replaced within the module. Figure 1-39 illustrates a typical light installation. The S-band antenna in the antenna package has a nonmetallic dome pressure-sealed to the structure which allows the antenna to be serviced from within the antenna package. The antenna package is normally unpressurized, but has the capability to be pressurized for maintenance purposes. Figure 1-40 illustrates the antenna installation arrangement.

The mechanisms associated with the berthing port (latches), the solar array turret (motors and bearings), and the K-band antenna (motors and bearings) are all located with a pressurizable area and, consequently, can be maintained in a shirtsleeve environment.

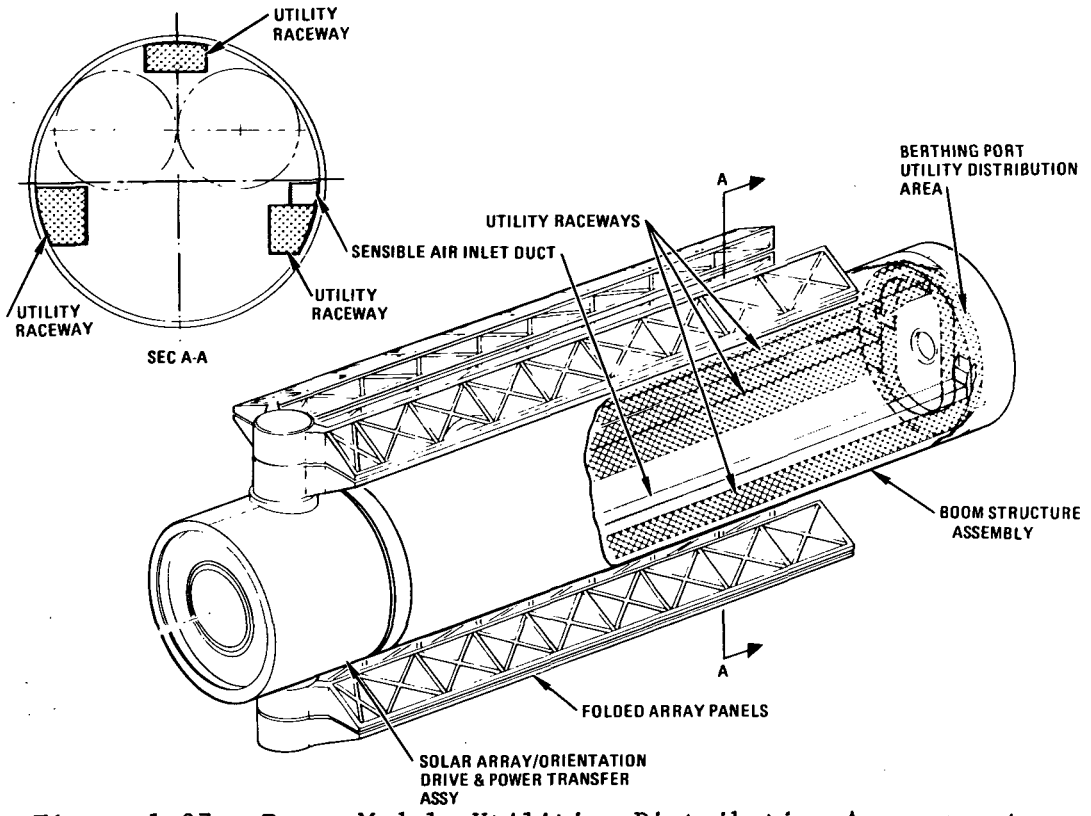


Figure 1-37. Power Module Utilities Distribution Arrangement

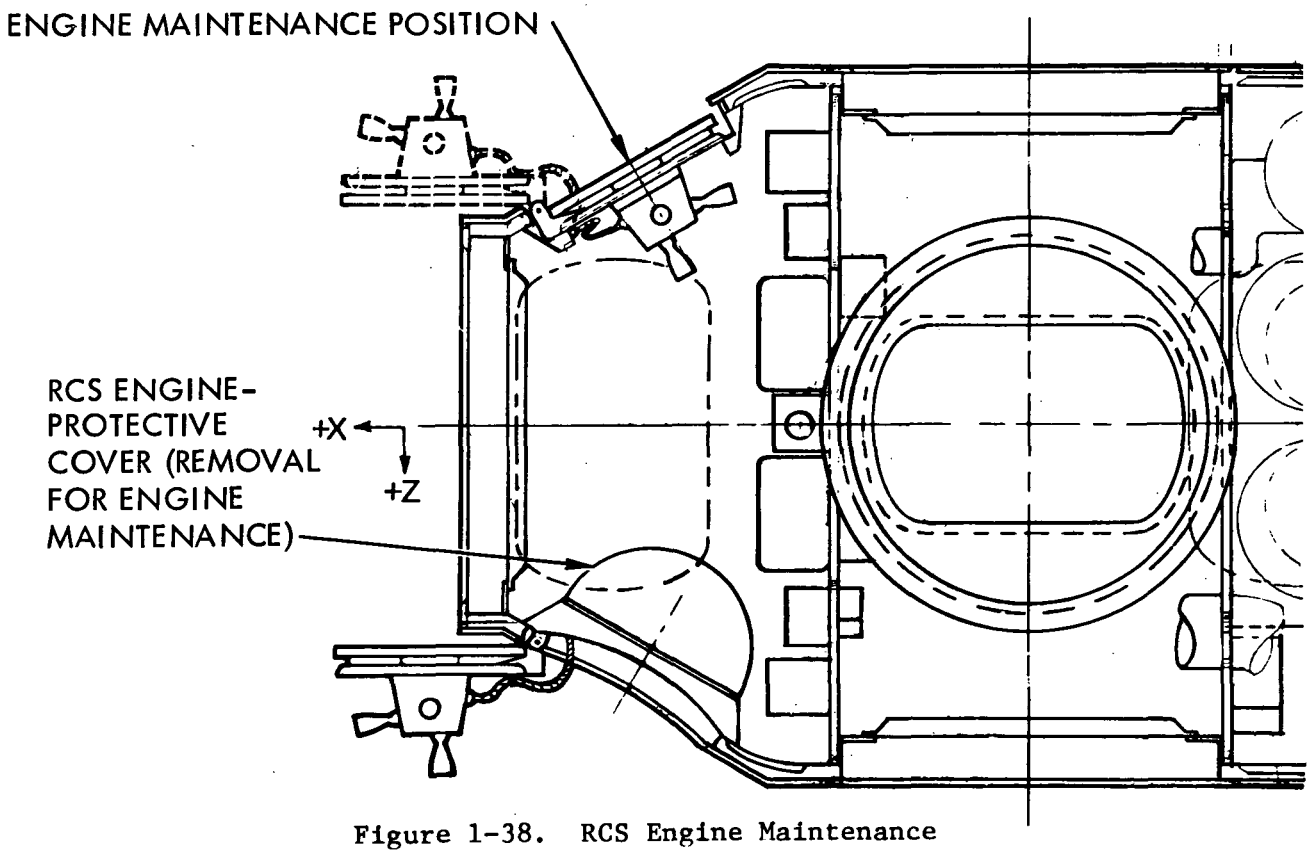


Figure 1-38. RCS Engine Maintenance

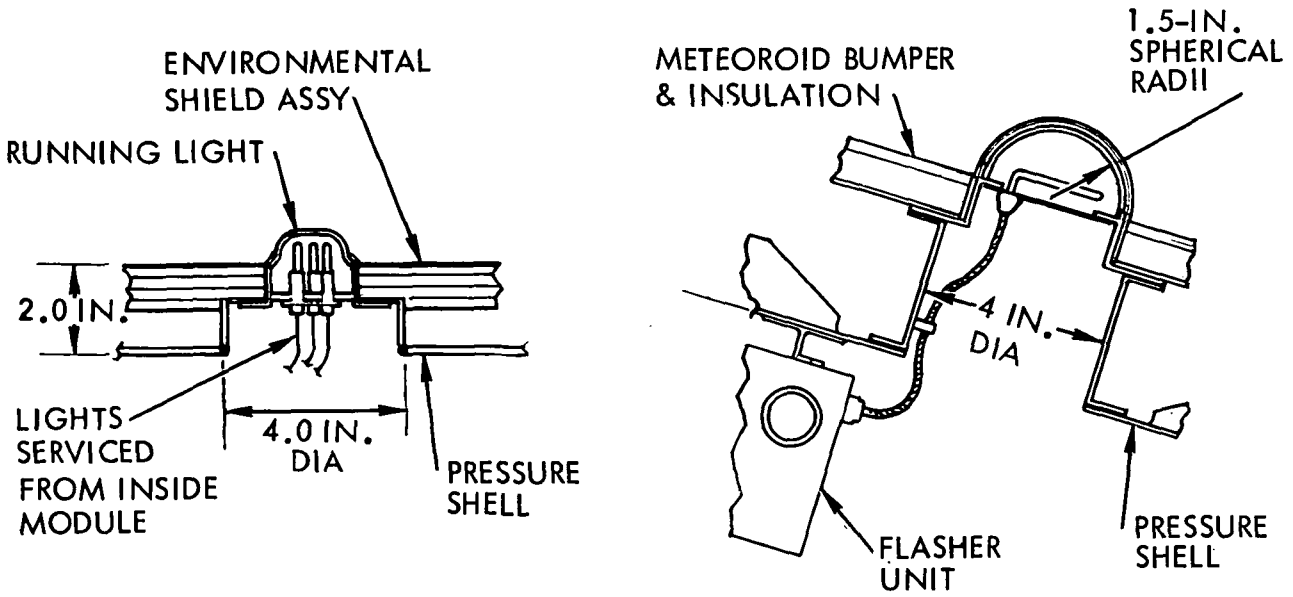


Figure 1-39. Typical Exterior Light Installations

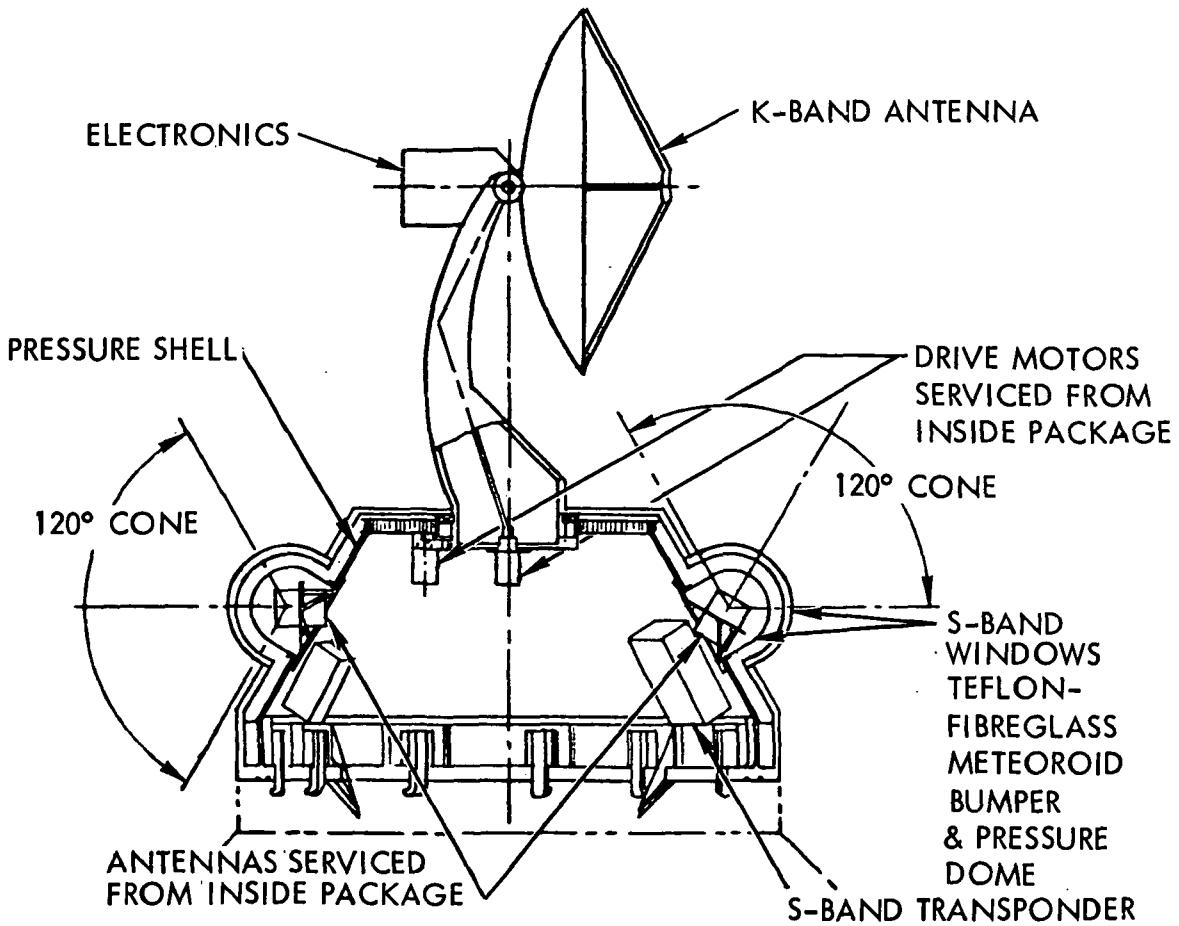


Figure 1-40. Antenna Package Installation

1.4 GROWTH STATION CONFIGURATION

The initial station configuration has the capability to increase its facilities to accommodate a 12-man crew and to provide facilities that are equivalent to the 33-foot diameter station A configuration. This configuration will be assembled five to six years after the initial station has been operable and will extend the space station program to the full 10-year life.

1.4.1 GROWTH REQUIREMENTS

The growth station retains the dual habitable volume concept that was established for the initial station. Consequently, the crew quarters and facilities such as the personal hygiene facility must be placed in each volume. Additional air revitalization facilities to accommodate the full crew in either volume must also be distributed between Volume 1 and Volume 2. Additional dining facilities to accommodate 12 crewmen must be provided.

In addition to the increased crew facilities, additional power is required which is accommodated with the replacement of the 7000-square foot solar array with a 10,000-square foot solar array assembly. An increase in RAM accommodations from two to three is also required as well as additional GPL area. Increased control capacity for the additional experiment facilities is also required.

1.4.2 GROWTH ACCOMMODATIONS

Station modules 5 and 6 are added to core module 1 on the Y-axis ports. These two modules provide the additional crew accommodations, split between the Volume 1 and Volume 2. An auxiliary passage is also provided between the modules. Figure 1-41 illustrates the distribution of the facilities within the modules.

The existing galley facility, however, will accommodate the additional crew. An increase in the frequency of frozen food delivery, however, must be made since no additional freezer capacity is being provided. The dining facility area is sufficient also to accommodate the 12 crewmen. The dining tables, however, must be increased in size to provide seating for 12 crewmen. Figure 1-42 indicates the dining area arrangement for the growth station.

A short (20-foot) core module, core module 2, is added to provide the additional ports to accommodate the RAM requirements. The addition of core module 2 to the station configuration also requires that RCS control be added to the configuration. This is accomplished by adding two RCS assemblies to the end of core module 2 and deactivating the units on the -X end of core module 1. Additional EPS equipment is also required to be compatible with the increased solar array. A description of station modules 5 and 6 of core module 2 is found in the detailed description section of this volume.

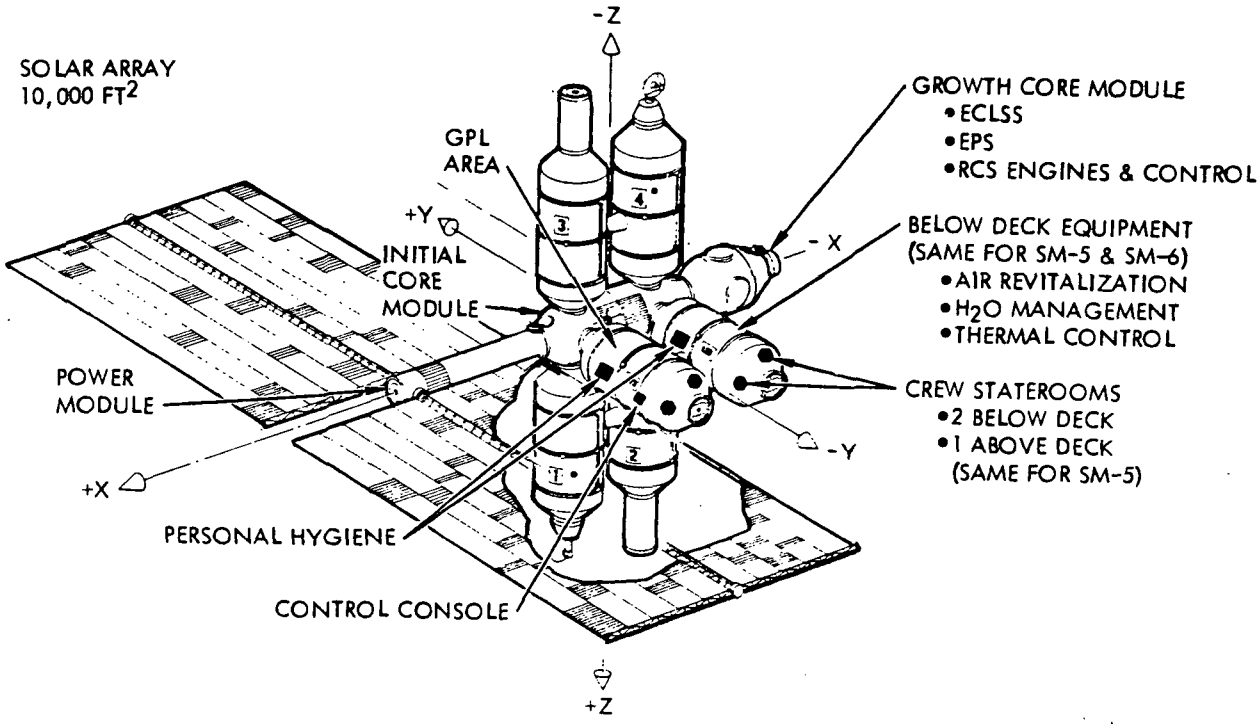


Figure 1-41. Growth Station Functional Allocations

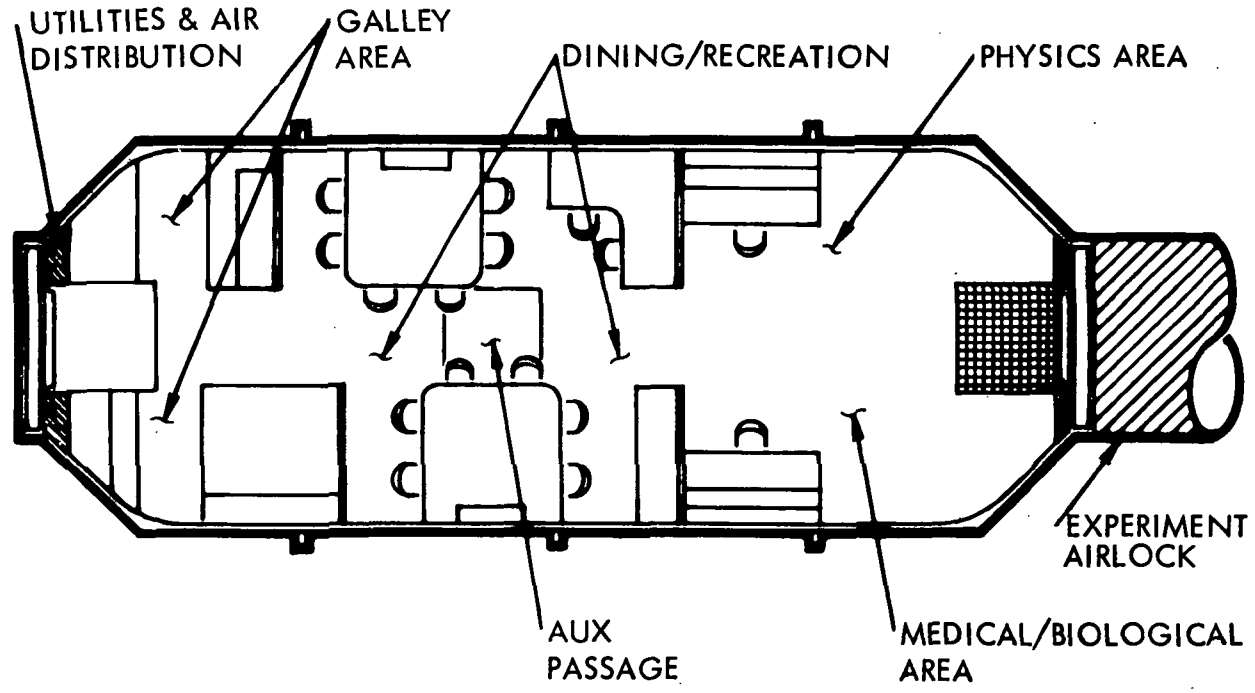


Figure 1-42. Station Module 3 Growth Galley and Dining Arrangement

The growth solar array assembly is attached to the initial station power boom. A short adapter section is added to the orientation drive and power transfer turret to accommodate the increased size of the solar array panels. The operational procedure required to replace these arrays is described with the growth solar array detailed description.

1.4.3 STRUCTURAL ARRANGEMENT

Station modules 5 and 6 are classified as common modules and core module 2 and the solar array assembly as special modules. Table 1-8 lists these modules. The structural arrangement of station modules 5 and 6 is identical to that of station modules 1 and 4. These growth modules utilize the split level floor arrangement that provides identical crew quarters as provided in the initial station.

Table 1-8. Module Classification

Growth Station	
Common Modules	Special Modules
Station modules SM-5 SM-6	Core module 2 Power module Power boom (initial station) Solar array assembly and growth

The core module structural arrangement is identical to core module 1 utilizing the skin and stringer concept with four radial berthing ports and two berthing port stiffening and equipment mounting bulkheads.

The solar array assembly adapter is fixed to the orientation drive and power transfer turret and, consequently, is not a part of the station structure.

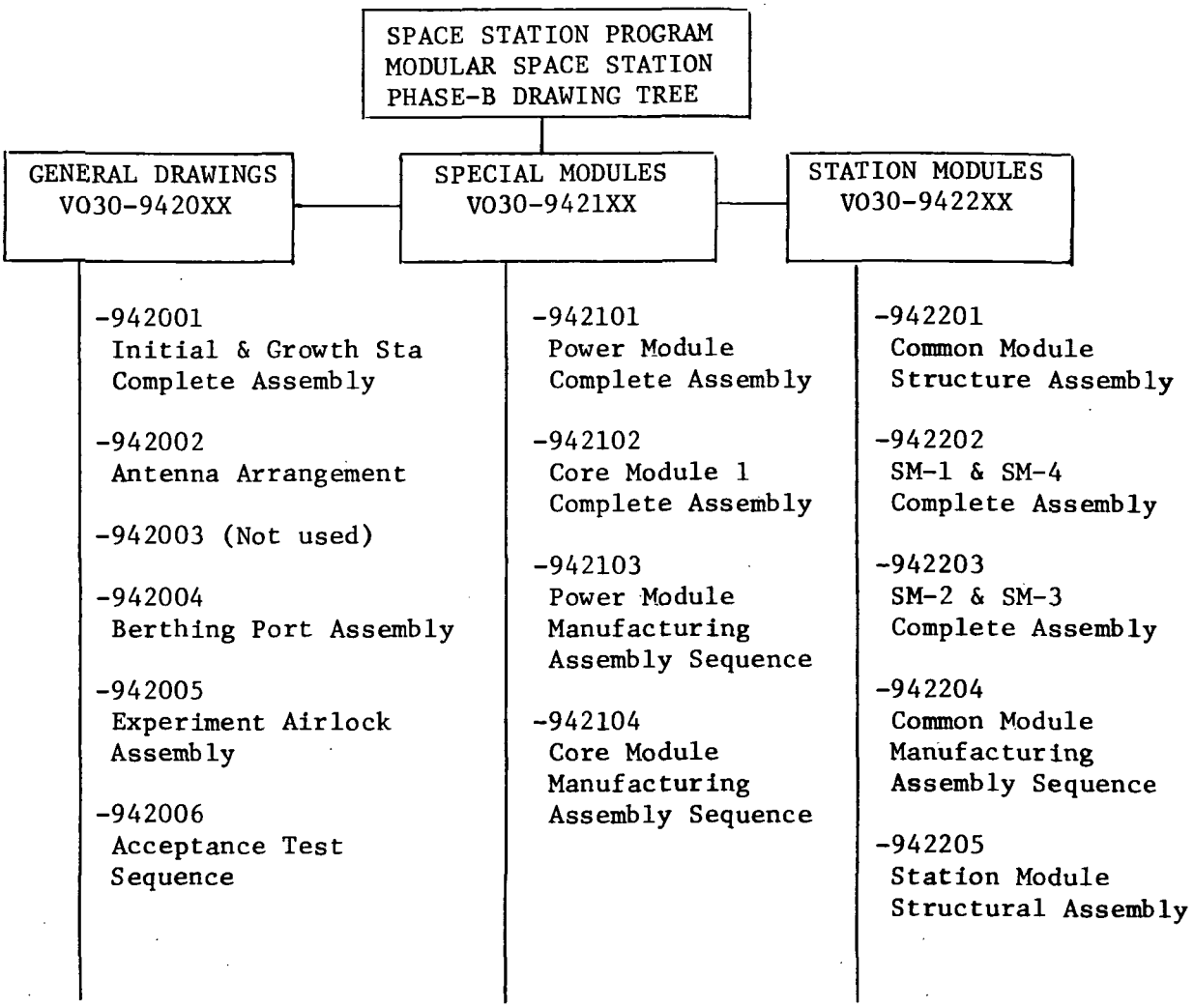
The utilities distribution arrangement, as defined in the station modules and core module of the initial station configuration, is also utilized in the growth station modules. The maintenance features are also identical for the subsystem equipment located below deck and for running light maintenance.

No significant design complexities were encountered in adapting the initial station configuration to the growth station configuration.

1.5 PRELIMINARY DESIGN DESCRIPTION OF MODULES

This section is devoted to a detailed description of each of the modules, the antenna and airlock packages, and the berthing port design. Preliminary design drawings of each of the units discussed will be found in NR report, SD71-216 Modular Space Station Drawings. The drawing tree of the preliminary design effort is shown in Table 1-9. This list includes four manufacturing assembly sequence drawings as well as the design drawings.

Table 1-9. Preliminary Design Drawing Tree



1.5.1 CORE MODULE 1

The core module of the modular space station is the first module inserted into orbit and is the nucleus of the space station assembly. This module provides the primary intravehicular passageway between station modules for crew and equipment and also accommodates the guidance and control subsystem, the electrical power subsystem, and the reaction control subsystem. Drawing V030-942102 defines the core module complete assembly illustrated in Figures 1-43 and 1-44.

Design Requirements

The core module is sized to be compatible with the shuttle cargo bay envelope, weight limitations, and attachment configuration. The core module is divided into two isolatable pressure volumes separated by an IVA/EVA airlock. Critical subsystems are divided between the two separate pressure volumes. These and other key design requirements are presented in Table 1-10.

Design Description

The external diameter of the core module is 12 feet 8 inches with a clear interior diameter of 12 feet. The core module external configuration is contained within the 15-foot-maximum module diameter as illustrated in Figure 1-45. The berthing port interface rings protrude to the maximum diameter envelope. The 40-foot length of the core module is determined by the 5-foot-clearance spacing between station modules. The 5-foot clearance provides the capability for direct docking. The core module provides an IVA/EVA airlock between the two separate pressurizable volumes (V_1 and V_2). All of the subsystem equipment is mounted on the transverse stiffening bulkheads except for the G&C sensors which require external viewing. This arrangement simplifies system installation and design. All of the ports in the core module are passive. The entire assembly is enclosed by the environmental shield. One hundred and eighty-five square feet of radiator is provided for the station buildup operations active thermal control. Shuttle and manipulator pickup points and running and acquisition lights are provided. Environmental covers over the Y-plane berthing ports only are provided. S-band and VHF antennas are provided for the station buildup operations.

The core module assembly consists of the various elements of the structure subsystem and provides for the installation of the various components of the electrical power subsystem, guidance and control subsystem, reaction control subsystem, information subsystem, and the environmental control/life support subsystem.

Structural Arrangement

The core module is of semimonocoque construction. The sidewalls are integral skin stringer machined from 2219-T87 aluminum on a 144-inch diameter. The basic skin thickness (0.040) is designed by the ultimate pressure condition. The preferred selection from the family of aluminum alloys is 2219-T87 for application to the pressure vessel wall because of good strength/weight ratio , good weldability, and excellent fracture toughness. The stringer

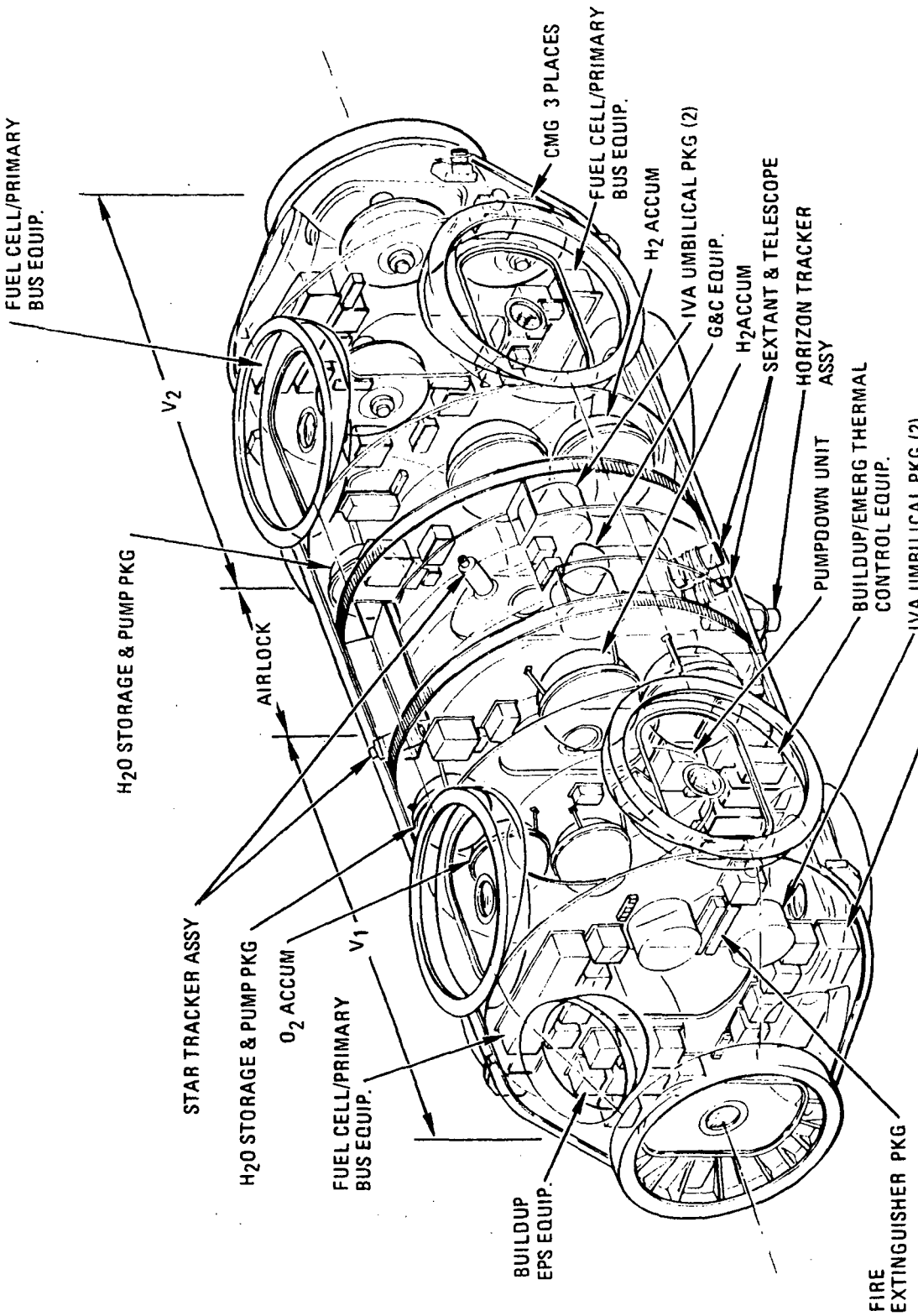


Figure 1-43. Core Module Interior Arrangement

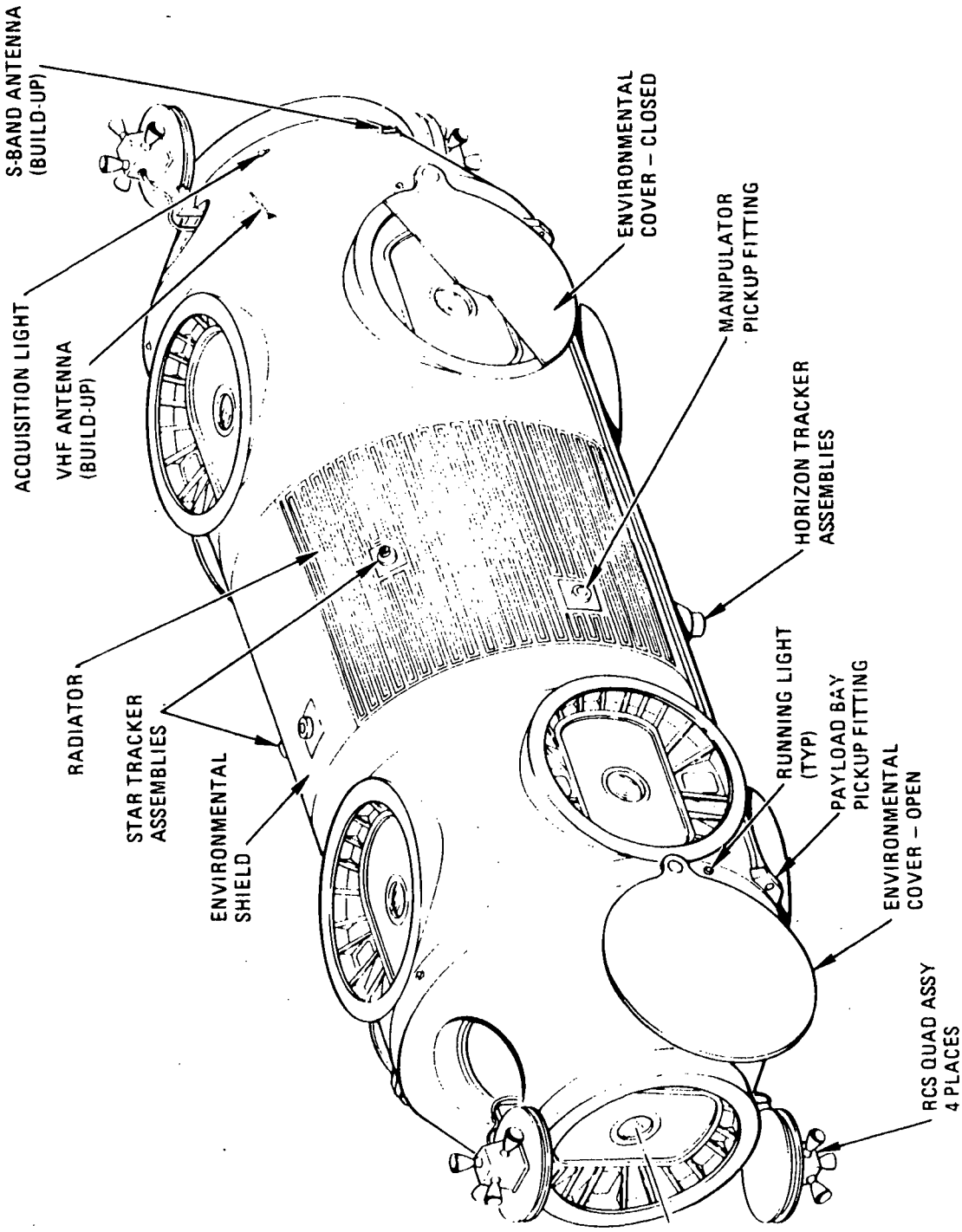


Figure 1-44. Core Module Exterior Arrangement

Table 1-10. Core Module Design Requirements

Item	Requirement
Size	14 foot diameter by 58 feet long with local protrusions to 15 foot diameter by 60 feet long
Weight	20,000 lb target 25,000 lb maximum launch
Berthing	10 passive ports 5-foot clearance between modules
Corridors	Accommodate 40 by 40 by 50-inch package size
Accessibility	Access to all pressure walls - as a goal. Three sides of all subsystem equipment accessible for maintenance. Utility runs accessible
Safety	Two separate pressurizable volumes (V_1 and V_2). Critical functions duplicated in V_1 and V_2. EVA/IVA airlock sized to accommodate two suited crewmen with EVA equipment.
Structural capability	Shuttle loads - crash landing: N_x -8.0, N_y ±1.5, N_z -4.5. Berthing/docking loads - 0.05 fps axial velocity. Pressure loads - 14.7 ± 0.2 psi, 2.0 factor of safety.
Environmental protection	0.90 probability of no meteoroid penetration
Subsystem installation	
EPS and RCS	Split between V_1 and V_2 - common installations
G&C sensor locations	Locate for optimum viewing angles
Inertial reference system	Locate for short optical alignment paths to RAM berthing ports
CMG's	Locate for best stabilization and control of the attached RAM's

Table 1-10. Core Module Design Requirements (Cont)

Item	Requirement
ECS	For equipment details, refer to DRL 66, Preliminary Performance Specification
Gaseous storage	Pumpdown
Atmospheric control	Humidity ducting, sensible ducting, humidity duct fan, ventilation fans, sensible HX and fan assembly, explosion detector
Thermal control	RAM HX's, water pump package (emergency and buildup), freon pump package (emergency and buildup), freon/H_2O intercooler (emergency/ buildup), radiator 185 ft^2 (buildup)
Special life support	Fire extinguisher package and detector, IVA connects
EPS	
Energy storage	Batteries, fuel cells, electrolysis units, water storage tank and pump assemblies, hydrogen tanks, oxygen tanks
Power conditioning	Inverters, regulators, sequencers
Distribution, control and wiring	Primary buses, secondary buses, contactor, controls
G&C	
Inertial reference	Strapdown IMU, IMU preprocessor
Optical reference	Horizon tracker optics and electronics, sextant/ telescope, star tracker optics and electronics, preprocessor
RCS electronics	Jet driver electronics, preprocessor
Momentum exchange	Control moment gyros, preprocessor
RCS	
Engines	Quad assemblies (4)
ISS	
Data processing	Buildup data processor
Command/control and monitoring	Emergency G&C control, local monitor alarm

Table 1-10. Core Module Design Requirements (Cont)

Item	Requirement
ISS (continued)	
External communications	S-band antennas and transponders, VHF antennas and transponders, buildup communications
Internal communications	Audio video units, hardwire intercom
Crew and Habitability	
General/emergency equipment	Tool set, portable lights, radiation detection, emergency O_2 masks, IVA umbilicals, mobility aids and restraints, first aid kit

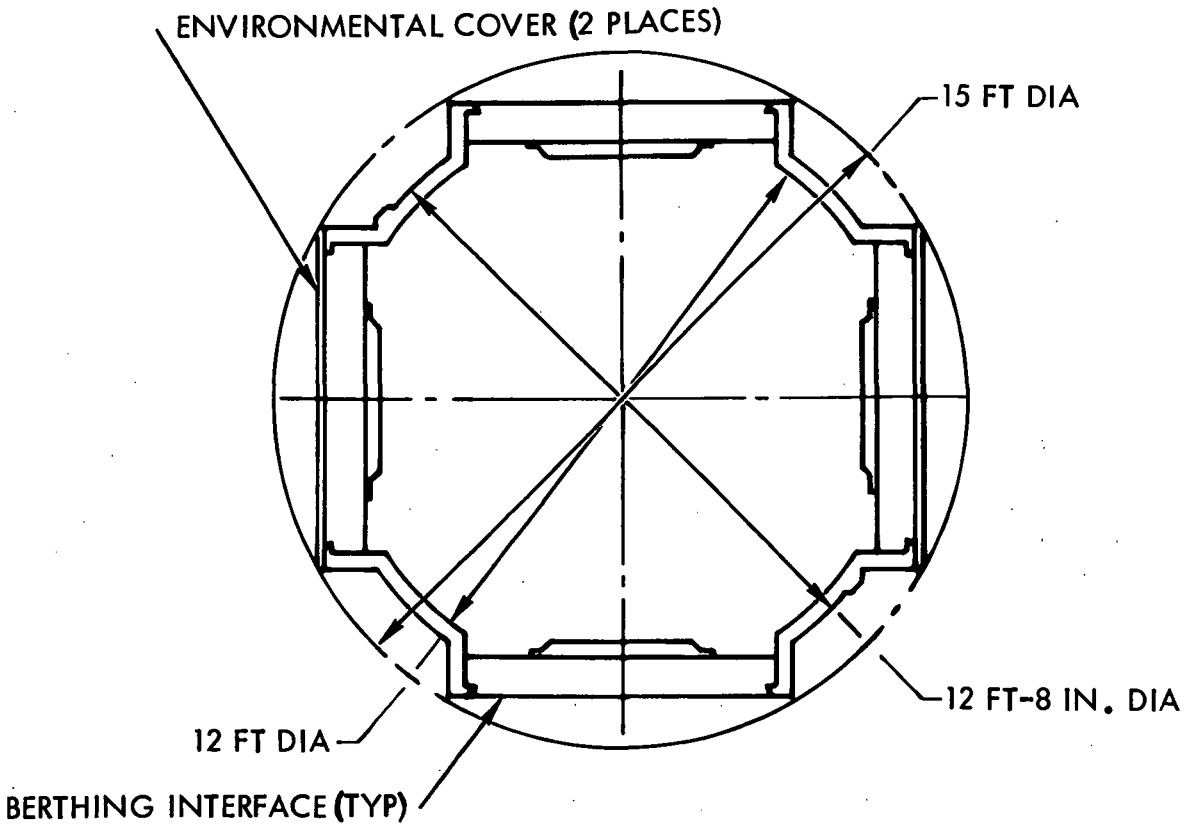


Figure 1-45. External Diameter Configuration

spacing is approximately 8 inches. The end bulkhead blends into the cylindrical sidewall with a Cassinian curve and the berthing port ring with a cone. The Cassinian curve minimizes discontinuity stresses and eliminates the need for a pressure kick frame. The bulkhead is also of skin-stringer construction. The skin is 0.040-inch 2219-T87 aluminum with bonded 7075-T6 aluminum stringers on the outside. Bonded stringers are used in the bulkhead area to simplify the double curvature forming of the bulkhead skin. The bulkheads are formed in six gore segments, then welded together with the berthing ring to form the total bulkhead. The cylindrical sidewall is formed into quarter panels, and then welded longitudinal to form sections of the cylinder. These sections are then welded circumferentially to form the cylindrical section. The environmental shield is attached to the outstanding flanges of the stringers.

The longerons (2219-T87 aluminum, one each side) are welded into the sidewall pressure shell and redistribute the shuttle attachment loads for crash landing. The core module provides the EVA/IVA airlock and separates the two pressurizable volumes. The pressure bulkhead in the airlock must contain the ultimate pressure in both directions. This is a 10-inch-thick flat bulkhead with one facesheet constructed from 2219-T87 aluminum so that it can be welded into the sidewall skin; the other facesheet is 7075-T6 with aluminum sandwich. The facesheets are tapered to a maximum thickness of 0.12 inch.

External Arrangement

The outer shell of the core module consists of two 92.5-square-feet radiators and an environmental shield.

The radiators are provided as part of the environmental control/life support subsystem and are utilized during the station buildup operations. The radiators are independent assemblies supported but thermally isolated from the module primary structure.

The environmental shield covers the entire exterior of the module except for the areas utilized by the radiators. The shield is penetrated in numerous places by the guidance and control subsystem optics, the S-band and VHF antennas, running and acquisition lights, manipulator pickup, and shuttle pick-up fittings. The environmental shield provides both thermal and meteoroid protection. An external fiberglass shell is provided as a meteoroid bumper and also provides the supporting structure for the thermal insulation. The environmental shield is structurally and thermally independent but supported by the module primary structure. Individual sections are replaceable, if required, as a ground operation.

Environmental covers are provided over the +Y and -Y plane berthing ports only. These ports are utilized for RAM and cargo module berthing. The covers provide the thermal control for these interfaces. Since the core module is unmanned during the first 5-month buildup period, it is not considered mandatory to provide the thermal protection provided by covers at the ports dedicated to the station modules, power module, and shuttle adapter. The Y-plane covers, which provide both thermal and micrometeoroid protection, are a swing-away design. A single actuator, which first lifts and then rotates

the cover in one direction, is utilized at all four cover locations. All the covers rotate outboard in order to eliminate interference with the radiators and G&C optics. The direction of rotation chosen and shown by Drawing V030-942102 (refer to SD 71-216, Modular Space Station Drawings) is required to clear the VHF antenna installations.

Exterior lights are located on the core module to aid the rendezvousing shuttle in acquiring a visual fix on the module and to define the module orientation. Space station exterior lighting will be activated 90 minutes prior to arrival of the shuttle for berthing. The lights will be illuminated whenever the shuttle is stationkeeping, which could be as long as 5 days. Exterior lighting shall be provided for approximately 90 minutes after shuttle/station separation and during preparation for shuttle deorbit.

Acquisition lights are located on the +X and -X ends of the core module. These are high-intensity flashing lights to aid the crew of the rendezvousing shuttle in visually acquiring the space station within 2000 feet. The installation of these lights is such as to permit servicing by a shirtsleeved crewman from within the core module. With the addition of the power module, the core module +X acquisition light is deactivated and is replaced by two acquisition lights located on the orientation drive and power transfer section of the power module.

Running lights are installed adjacent to each berthing port. These lights define the position/attitude of the core module when viewed from any angle by the shuttle crew. To define the attitude orientation, the lights are colored in the following manner: +Y ports (2) - green; -Y ports (2) - red; +Z ports (2) - yellow; and -Z ports (2) - white. Since the +Y and -Y ports may be unoccupied for long periods of time between occupancy by RAM's and cargo modules, the running light installation for these locations are designed for inflight servicing by a shirtsleeved crewman. The +Z and -Z port lights are not shirtsleeve maintainable. These lights are replaced by the running lights on the outboard end of the station modules that are attached to the Z-plane ports.

Initial station communication is accomplished with VHF and S-band communication equipment located in the core module. The two S-band and two VHF antennas are shown in Figure 1-43. The two VHF antennas, located 180 degrees apart, are folded during shuttle transport and erected upon module activation. These communication systems are deactivated upon activation of the modular space station's primary communication systems. These antennas will be nadir pointing during the initial buildup phase of the station because of the gravity gradient orientation of the core module.

Interior Arrangement

The IVA/EVA airlock is located in the center of the module and divides Volume 1 from Volume 2. The G&C inertial reference and optical reference assemblies are located within the airlock. Various items of crew equipment, such as the IVA umbilicals, crew first aid kit, etc., are also stowed here. Two additional IVA umbilicals are stowed in V_1. The airlock provides a clear area 5-feet long by approximately 10 feet in diameter which exceeds

the criteria of 5 by 7 feet to accommodate two pressure-suited crewmen complete with EVA backpacks and equipment. The G&C optics, such as horizon tracker (4), star trackers (2), sextant, and telescope, are located here to get the optimum viewing angles between the modules of the completed station. All of these instruments can be serviced and replaced in a shirt-sleeve condition. This location for the inertial reference subsystem of the G&C system provides a clear, short optical alignment path to the RAM berthing ports, which allows calibration between the berthed RAM's and the space station inertial reference system. The EVA hatch is located in the ECLSS radiator area. The radiator area displaced by the hatch is replaced by making the right-hand radiator assembly longer than the assembly on the left-hand side of the core module. This arrangement is shown on drawing V030-942102, SD71-216. The EVA hatch is covered by an environmental shield assembly and contains the standard viewing window with provisions for window replacement from inside the core module.

RCS Engines

The four RCS quad assembly locations are shown on Figures 1-44 and 1-46. The quad assemblies are retracted during shuttle delivery. The engine quad mounting structure, hatch covers, engine covers and associated hardware are common at all four locations, minimizing cost and spares requirements. Shirt-sleeve service and replacement access for the engines is provided by rotating the quad assembly into its well, equalizing the pressure in the engine cover and removing it; the engines are thus exposed to the shirtsleeve atmosphere of the core module. The associated electronics equipment is bulkhead-mounted in Volumes 1 and 2 adjacent to the paired quad assemblies. An emergency G&C controller may be attached to the RCS electronics equipment in each volume and is stowed nearby.

G&C Momentum Exchange Assembly

The three control moment gyros (CMG's) are located as shown by Figure 1-43. This location provides the best stabilization and control for the attached RAM's. Figure 1-46 defines the CMG and RCS quad relationships. The proximity of two of the CMG's to the adjacent RCS quad assemblies is such that in order to service and replace an RCS quad, the following action to the adjacent CMG must be taken: despin the CMG. Remove the protective cover and collapse the gimbals to provide the necessary room in order to remove the RCS engine cover.

Electrical Power Subsystem

The electrical power subsystem (EPS) equipment located in the core module is equally divided between V_1 and V_2, except for the buildup equipment that is located in V_1. This buildup equipment consists of three batteries, two inverters, and two sequencers. All or part of the above may be off-loaded after buildup, if desirable. The hydrogen and oxygen accumulators are utilized as high pressure (3000 psi) storage tanks during the first 60 days of buildup operations. Once the solar arrays are activated and the EPS system is operating normally, the tanks are utilized as 300-psi accumulators. Because of the initial high pressure usage, the tanks, mounts, and attachments are designed

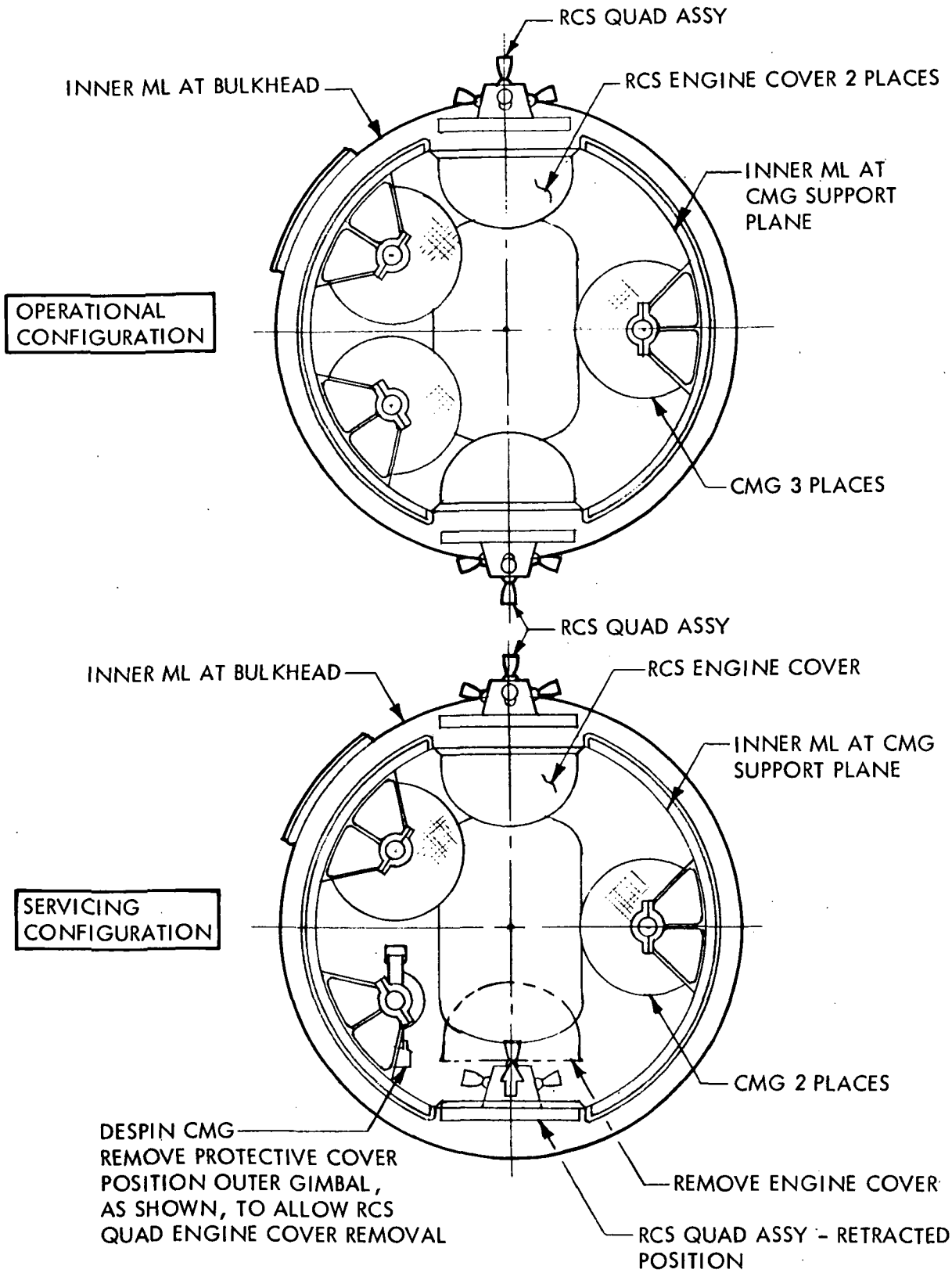


Figure 1-46. CMG/RCS Engine Interface

for the 3000-psi operation. The H_2O tanks and pump packages (one each in V_1 and V_2) are sized for 540 pounds of water each, which is a buildup requirement. For normal operations the tanks contain 40 pounds of water each. As stated previously, the equipment is separated into V_1 and V_2 for safety and redundancy. The two primary and two secondary bus systems of each volume are also separated for increased redundancy and safety. The hydrogen lines routed through the core module utilize a double containment concept. Where possible, the hydrogen lines are routed exterior to the pressure hull. These lines are not double containment lines.

Environmental Control and Life Support Subsystem

The core module atmospheric control sensible duct system consists of a supply and return duct. The supply duct extends to the interface with the power module. The sensible heat exchanger and fan assembly is the heart of this system. The atmospheric control humidity duct system in the core module serves as the manifold to interconnect the initial station modules and -X berthing port humidity duct interfaces. One humidity duct fan is located in the duct system; and three ventilation fans are located in V_1, V_2, and the IVA/EVA airlock, respectively.

The initial station thermal control equipment, such as the buildup freon pump package, buildup water pump package, etc., are located in V_1. A gas barrier is provided for the freon loop equipment. The volume is sealed to prevent the escape of any gas into the space station atmosphere. An overboard dump valve is provided. The freon lines inside the habitable volume also utilize the double containment concept. Where possible, the freon lines are routed outside the pressure hull.

Two RAM heat exchangers are located adjacent to the RAM berthing ports. A pumpdown unit is stowed in V_1 and V_2 near the berthing ports of each volume. This unit is portable and is attached to the pumpdown valve at the interface of the module to be evacuated.

The special life support equipment provided consists of a fire detection system and a stowed fire extinguisher package. An IVA umbilical hose connection is provided in the airlock with another provided in V_2.

Crew Equipment

The items of crew equipment located in the core module fall under the category of general and emergency equipment. A storage locker is provided in the IVA/EVA airlock for the following items of equipment:

Item	Quantity
Tool set	1
Portable light	1
Emergency O_2 mask	3
Mobility aids and restraints	1 set
First aid kit	1

This location was chosen as being the most central location of the core module.

Two IVA umbilicals are stowed in the airlock. This again is a central location, accessible to the IVA connectors in both the airlock and V_2 and accessible from either volume in the event one volume must be isolated. Two spare umbilicals are stowed in V_1.

Utility Runs

Dual utility runs are provided throughout the core module. These runs are redundant and located on opposing sectors of the module diameter for safety. At each berthing port a utility distribution ring is provided which is utilized to route the berthing port interface utilities into the core module longitudinal utility raceways.

1.5.2 POWER MODULE

Drawing VO30-942101, SD 71-216, represents the preliminary design of the power module assembly. The complete assembly is composed of two subassemblies, the solar array/orientation drive and power transfer assembly (SA/ODAPT) and the boom structure assembly. The boom structure acts as the main support for the SA/ODAPT assembly and provides the mechanical and electrical interface between the SA/ODAPT and the core module (Figure 1-47).

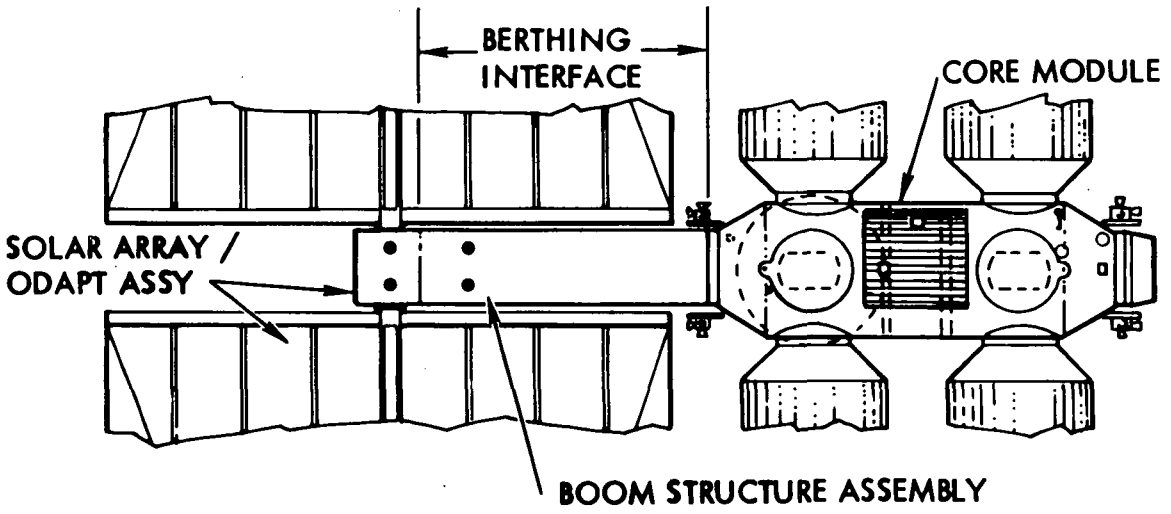


Figure 1-47. Power Module Installation

Design Requirements

The power module assembly has been designed to meet the basic shuttle payload requirements of weight, size, and launch g-loads. It is also designed to meet the pressure requirements needed to launch the assembly in a pressurized condition and to provide the capability for shirtsleeve maintenance of equipment while in orbit. The crew safety requirement of dual egress is provided by the hatches located at the extremities. Environmental

shield panels cover the exterior surface of the power boom and ODAPT, providing the meteoroid protection and thermal control. The storage requirement for EPS and repressurization gases is provided by 10 spherical tanks installed as shown on Figure 1-48. Control and monitoring equipment for the EPS and repressurized gases is installed at the core module end of the boom.

The SA/ODAPT assembly (vendor-furnished item) as an integral part of the design includes an active port and a passive berthing port, and a 44-inch diameter pressure hatch (see Figure 1-48). These features of the SA/ODAPT assembly permit the complete assembly to be pressurized for launch and permits the SA/ODAPT assembly to be removed and replaced while in orbit.

Design Description

The power module general arrangement is shown in Figure 1-48.

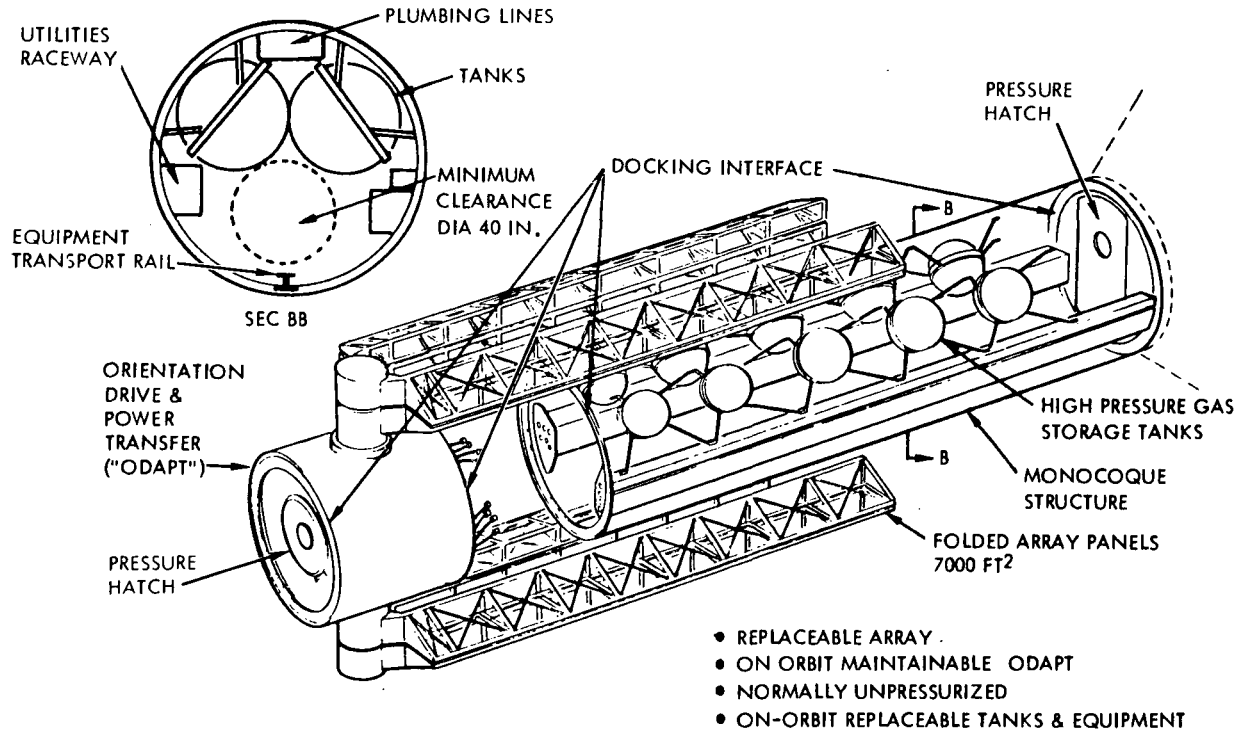


Figure 1-48. Power Module

The power module assembly is 33 feet 10 inches long and will fit within a 15-foot-diameter envelope. It is composed of two separate subassemblies: (1) the solar array/orientation drive and power transfer assembly and (2) the boom structure assembly. As SA/ODAPT is a vendor-supplied assembly, the boom structure will be the only item described.

Boom Structure

The boom structure has an overall length of 27 feet 6 inches and an external diameter of 7 feet 4 inches (88 inches). The structure style is monocoque and consists of an 80-inch internal diameter tube made from 0.145-inch-thick aluminum alloy sheet, with five 3-inch-deep aluminum alloy

circumferential stiffener rings bonded to the exterior of the tube. The skin and stiffener rings are sized to meet the 14.7 psia pressure required for shirtsleeve maintenance of equipment while in orbit. Two drag longerons (aluminum alloy), attached 180 degrees apart at the core module end, provide the launch and crash load requirements.

A modified passive berthing port (no pressure bulkhead or hatch) is located at the solar array/ODAPT end, and a standard active berthing port with pressure bulkhead and hatch is located at the core module end. (See berthing port assembly drawing V030-942004, SD 71-216). Four module support fittings are provided and are located compatible with the shuttle payload bay support fittings. Four manipulator sockets are located at Station 155 (45 degrees to the Y-Y axis) for handling and positioning. An equipment transport rail is provided within the boom assembly for storage tank replacement operations.

Environmental Protection

Environmental protection, thermal and meteoroid, is accomplished by specially designed environmental shield panels which are attached externally to the stiffener rings by means of captive threaded fasteners. An external fiberglass shell is provided as a meteoroid bumper which also provides support for the insulation. An inner Kapton liner provides thermal insulation protection and also acts as a secondary meteoroid bumper. The environmental shield is structurally and thermally independent but supported by the module's primary structure. A portion of the environmental shield installation is depicted by Figure 1-49.

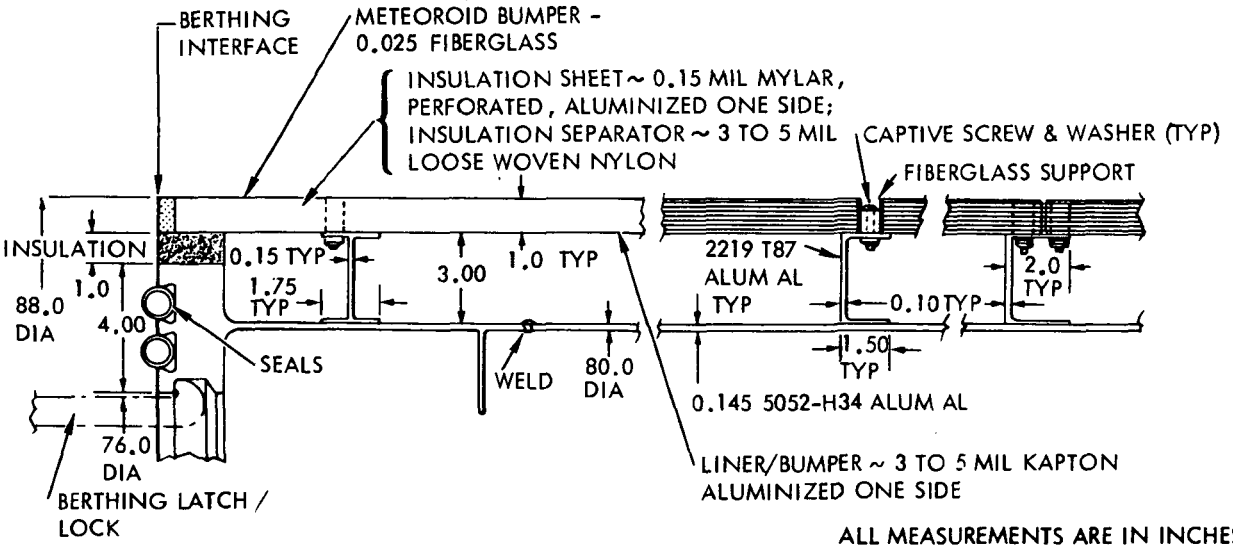


Figure 1-49. Environmental Shield Installation

Internal Arrangement

The internal volume is utilized to mount 10 spherical tanks that are used to store the high-pressure gases (3000 psia) required for repressurization and fuel cell operation. The tanks are spaced 20 inches apart to allow for normal maintenance and removal operations, and are mounted in such a way that a clear area 40 inches in diameter extends the length of the boom, which is used for crewman passage and tank replacement. The plumbing lines and control valves are installed longitudinally between the tanks (see Figure 1-48).

The sizes and locations of the tanks are shown in Figure 1-50. For safety purposes gases (O_2, H_2, N_2) have individual manifolds which are plumbed to the proper storage tanks and are vented overboard through the boom pressure wall.

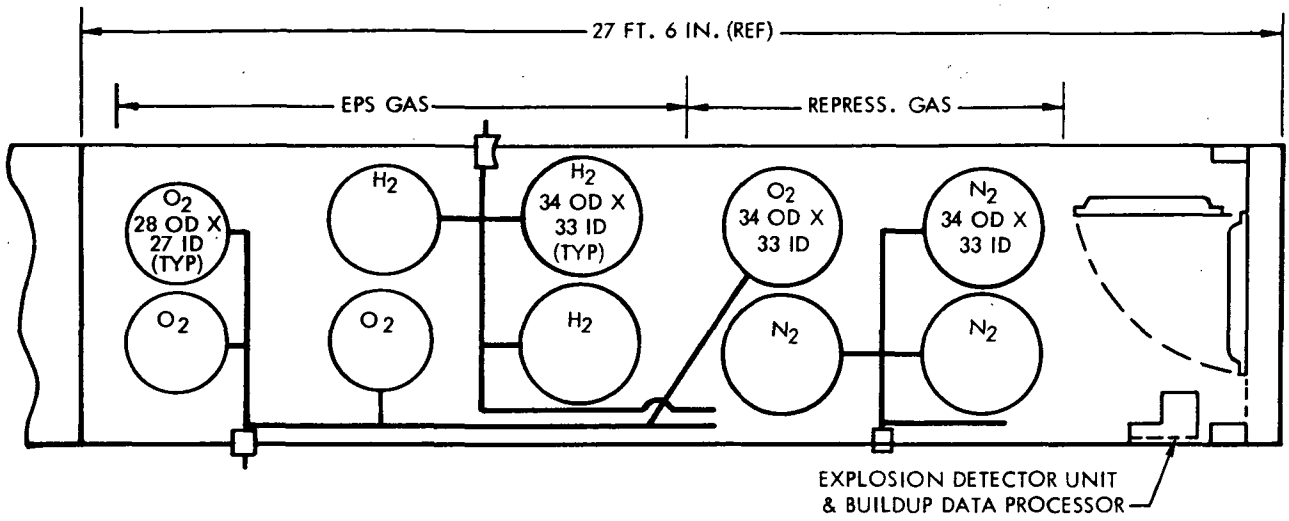


Figure 1-50. Power Module Tank Locations

The interconnecting utilities within the boom include all the interconnecting hardlines, electrical power buses (primary and secondary), and data and signal cabling. The utilities are redundant and are routed through raceways on either side of the boom (see Figure 1-48). An air supply duct extends the length of the boom, but is only used when crewmen enter the boom for repair or maintenance of the equipment. (Return air is routed through the open hatch at the core module end.)

Maintenance Operations

The assembly is launched pressurized and is attached on-orbit to the core module. Pressure lost during this operation is replenished and all interconnections and checkout is performed by crewmen in a shirtsleeve environment. After checkout, the hatch at the core module end is closed, and the power module pressure is allowed to decay to an unpressurized condition which is the normal orbital operating mode dictated by the SA/ODAPT assembly design and operation. When subsequent maintenance or repair is

required, the power module assembly is repressurized and environmentally controlled for shirtsleeve maintenance. Replacement of any high-pressure tank is readily accomplished by disconnecting appropriate plumbing connections, loosening the fasteners that hold the tank in place, and placing it in a support on the equipment transfer rail for removal. The crewmen exit through and lock the hatch at the core module end, depressurize the boom, and resume operations.

Secondary Utilization

The power module assembly also has the capability to be utilized as an airlock. The 40-inch-diameter clear opening through the boom and in the ODAPT, in conjunction with the pressure hatch in the end of the ODAPT, provides the capability for a suited crewman to exit or enter the power module.

1.5.3 STATION MODULE COMMON STRUCTURE

The station modules all have a common primary structural arrangement and are defined in preliminary design drawing V030-942201, Common Module Structure Assembly. In general, the external configuration of the modules is also identical with the exception of window installations and auxiliary passage provisions. Two interior floor arrangements are utilized in the modules, a single level arrangement for station modules 2 and 3, and a split level arrangement for modules 1 and 4. Preliminary design drawing V030-942205, Station Module Structural Assembly, defines the floor arrangement, the window and auxiliary port installations.

The common module structural arrangement is shown in Figure 1-51.

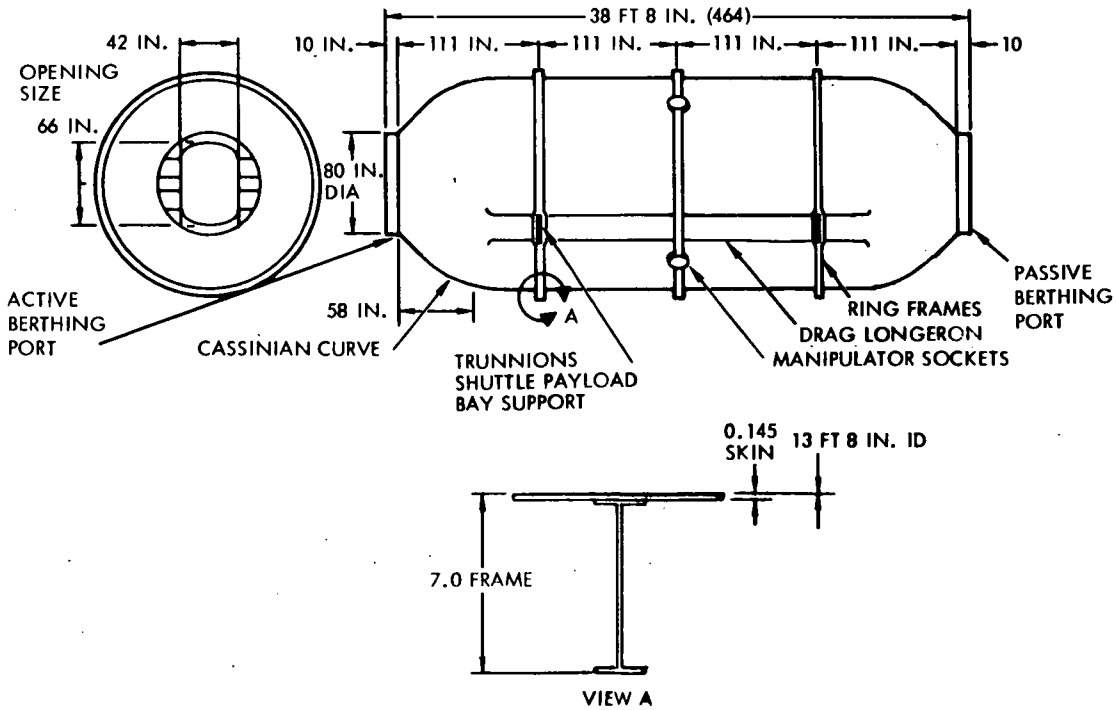


Figure 1-51. Common Module Structural Arrangement

The sidewalls and end bulkheads are of pure monocoque construction made from 0.145-inch 5052-H34 aluminum. The internal diameter is 164 inches and is completely free of any protuberances. The cylindrical section is faired into the conical section by a Cassinian curve. A 6- by 6-inch H section drag longeron made from 2219-T87 aluminum provides the reaction for the shuttle attach trunnion fitting loads for crash landing. The station module has three ring frames 111 inches on center to react the shuttle trunnion fitting and manipulator fitting loads. The end frames attach the module to the shuttle on both sides (4 points). The center frame accommodates manipulator fittings at 4 points. The frames are made from 7075-T6 aluminum and are bonded to the outside surface of the pressure shell. The end frames are a 7-inch-deep H section, 4.5 inches wide, and approximately 0.30-inch thick in the critical section. The center frame is a 7-inch-deep H section, 2.0 inches wide and 0.15-inch thick.

The station modules are each equipped with full circumferential radiators 30 feet 4 inches long, with a net capacity of 1200 square feet. Radiators are provided as part of the environmental control/life support subsystem. The radiators are independent assemblies, supported but thermally isolated from the module primary structure, doubling as meteoroid and thermal shields. Figure 1-52 represents a typical cross section of the radiator installation. The radiator surface is interrupted by the two drag longerons, the three structural ring frames, and an auxiliary passage (Figure 1-53).

The auxiliary passage port location varies according to the position of the modules in the space station. In station modules 2 and 4 the port is located in the ceiling of the module. The ceiling located ports are active ones which are in a retracted position in the module until connection is to be made to the adjacent module. The port is then extended to reach and connect to the passive port on the adjacent module. Station modules 1 and 3 have a passive port which does not extend, but receives the active port from the adjacent module. Figure 1-54 shows the active and passive port configurations and the connection sequence for modules 1 and 4. The same arrangement occurs between modules 3 and 4. The passive ports are located below the deck in the pressure wall. Both the active and the passive ports provide adjustments to compensate for angular and module spacing tolerances. Each port hatch contains a 4-inch-diameter window, which is utilized for visual alignment during extension and also provides a visual cue during use in normal station operations. Station pressure is utilized to extend the passageway. A restricting device is provided to control the extension velocity during this operation. Latches provide the structural attachment of the auxiliary passage to the passive ring of the mating module.

Running lights are located on the end of each module opposite the core module end. Each module has two lights diametrically opposite on the centerline in the Z-plane. The color of the lights reflect the position of the module in the space station configuration. The lights each contain six bulbs on two independent circuits. The light installation is designed to provide shirtsleeve maintenance from inside the module.

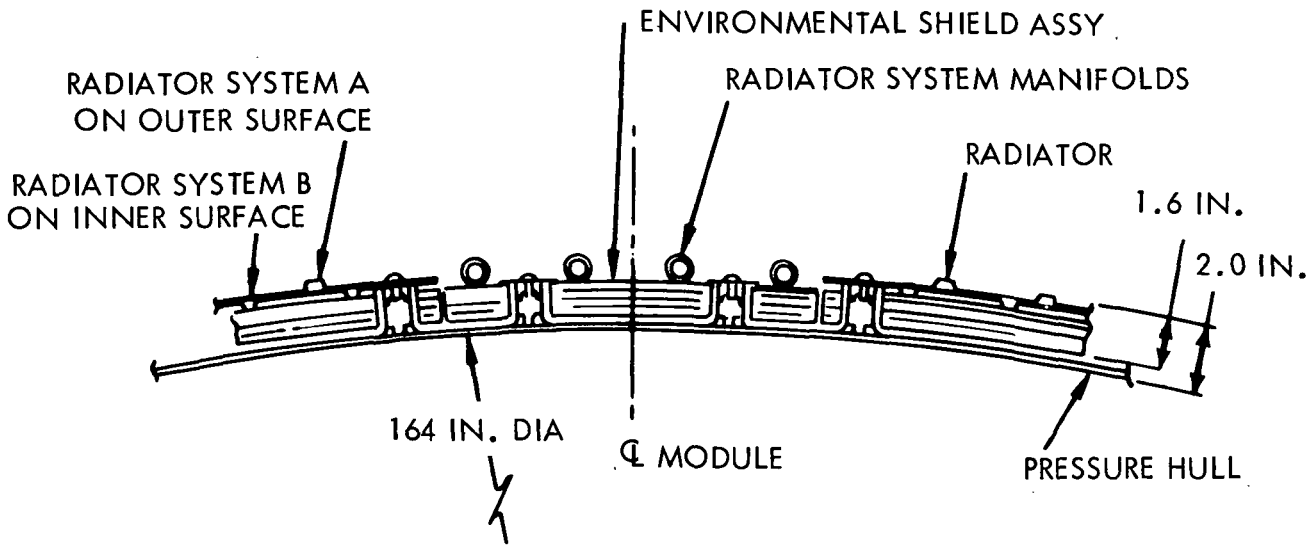


Figure 1-52. Radiator/Environmental Shield Assembly

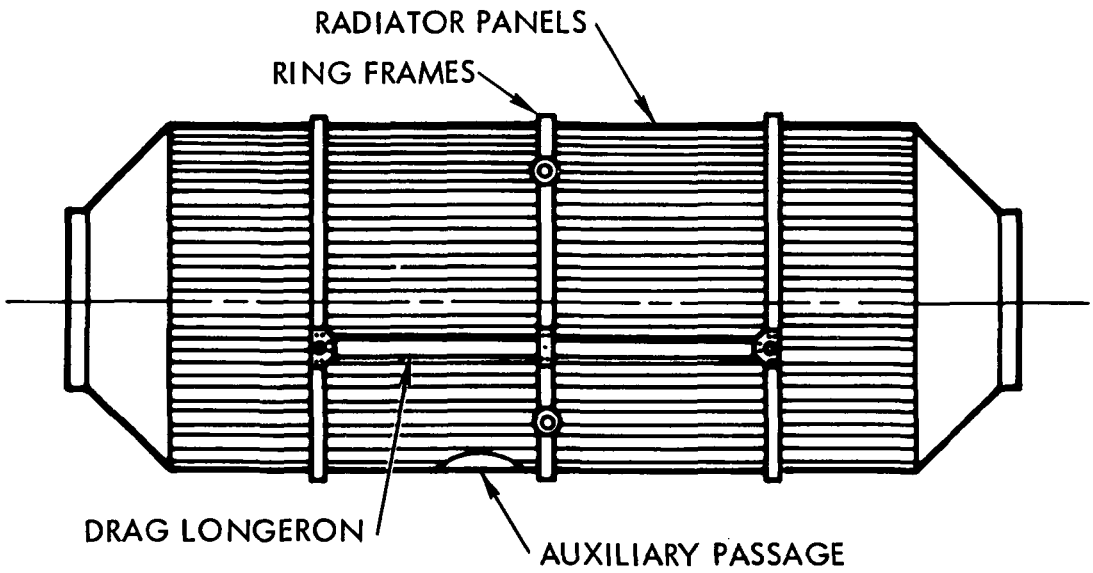


Figure 1-53. Typical Radiator Arrangement

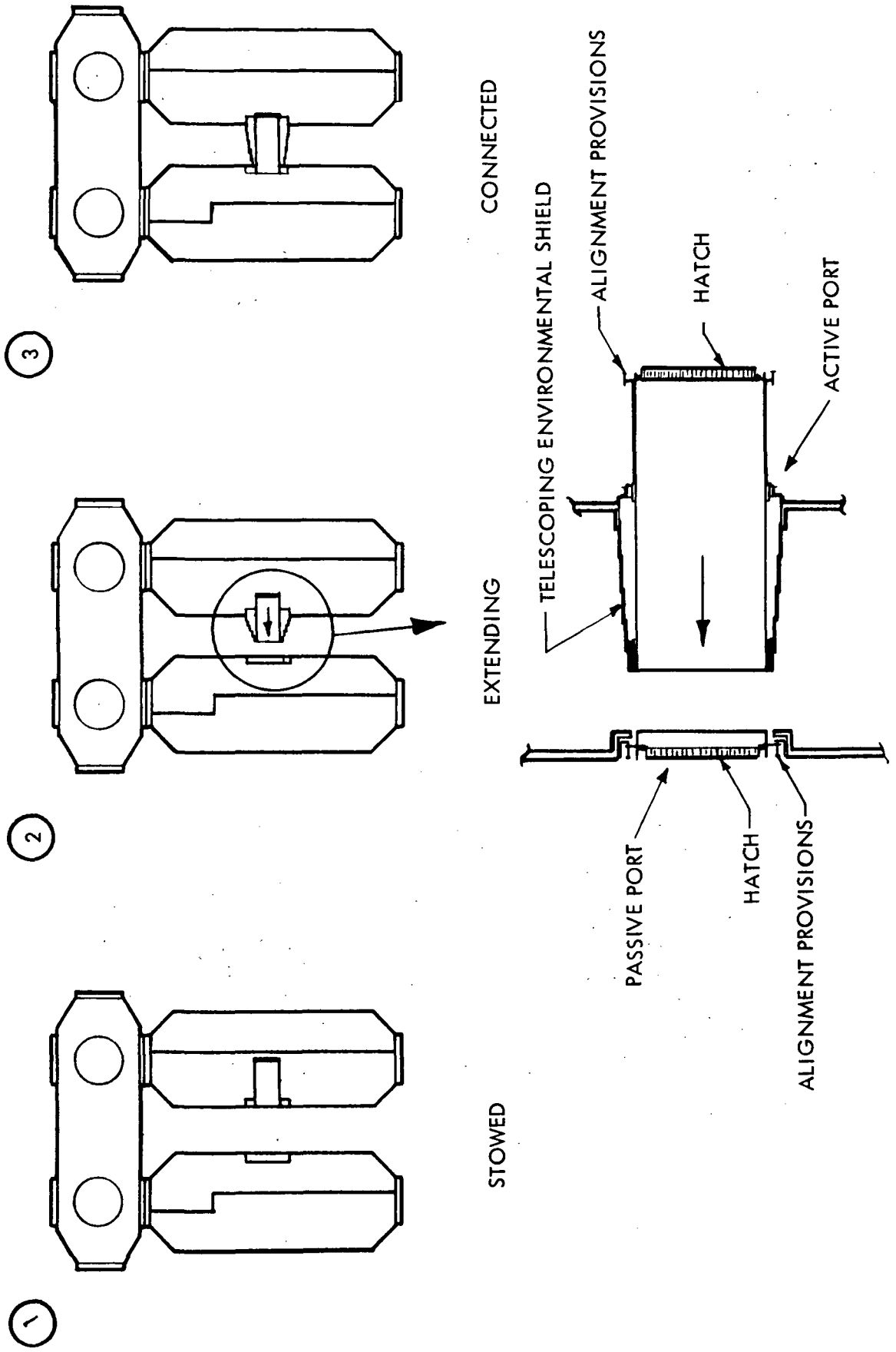


Figure 1-54. Auxiliary Passage Activation

1.5.4 STATION MODULES 1 AND 4

Drawing V030-942202 represents the preliminary design for station modules 1 and 4. These modules are the living quarters modules of the initial station, each module containing staterooms for three crewmembers. Station module 1 and station module 4 have a longitudinal split-level deck. The raised deck area provides the stateroom accommodations. The main deck is utilized for other functional activities. The volume below the main deck houses subsystem equipment and storage.

Design Requirements

The maximum envelope diameter of 14 feet is required for all station modules with local protuberances extending to 15 feet. A common length for all of the station modules was to be determined. The functional areas to to be provided in station module 1 consists of GPL data analysis and photo process. Control center 1, a hygiene facility, a backup medical facility, and crew quarters for two crewmen and a commander/executive stateroom/office, is also to be provided. Waste and water management, heat rejection, and EPS electrolysis units subsystem equipment installed below decks completes station module 1 requirements. Station module 4 differs from station module 1 only in the functional facility requirement. A medical crew care, intensive care, and medical supply area fulfills station module 4 functional requirements. Table 1-11 defines the major design drivers and equipment requirements for station modules 1 and 4.

Design Description

Station module 1 is the first station module to be delivered to space and berthed to core module 1 in the +Z (nadir) direction. Figure 1-55 illustrates the configuration of station module 1. Station module 4, the fourth station module to be delivered to space, is berthed to core module 1 in the -Z (zenith) direction. Figure 1-56 illustrates the configuration of station module 4.

Berthed to the free end of station modules 1 and 4 is an antenna package (Drawing V030-942002). This antenna package is launched with the station module but has the capability of being replaced in space. Access to the antenna package for maintenance is provided.

Normal access between modules is accomplished through the core module. A secondary access for emergency use is provided by an auxiliary passage approximately half way along the length of the modules. The auxiliary passage is a 3-foot-diameter cylinder with a telescoping environmental shield and is stowed in station modules 2 and 4 during launch. After these modules are berthed to the core module, the auxiliary passage cylinder is extended and attached to the adjacent modules, station modules 1 and 3. Egress from station module 1 via the auxiliary passage is obtained by opening the hatch cover in the subsystem (below deck) area and proceeding along the passage to station module 2. Egress from station module 4 is obtained by opening the hatch cover in the false ceiling and proceeding through the cylinder to station module 3. A second means of access between the above and below deck areas

Table 1-11. Station Module 1 and 4 Design Requirements

Item	Requirements
Common requirements	For equipment details, refer to DRL 66, Preliminary Performance Specification
Size	14-foot diameter by 58 feet long with local protrusions to 15-foot diameter by 60 feet long
Weight	20,000-lb target 25,000-lb maximum launch
Berthing	One active port - core module end One passive berthing port
Crew accommodations	2 crewman staterooms 1 commander/executive stateroom/office
Corridors	Accommodate a 40- by 40- by 50-inch package size
Windows	At each control center - 14 inches in diameter
Ceiling height	82-inch clear headroom in mobility areas
Accessibility	Access to all pressure walls - as a goal Three sides of all subsystem equipment accessible for maintenance. Utility runs accessible Access to front and rear of all electronic equipment
Safety	Two ways out of all compartments and modules Redundant and separated utility runs
ECS	
Atmospheric control	Fan assemblies. Pressure relief and sensors Explosion detector, local charcoal canisters
Heat rejection loop	Freon/H_2O intercooler, pump package, reservoir 1230 ft^2 radiator
Water management	Water reclamation, water storage
Waste management	Fecal collection, urine collection
Hygiene	Shower, sink
Fire control	Fire extinguisher package, fire detector

Table 1-11. Station Module 1 and 4 Design Requirements (Cont)

Item	Requirement
EPS	
Energy storage	Electrolysis units
Power conditioning	Secondary bus
ISS	
Data processing	Located in operational control console and mass memory rack
Command/control and monitoring	Operational control console Commander's control console Portable control unit Mass memory rack
External communications	K-band, S-band, VHF } antenna package
Internal communications	Communications rack Audio/video unit Hardwire intercommunications TV monitor - color
Station module 1	For equipment details, refer to DRL 66, Preliminary Performance Specification
GPL facilities	Data analysis area Photo processing area Backup medical/exercise area
Station moduel 4	
Medical/crew care	Medical storage/diagnostic area Medical intensive care area Medical crew qualification area

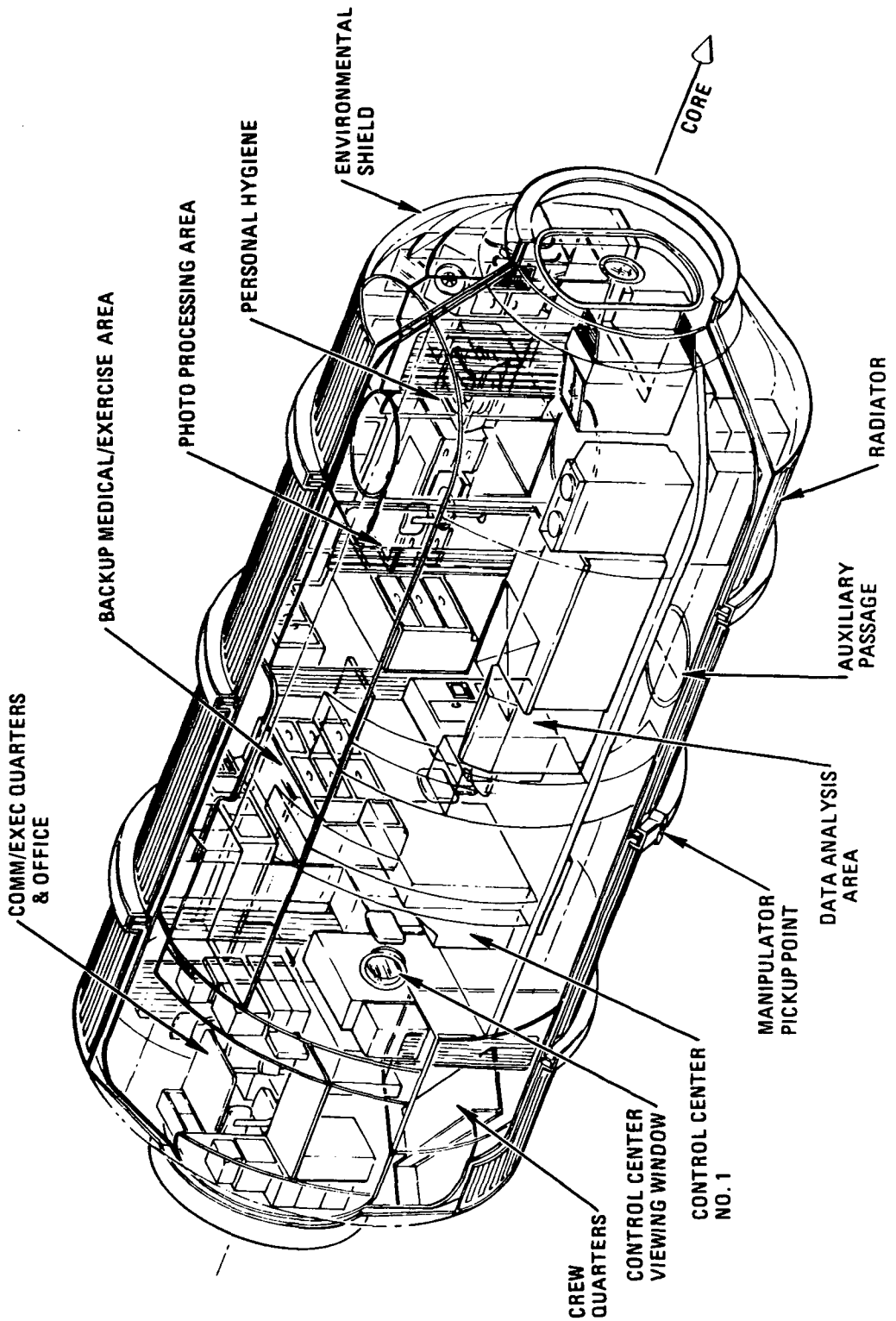


Figure 1-55. Station Module 1

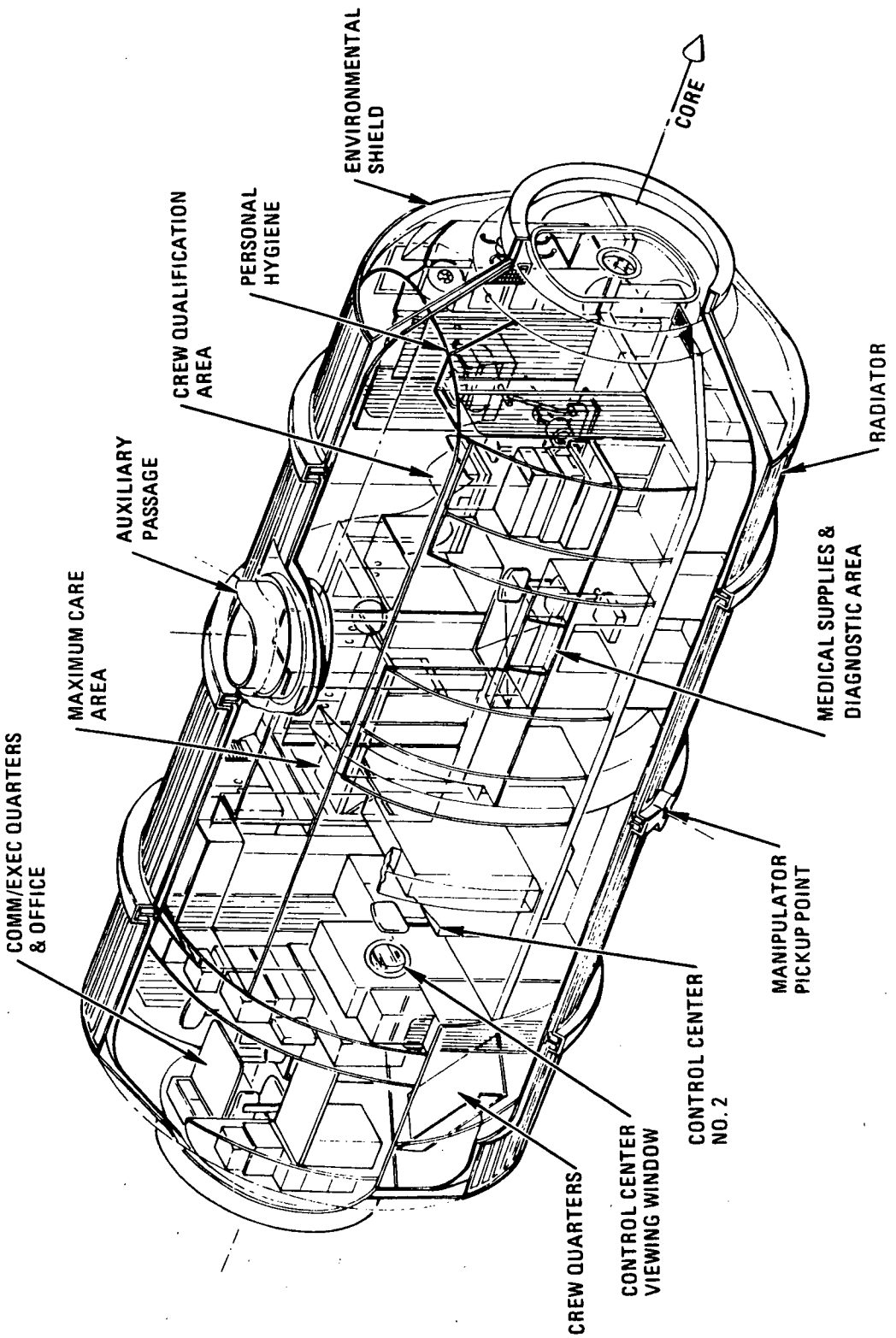


Figure 1-56. Station Module 4

(other than at the core end) in any station module is through an auxiliary access opening located in the main deck and in direct line with the auxiliary passage. For normal operation this 42-inch-square access opening has a cover installed flush with the main deck.

Station modules 1 and 4 are each equipped with a window installed in the pressure shell adjacent to the control center console. Observation through the window located in station module 1 is in the -Y direction, and observation through the window located in station module 4 is in the +Y direction. Figures 1-57 and 1-58 represent the floor plans of station modules 1 and 4 for both the upper and lower deck areas.

Both modules (station modules 1 and 4) contain three staterooms, a control center, hygiene facilities, and subsystem equipment. Station module 1 provides these facilities in Volume 1 while station module 4 provides the same facilities in Volume 2. Station module 1 also contains a photo processing area, a data analysis area, and a backup medical and exercise area. Station module 4 provides the medical/crew care facility.

Structural Arrangement

Station modules 1 and 4 utilize a longitudinal split level floor arrangement with a 20-inch-high step approximately 27 feet from the core module end of the module. The main deck is 16 inches below the module centerline and the raised deck 4 inches above the module centerline. A false ceiling 82 inches above the main deck is installed for the length of the main deck only, no false ceiling is installed above the raised deck. Figure 1-59 illustrates the floor arrangement.

Interior Arrangement

Both station modules 1 and 4 are structurally identical, each having a split-level longitudinal deck 37 feet long. This deck is composed of two parts: the main deck and the raised deck. The main deck is 314 inches (26 feet 2 inches) long and approximately 160 inches (13 feet 4 inches) wide. The raised deck is 130 inches (10 feet 10 inches) long and approximately 164 inches (13 feet 8 inches) wide. The main deck is 4 inches thick, located 16 inches below the module centerline in the -X direction. The raised deck is 2 inches thick, located 4 inches above the module centerline in the +X direction. At each end of the module floor a 4-foot-square opening is provided. The opening through the main deck at the core module end provides the main passageway to and from the module and between the above and below deck areas. The opening through the raised deck end of the module is normally covered and is used only for antenna replacement or repair. A third opening, 42 inches square in the main deck, is located in direct line with the auxiliary passage. This opening is covered during normal operations, but provides the second means of access between the upper and lower deck areas. A false ceiling is located 82 inches (6 feet 10 inches) above the main deck. The volume above the false ceiling is utilized as an air supply plenum and for the distribution of utilities.

Air revitalization via the sensible heat exchanger fan assembly, located below deck, is obtained by use of a duct adjacent to the pressure wall. This

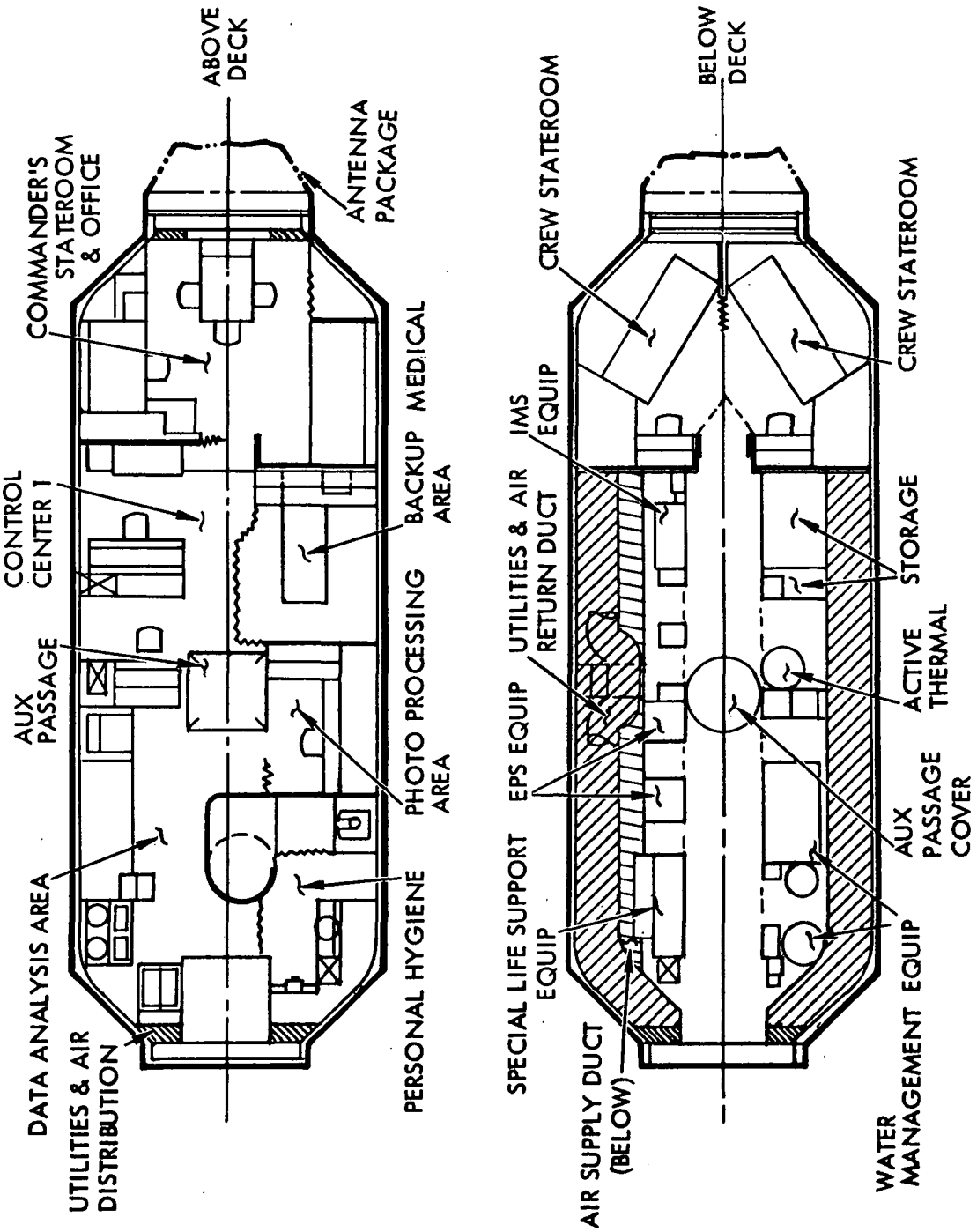
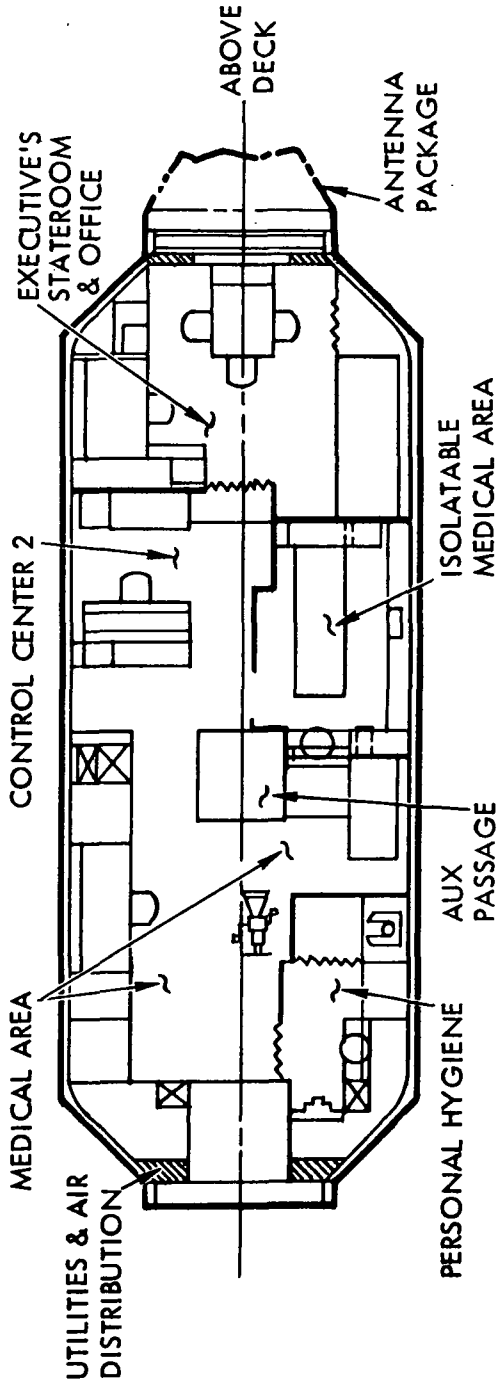


Figure 1-57. Station Module 1 Internal Arrangement



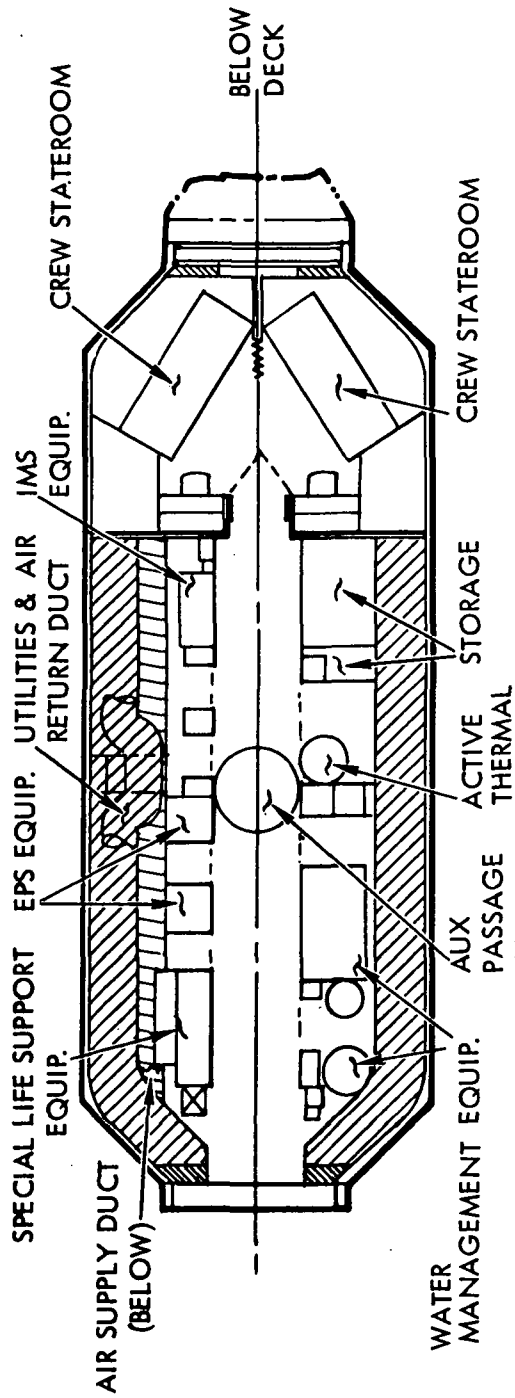
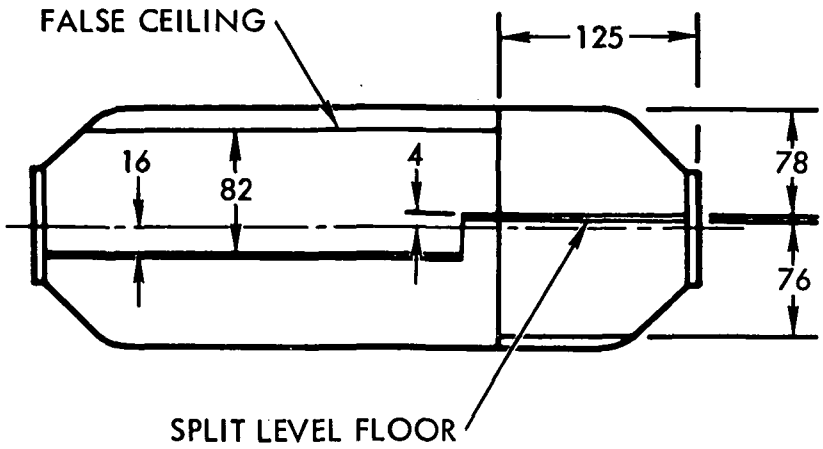


Figure 1-58. Station Module 4 Internal Arrangement



ALL MEASUREMENTS ARE IN INCHES

Figure 1-59. Floor Arrangement

duct extends from the false ceiling to a longitudinal plenum 4 feet below the main deck. Distribution of air is obtained by the use of registers located as required in the false ceiling (above deck) and in the longitudinal plenum (below deck). Return air ducts are located below deck on each side of the module, 58 inches from the module centerline. These ducts provide the air return routing for both the upper deck via vents through the floor and for the lower deck.

Incoming utilities from the core module are fed through the berthing port to a distribution ring adjacent to the berthing port. This utility distribution ring distributes utility lines from the core module to the false ceiling area above deck and also to the utilities raceways below deck. The below deck raceways are located on each side of the module 58 inches from the module centerline.

Both station modules 1 and 4 have an area designated as a station control center. The control stations are identical and are capable of performing operations and control of both station and experiment. This arrangement provides a capability in Volume 1 and an identical capability in Volume 2.

Utilities for the control consoles are routed from the false ceiling area via a duct adjacent to the pressure wall. Access to these utilities and to both the front and rear of the console is provided. Figure 1-60 illustrates the maintenance and installation flexibility provided by this arrangement.

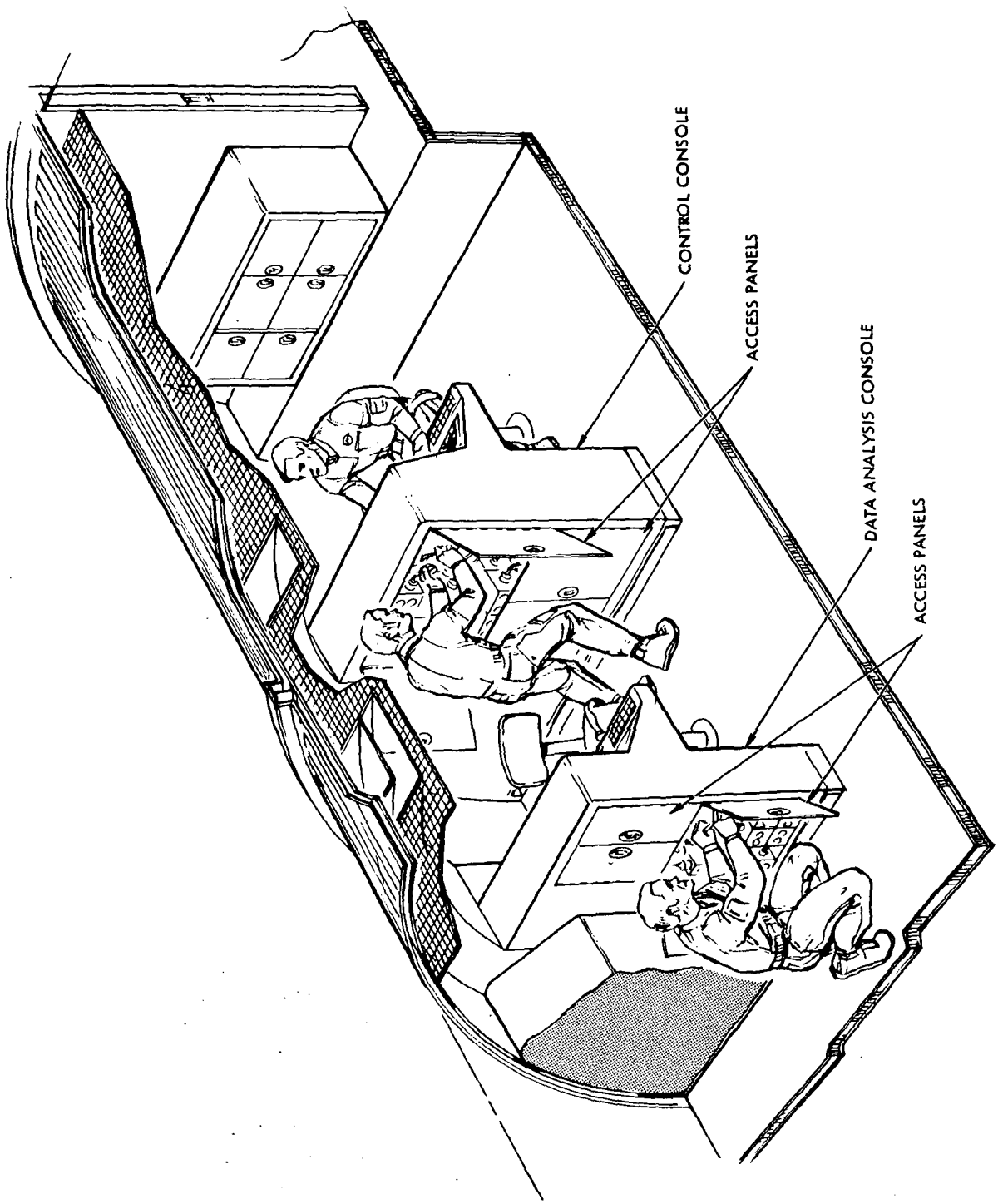


Figure 1-60. Control Center Installation and Maintenance Provisions

Behind the operational control console and mounted on the raised deck in front of the commander's or executive stateroom wall are a communication rack and stowage provisions for a portable control unit.

Two command control consoles are utilized in the space station; one console is located in the commander's stateroom and the other in the executive stateroom. The command control console is mounted on the wall that separates the control center from the commander/executive stateroom. This wall also provides the utilities routing to the command control console and communication rack.

The components of the data processing assembly not housed in the operational control console are mounted in the memory rack located below deck directly beneath the control center.

Located on the pressure wall directly below the window in the control center is an audio video unit and a hardwire itercom.

There are six audio video units (AVU's) in both station module 1 and station module 4; one AVU is provided in each stateroom, one in the control center and two below deck at each end of the subsystem volume.

The hardwire intercom provides voice communication between the modules during the station buildup before the control center is operational. The units installed in subsequent modules serve as a backup to the paging system.

Station modules 1 and 4 are each equipped with four-color television monitors. One TV is located in each of the three staterooms and the other is located in the data analysis area in station module 1 and in the medical/intensive care area in station module 4.

Station modules 1 and 4 are both furnished with a personal hygiene facility; each facility contains a fecal unit, sink unit, urinal, and storage. Station module 1 also contains a shower.

The fecal unit is mounted to the deck in a cubicle with access by means of a privacy curtain. The unit is the "dry john" type consisting of two independent systems: urine collection and transportation, and a feces collection container. The feces container is periodically removed and replaced with a new unit.

The sink unit consists of a sink,vomitus collector, drinking water spigot, and dental hygiene facility. The sink is an enclosed chamber with entrance ports for the hands (sealing around the lower arms). Inside the chamber are controls for the flow rate of water, soap, and air. Storage below the sink contains towels, pre-moistened paper wipes, toilet supplies, and a disposal bin. A mirror and lights are located above the sink.

The urinal is a wall-hung unit which can be adjusted to the individual height of the user.

A storage cabinet between the sink and fecal unit houses all the personal hygiene facility supplies. This cabinet is movable to provide access to the utilities behind the sink unit and the plumbing and electrical lines to the fecal unit. The wall section between the sink and the urinal is also removable for access to the utility lines in this area.

The shower located in the hygiene facility of station module 1 is a self-contained rectangular unit. One end of the rectangle houses a cylindrical stall with access door complete with seal, and the other end houses the recirculation air duct plumbing and machinery. The top of the stall is equipped with an air heater and distribution plenum to direct the flow of air downward. The bottom of the enclosure has a raised grid-like floor permitting the passage of both air and water from the enclosure. Water is moved by the air flow to a dynamic centrifuge phase separator pump where the water and air are separated.

Both station module 1 and station module 4 have identical below-deck arrangements. This volume is divided into two sections: the subsystem equipment volume below the main deck and the crew staterooms below the raised deck. The subsystems equipment consists of water and waste management, heat rejection, electrolysis, storage, and miscellaneous electronic equipment (see Figure 1-57).

The water and waste management equipment is divided into two groupings located at the core module end directly beneath the hygiene facility. The first group contains a purity monitor system and two potable water tanks. Included in this group at the end of the module is an audio video unit, a fire detector, and fire extinguisher package. The second group contains a vent accumulator, vent accumulator pump, and water recovery unit. The spacing between the groups of equipment is provided for equipment maintenance and access to the utility lines located at the sides of the module. A heat rejection equipment grouping is located adjacent to the water management equipment. This group of equipment is all encased in a gas barrier for environmental protection. The package consists of a freon reservoir, freon/water intercooler, freon pump package, and a water pump package. A storage volume and general emergency equipment is located adjacent to the heat rejection equipment and extends to the crew quarters partition.

At the core module end of the lower deck volume on the other side of the module is located the storage facilities for the pressure garment assemblies (PGA's) and portable life support system/oxygen purge systems (PLSS/OPS) for two crewmen. Adjacent to this storage area is located the electrical power supply (EPS) electrolysis units. These units are complete with gas barrier and separated for access to the utility raceway. Adjacent to the second electrolysis unit is an explosives detector and secondary bus equipment. The remaining volume to the stateroom partition is utilized for the sensible heat exchanger fan assembly, another secondary bus equipment package, and the station control system memory rack. Also next to the stateroom partition is an audio video unit, fire detector, and fire extinguisher package.

The crew staterooms are located below the raised deck (Figure 1-61). Each stateroom contains a desk, wardrobe-type closet, bunk, overlap crew bunk, television, audio unit, and storage facilities. The crew staterooms are arranged to permit either individual staterooms or a shared stateroom. An accordion-type partition provides the capability to separate the total crew quarters into two individual staterooms. The crewman's bunk is located on a bias to fit the conical end of the pressure wall. A short partition separates the head end of the bunks and provides the close-out for the room divider. Two bi-fold doors provide the entrance facilities to the individual staterooms. The crew overlap bunk is stowed against the ceiling above the main bunk. The bunk is lowered and locked on supports midway between the main bunk and the ceiling when required for the additional crew facility. Two egress panels are provided through the ceiling to provide the second means of access from these compartments and also for the commander/executive stateroom directly above. Above each crewman's desk is a cabinet containing storage, a television and audio video unit, and ventilation fan. The volume below each bunk is dedicated to storage for the crewman's personal effects.

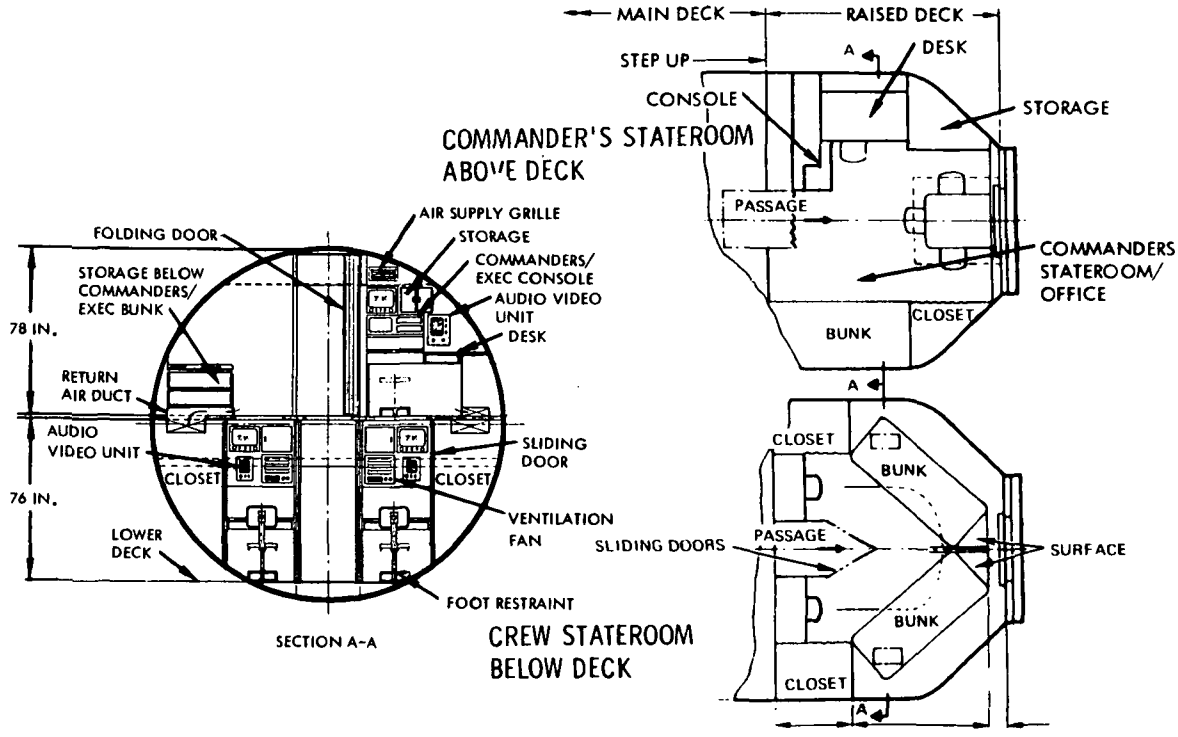


Figure 1-61. Crew Staterooms

The commander's and executive's stateroom and combination office is located directly above the crew staterooms. This facility contains a desk, conference table, bunk, command control console, wardrobe-type closet, television, audio unit, crew overlap bunk, and storage. This stateroom is separated into three functional areas: personal, office and conference. The personal area includes the bunk and personal storage located below the bunk and in the wardrobe-type closet. The office area contains a desk and storage facilities and the command control console. The conference area provides a conference table and three seating restraints. The crew overlap bunk utilizes this conference table in conjunction with stowable frames that attach to each side of the table to provide the full 78-inch length. The conference can also be removed to provide access to the antenna package located on the ends of the modules.

The office area desk and command control area utilizes a single swivel-mounted seat restraint. Access to the command control console is provided from both the front face and the rear. The utilities are routed from the partition between the stateroom and the control center. The television audio video unit, and storage are located above the command control console. An accordion-type door closes off this stateroom-office complex from the main deck area of the module.

Ventilation fans are located throughout the station to provide air distribution. Eight fans are located in both station module 1 and station module 4. One fan is located in each of the staterooms. Two fans are located in the subsystem volume, one at the core module end and the other adjacent to the staterooms. The remaining three fans are distributed in the main deck volume, one of which is located in the personal hygiene facility. Station module 1 has a fan located in the data analysis area and another in the backup medical care area. In station module 4 one fan is located in the medical storage area and the other in the medical-intensive care facility.

The GPL facilities provided in station module 1 are the data analysis and photo processing functions. A backup medical care and exercise area is also provided in this module. The data analysis area comprises an X-Y plotter, film viewer/editor, tape deck/strip chart, and the data analysis photo process control console. This area provides the capability for film and taped data review. This will include film editing, viewing, projection onto viewing screens, illuminated table film viewing, audio taping and playback, and X-Y plotting.

The photo processing area will provide a low-level capability for photographic processing. The photo processing equipment is contained in an 80 by 60-inch room containing a desk, light table, and storage facilities.

The backup medical care area contains a fold-away examination table and medical supply cabinet. This area is also used as an exercise area with room for a portable ergometer. When privacy is required, the area can be enclosed by a draw curtain.

Station module 4 contains medical storage, crew qualification, and intensive care areas.

The medical storage area also contains storage for distilled water supply, a trash compactor, and communication recording units. Crew qualification consists of three units: an ergometer, body mass measurement device, and lower body negative pressure device. The intensive care area is a room that can be sealed off with a sliding door. There are a fold-away examination table, a sink unit, storage, and counter surface in this room. Also contained in this room are a portable X-ray unit, a defibrillator, and an EKG unit.

1.5.5 STATION MODULE 2 AND 3

Station modules 2 and 3 provide the space station food storage, preparation, and servicing facilities and the general purpose laboratory facilities. Environmental control system air revitalization equipment with 6-man capability is also contained in each module. Drawing V030-942203 shows the complete assembly of these modules.

Design Requirements

The station modules must be compatible with the shuttle payload bay envelope, payload weight, and payload attaching provisions. One passive berthing port and one active berthing port is required. Active thermal control radiators are required on the exterior of both modules. Air revitalization equipment to accommodate six crewmen is required. Accommodations for dining and recreation are provided. GPL facilities include for mechanical, electrical, and optical functions, physics and medical/biologic laboratories and experiment operation areas. An experiment airlock and airlock loading facilities are required in each module. Table 1-12 lists the major design requirements, GPL equipment, and crew functional requirements.

Design Description

Both station modules are identical in size and construction, with variations in internal arrangement and secondary structure. Drawing V030-942205 defines the modules structural arrangement and exterior configuration. Active thermal control radiator panels cover the exterior cylindrical surface. Environmental shield panels of meteoroid bumper and insulation blanket assemblies cover the conical ends of the module. Active and passive berthing port assemblies are located on the ends of the module. The active berthing port attaches the core module at one end, and the passive port provides the attachment of the experiment airlock to the other end.

A single-level floor divides the module into an upper deck area which contains the main activity areas and a lower deck area which contains the subsystem equipment area. Figures 1-62 and 1-63 illustrate the overall configuration and internal arrangement of the modules.

Table 1-12. Station Module 2 and 3 Design Requirements

Item	Requirement
Common requirements	For equipment details, refer to DRL 66, Preliminary Performance Specification
Size	14-foot diameter x 58-feet long with local protrusions to 15-foot diameter x 60-feet long
Weight	20,000-lb target 25,000-lb maximum launch
Berthing	One active port - core module end One passive port
Corridors	Accommodate a 40- x 40- x 50-inch package size
Ceiling height	82-inch clear headroom
Accessibility	Access to all pressure walls - as a goal Three sides of all subsystem equipment accessible for maintenance Utility runs accessible
Safety	Two ways out of all compartments and modules Redundant and separated utility runs
ECS	
Gaseous storage CO_2 management	Pump down unit CO_2 removal unit CO_2 reduction unit Vent gas accumulator Accumulator pump Water electrolysis unit Water accumulator V/C water feed pump
Atmospheric control	Ventilation fans Hx and fan assembly Humidity control unit and fan assembly Pressure controls Contamination control unit Explosion and gas monitor detectors Local charcoal assembly
Special Life support	Fire extinguisher package Fire detector LiOH assembly and storage

Table 1-12. Station Module 2 and 3 Design Requirements (Cont)

Item	Requirement
EPS	
Distribution control	Secondary bus
RCS	
Propellant accumulator	H_2 and O_2 accumulator
ISS	
Command/control and monitoring	Local monitor alarm Microfilm projector
Internal comm.	Audio/video unit Hardwire intercom
GPL	Experiment airlock
Station module 2	
GPL	Optical supply/maintenance Electrical/electronic maintenance Mechanical maintenance Experiment operations area
Food management	Backup galley
Station module 3	
GPL	Physics area Medical/biological area Experiment operations area
Food management	Primary galley Dining facilities
Recreation	Recreation facilities Earth and celestial viewing window

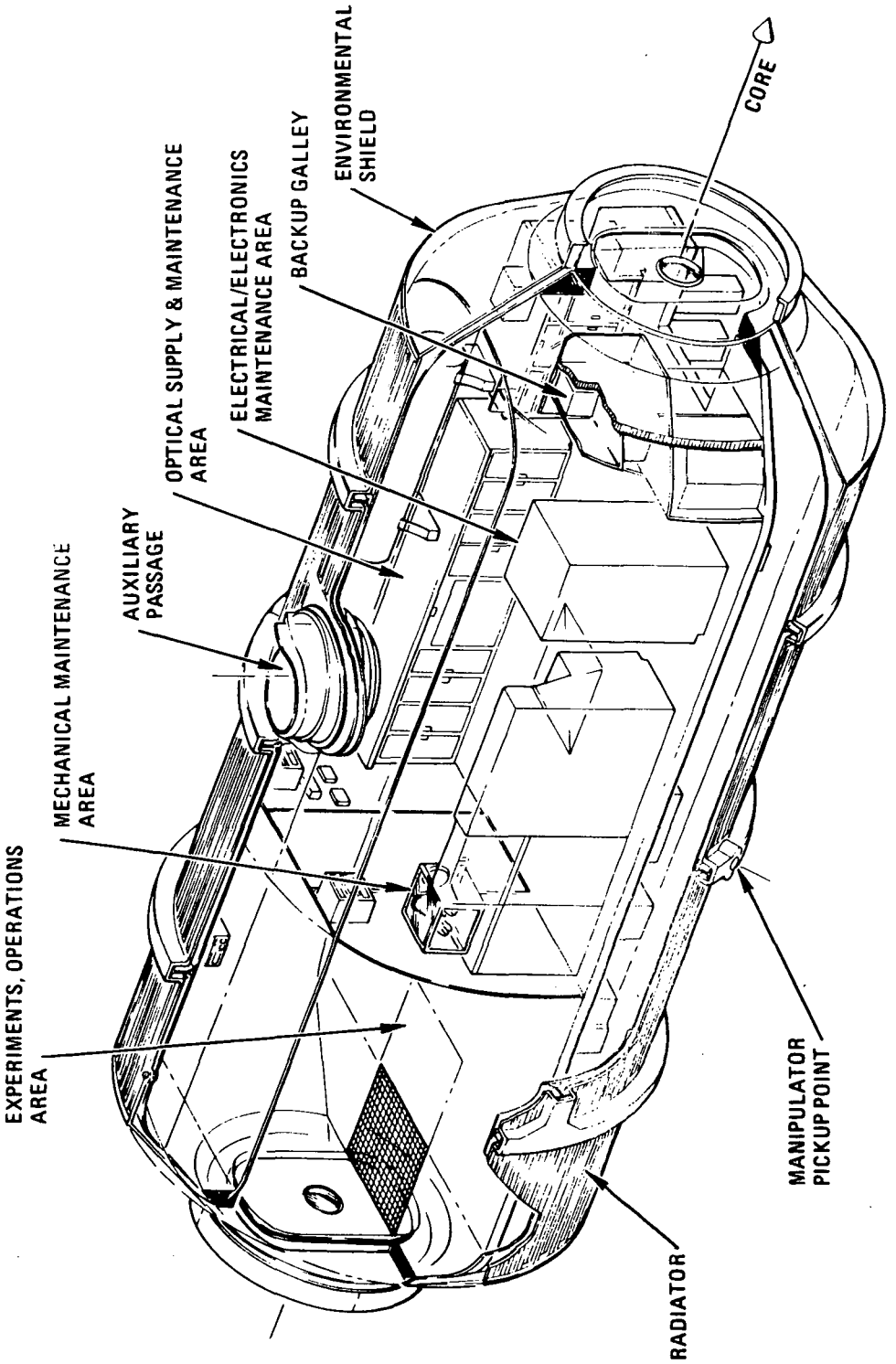


Figure 1-62. Station Module 2

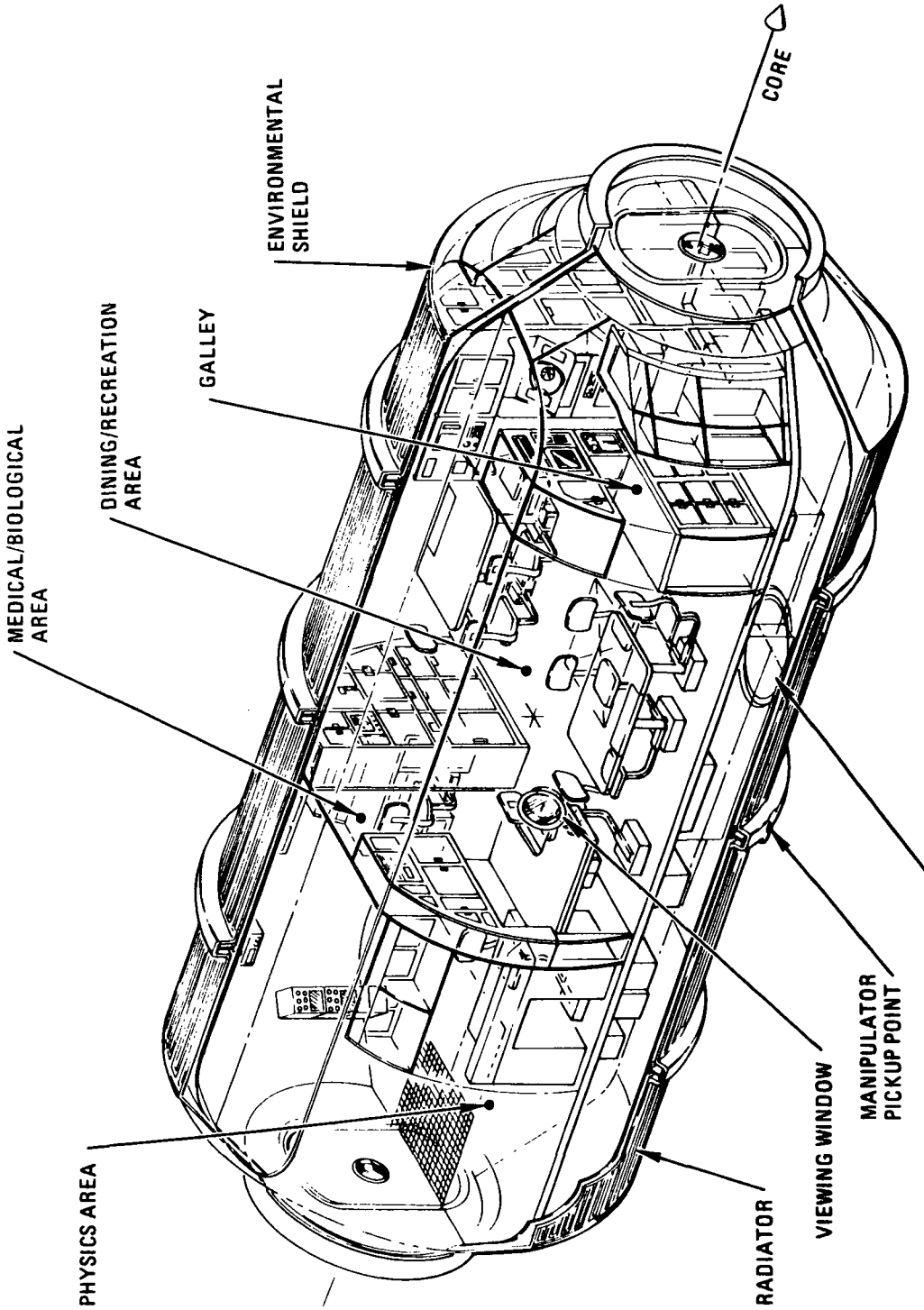


Figure 1-63. Station Module 3

Structural Arrangement

A single-level floor arrangement is utilized in these two modules. The floor is located 16 inches below the centerline of the module. A false ceiling above the floor provides an 82-inch-head height area. Figure 1-64 illustrates this arrangement. The floor assembly is a 4-inch-thick honeycomb sandwich structure attached to the pressure shell through longitudinal T-members and to fittings at the berthing port bulkhead.

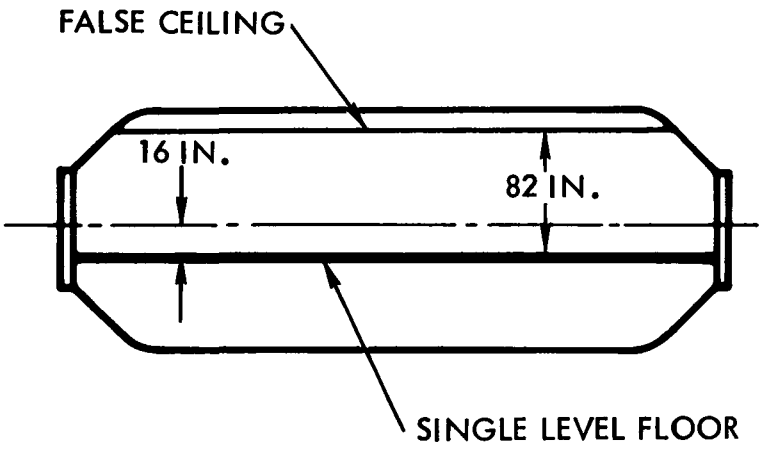


Figure 1-64. Floor Arrangement

Internal Arrangement

The lower deck area contains the air revitalization equipment. This equipment attaches to the underside of the floor on both sides of the aisleway which provides crew passage and access to the equipment. The 42-inch-wide aisleway is a maximum 60 inches high at the center and is reduced in height outboard from center by the curvature of the pressure wall. Items of equipment are spaced a minimum of 19 inches apart to provide access to the sides of the equipment in addition to the aisleway face. The air revitalization equipment includes CO_2 management, atmosphere control, contamination control, and thermal control functions. Fire extinguishers, explosion detection equipment, and electrical buses are also located in this below deck area.

Areas for utility runs and distribution are provided throughout the modules. Figure 1-65 depicts the general areas provided in both modules. An area inside the berthing port at each end of the module is reserved for distribution of the utilities, as they enter the module, to runs above and below the deck. These areas are annular around the hatch openings. The depth at the core module end is 10 inches and at the opposite end, 5 inches. This difference is attributable to the larger number and size of utilities feeding through at the core module end than at the opposite end which involves only the experiment airlock. Once inside the module, the utilities are distributed throughout the module through four raceways. In the upper deck area the utilities are located above the false ceiling. This area provides sufficient space and good access. Below-the-deck areas are provided on each side of the module behind the equipment. The proximity of these areas to the equipment areas keeps wiring and plumbing lines to minimum lengths. Another area utilized for an air supply duct is located adjacent to the aiselway below the air revitalization equipment.

Lines containing gases or liquids considered potentially dangerous are routed via double containment lines when inside the habitable area. The number and length of these lines are minimized, and they are only used for equipment interconnections. These barriered lines are vented overboard to eliminate any leakage into the habitable atmosphere.

Station modules 2 and 3 differ in the above deck area. Figure 1-66 shows station module 2 internal arrangement. Above the deck station, module 2 contains the backup galley and GPL facilities. The backup galley area is located adjacent to the core module berthing port and consists of cabinets for food storage, a food reconstitution unit, Skylab-type food tray receptacle, and a counter top. Laboratory areas and equipment are adjacent to the backup galley. An electronic work station, a multi-purpose test bench, and a mechanical work bench and storage area are on the same side of the module. Optical maintenance equipment is located on the opposite side. This area includes a zero-g bench, a calibration device, and an optical bench containing cameras, lights, and precision work fixture and equipment.

The end of the module opposite the backup galley is used for support and operation of the experiment airlock which is attached to that end of the module.

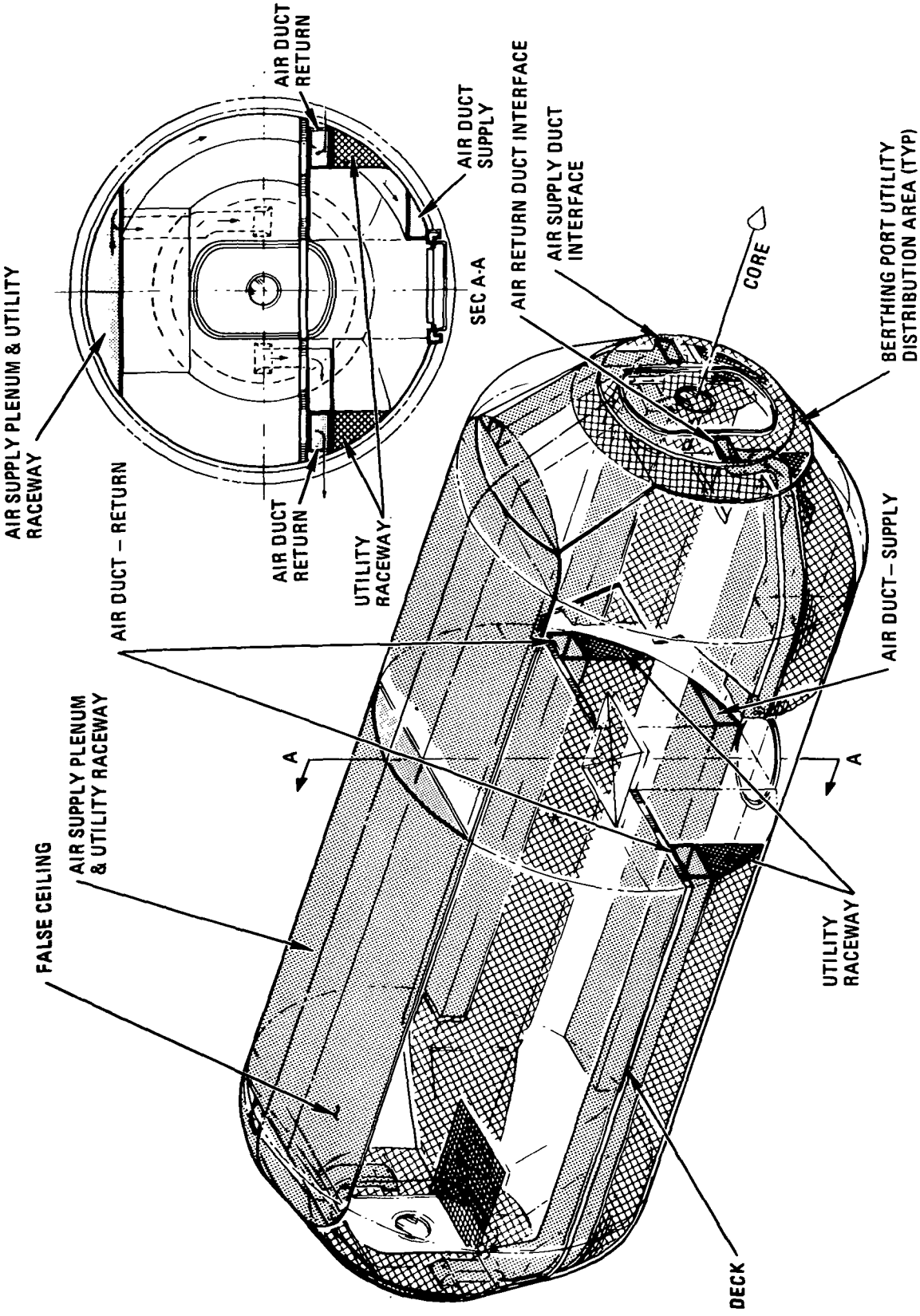


Figure 1-65. SM Utility Run Areas

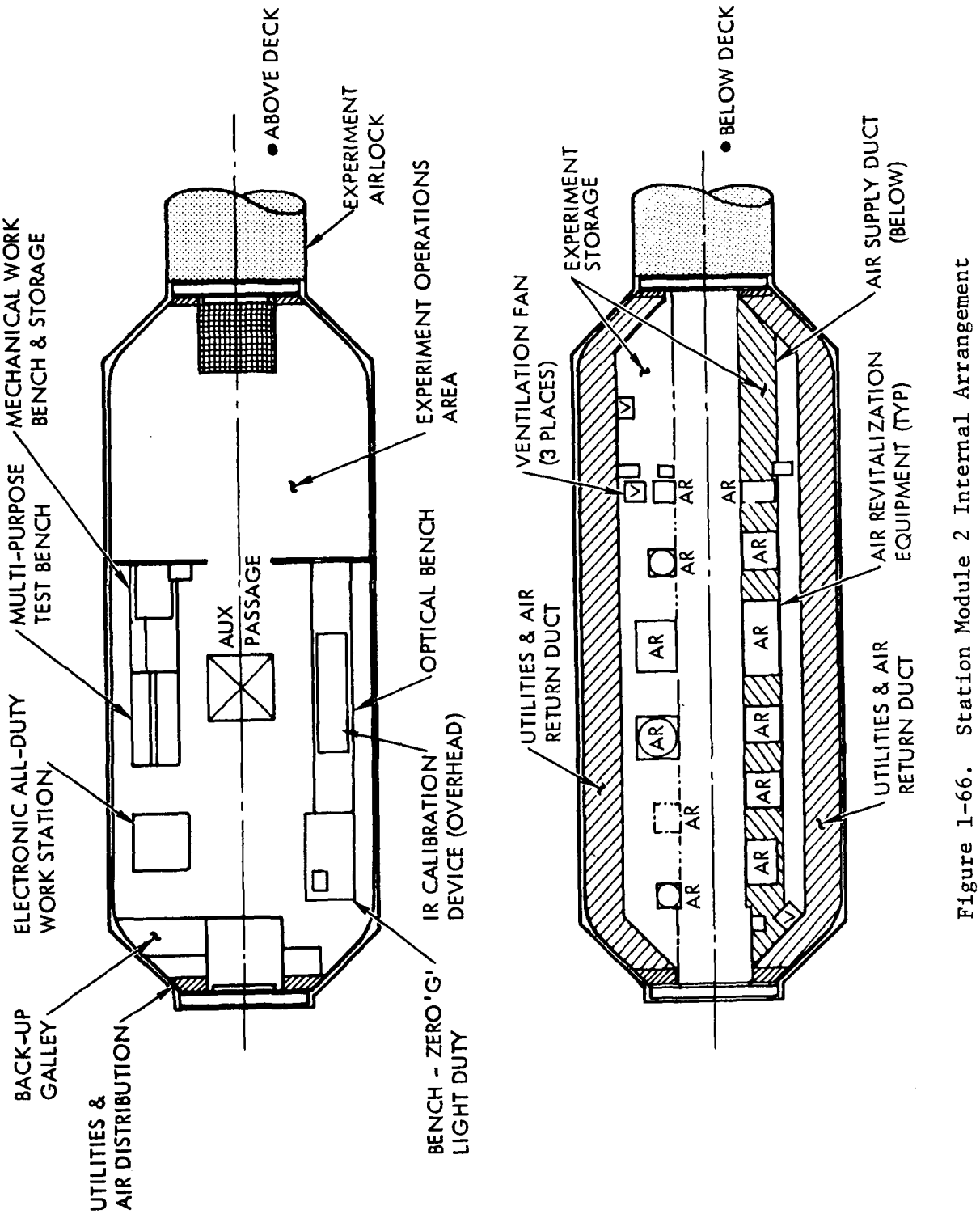


Figure 1-66. Station Module 2 Internal Arrangement

An active auxiliary passage port, previously described, is located in the upper sidewall 203 inches from the core module end as shown in drawing V030-942205. This port extends out from the upper sidewall to connect to station module 1 in the on-orbit configuration.

The upper deck area of station module 3 contains the primary galley, the dining and recreation areas, and laboratory facilities. Figure 1-67 shows this arrangement.

The galley area is located at the core module end adjacent to the berthing port. It extends to both sides of the module and includes food and utensil storage cabinets, a freezer, a refrigerator, microwave and resistance ovenes, food reconstitution unit, sink, trash compactor/processor, and food spillage unit. Inventory control equipment is also included.

The galley equipment is divided by a 42-inch-wide aisle. The galley area is adjacent to the dining area and a food pass-through opening is featured between the two areas. Two dining tables are provided in the dining area that will seat four crewmen each. A special table that will seat two people and contains storage space, is located next to the dining tables. This table is primarily used for recreational purposes, but if required during crew overlap periods, can be used as dining facilities. Each dining table has a food spillage unit incorporated into it. These units, and the one in the galley, maintain a local air flow that directs crumbs or other loose food or other particles into them. A color television monitor is located in this dining and recreation area, and storage space for dining equipment is also furnished. Emergency equipment, including portable lights, emergency oxygen masks, mobility aids and restraints, and first aid kits, is also provided in this area.

The remainder of this module above deck is devoted to laboratory areas. A physics work bench, located at the side of the module against the partition separating this area from the dining and recreation area, contains equipment used in physics experiments. A medical/biological work bench containing related equipment is located on the opposite side of the module. (These units are not installed simultaneously; that is, the area is time-shared between physics experiments and biomed experiments.) Incubators and storage space are also located in the area. Open space is shown in the vicinity of the berthing port on this end of the module which allows for operation of the experiment airlock. A cover over the access opening in the floor provides clearance for the airlock egress hatch and access to experiment storage provided below deck.

The auxiliary passage to the adjacent module is located below deck on station module 3. This passageway is located 203 inches from the core module end of the module. The auxiliary passage port connects to station module 4 when in the space station orbit operating configuration. A 42-inch square panel in the floor, in line with the auxiliary passage, provides the dual access from either the below deck area or the above deck area.

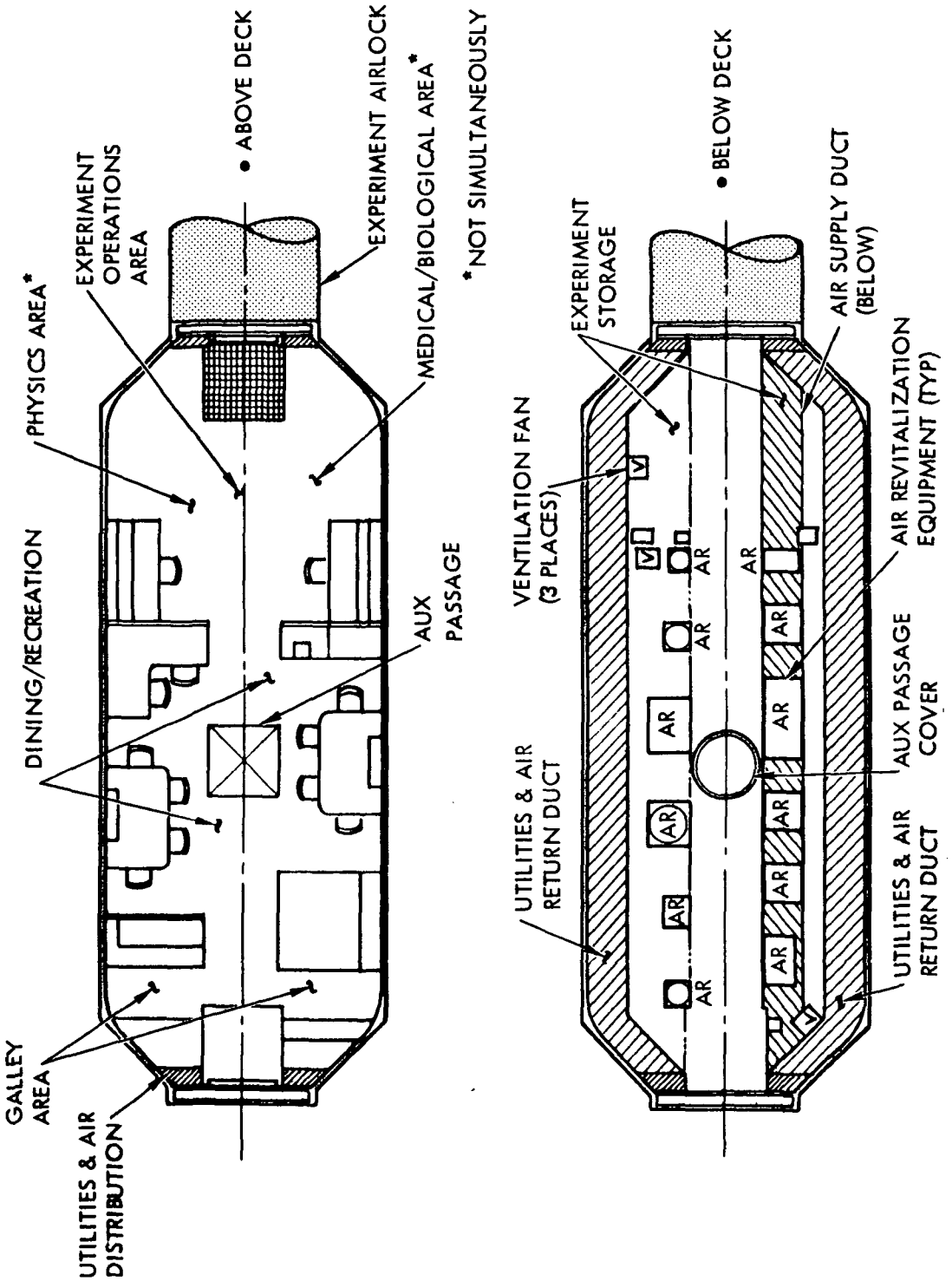


Figure 1-67. Station Module 3 Internal Arrangement

A window with a 14-inch diameter view is located in the sidewall in the dining and recreation area. This window, shown in detail on drawing V030-942205, is used for general crew recreation viewing and for verification of solar-array position.

1.5.6 BERTHING PORT DESIGN

The berthing concept is a means by which two modules are mated utilizing a manipulator to effect the mating. The manipulator provides a very slow closing velocity that permits mating with no active attenuation system. The berthing design concept developed for the modular space station utilizes an active berthing port assembly and a passive berthing port assembly. Normal operations will berth an active port to a passive port; however, a neuter capability is provided by which an active port can mate to another active port. The neuter arrangement provides a backup or emergency mode of berthing. Figure 1-68 illustrates the two berthing modes.

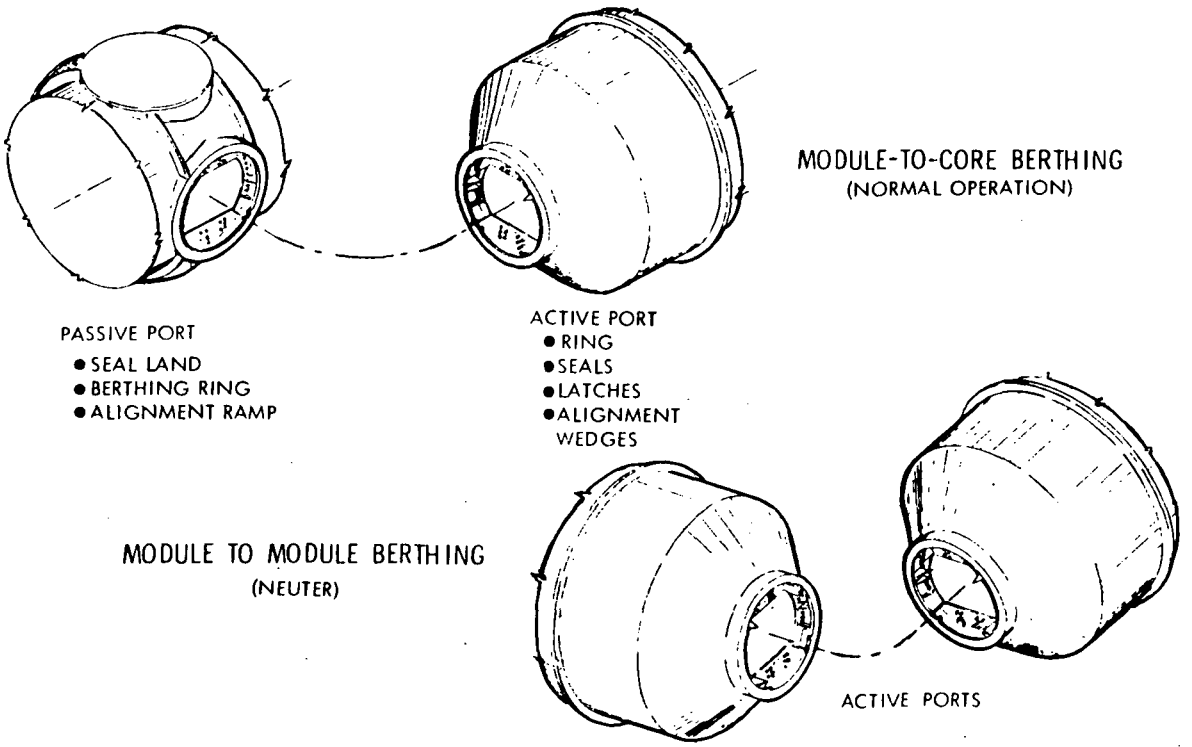


Figure 1-68. Berthing Modes

Design Requirement

The major functional requirements of the berthing design are: (1) to provide controlled mating of various modules of the space station program; (2) to provide a structural and dynamic attachment between the modules; (3) to provide a sealed volume before berthing and a sealed interface after berthing to afford a shirtsleeve environment for crewmen or cargo transfer; (4) to provide utilities interface connections for electrical power, data transfer, environmental control, fluids and gases; and (5) to provide for the installation of cargo transport facilities.

The operational requirements established for the berthing design are: (1) one common system to be used for all berthing conditions; (2) provide the capability of mating modules with large mass ranges; (3) provide the capability for direct docking by the addition of an attenuator system; (4) be capable of withstanding and transmitting maneuvering or attitude control loads applied by the shuttle; (5) have redundant mechanism; and (6) provide the capability for shirtsleeve maintenance.

The berthing design must also accommodate a $\pm$ 2-inch centerline miss distance, a $\pm$ 1-degree miss angle, an angular velocity of 0.10 degree per second, and lateral and longitudinal velocities of 0.05 foot per second.

The physical dimensions of the berthing port configuration are defined by the requirements for a nominal 5-foot-diameter clear opening capable of accepting a 40- x 40- x 50-inch maximum sized package. A common utilities interface arrangement for all ports was also established. Consequently, the utilities interfaces required for all of the modules were defined and are listed in Table 1-13.

Berthing alignment aid requirements were also established. These aids consisted of:

1. Four 15-watt lights per port
2. A 14-inch clear window centrally located in each hatch
3. Mounting provisions behind each core module berthing port hatch window for a camera
4. Alignment target and attachments behind the berthing port window of the power module, station modules, cargo module, and RAM module

Design Description

The berthing port design consists of three major assemblies: (1) the berthing interface ring, (2) a pressure bulkhead, and (3) a pressure hatch. The active and passive ports have identical pressure bulkheads and hatches. The berthing interface ring of the passive port contains only a flat berthing interface sealing surface and mating alignment guides. The active port, however, contains the interface seals, the alignment wedges that engage the alignment guides of the passive ports, and the structural latches. The active port ring also contains alignment guides that provide the capability for neuter docking. Figure 1-69 defines the passive berthing port configuration and Figure 1-70, the active port configuration. In order to accomplish neuter berthing - an active port mating to an active port - the alignment wedges are offset from a 45-degree reference as shown in Figure 1-70. This arrangement then permits the alignment wedges of each active port to engage the alignment guides of each active port which have been located adjacent to the alignment wedges. The latches are also offset to provide clearance during the neuter berthing operation.

The utilities interfacing connections are distributed around the periphery of the bulkhead and are separated to provide redundancy, minimize electrical interference, and to separate potentially hazardous gas and fluid lines.

Table 1-13. Berthing Port Utilities Interfaces

Interface	Ducting and Plumbing Utilities									
	Core	Power	SM-1	SM-2/5	SM-3/6	SM-4	RAM	Cargo	Ant Pkg	Al. Exp
Freon supply (pri & sec)	2		2	2	2	2				1
Freon return (pri & sec)	2		2	2	2	2				1
H_2O coolant supply (pri & sec)	2		2	2	2	2	2	2	1	
H_2O coolant return (pri & sec)	2		2	2	2	2	2	2	1	
H_2O potable supply	1		1	1	1	1	1	1		
H_2O waste return	1		1	1	1	1	1	1		
H_2O electrolysis	1		1	1	1	1	1	1		
O_2 supply (EPS)	2	2	2	1	1	2	1	1		1
N_2 supply	1	1	1	1	1	1	1	1		1
H_2 RCS or EPS	2	2	2			2		1		
Air pressure	1	1	1	1	1	1	1	1	1	1
Air processing ducts	2	2	2	2	2	2	2	2		

Interface	Electrical Utilities									
	Core	Power	SM-1	SM-2/5	SM-3/6	SM-4	RAM	Cargo	Ant Pkg	Al. Exp
Power-primary (20 kw)	8	8								
Power-secondary (7 kw)	4	4	4	2	2	4	2	2	4	2
G/N-RCS	X	X	X			X				
ECLSS	X	X	X	X	X	X	X	X		
ISS	X	X	X	X	X	X	X	X	X	
Comm.-Audio/visual	X	X	X	X	X	X	X	X	X	X
Data-digital/analog	X	X	X	X	X	X	X		X	X

Space Division
North American Rockwell

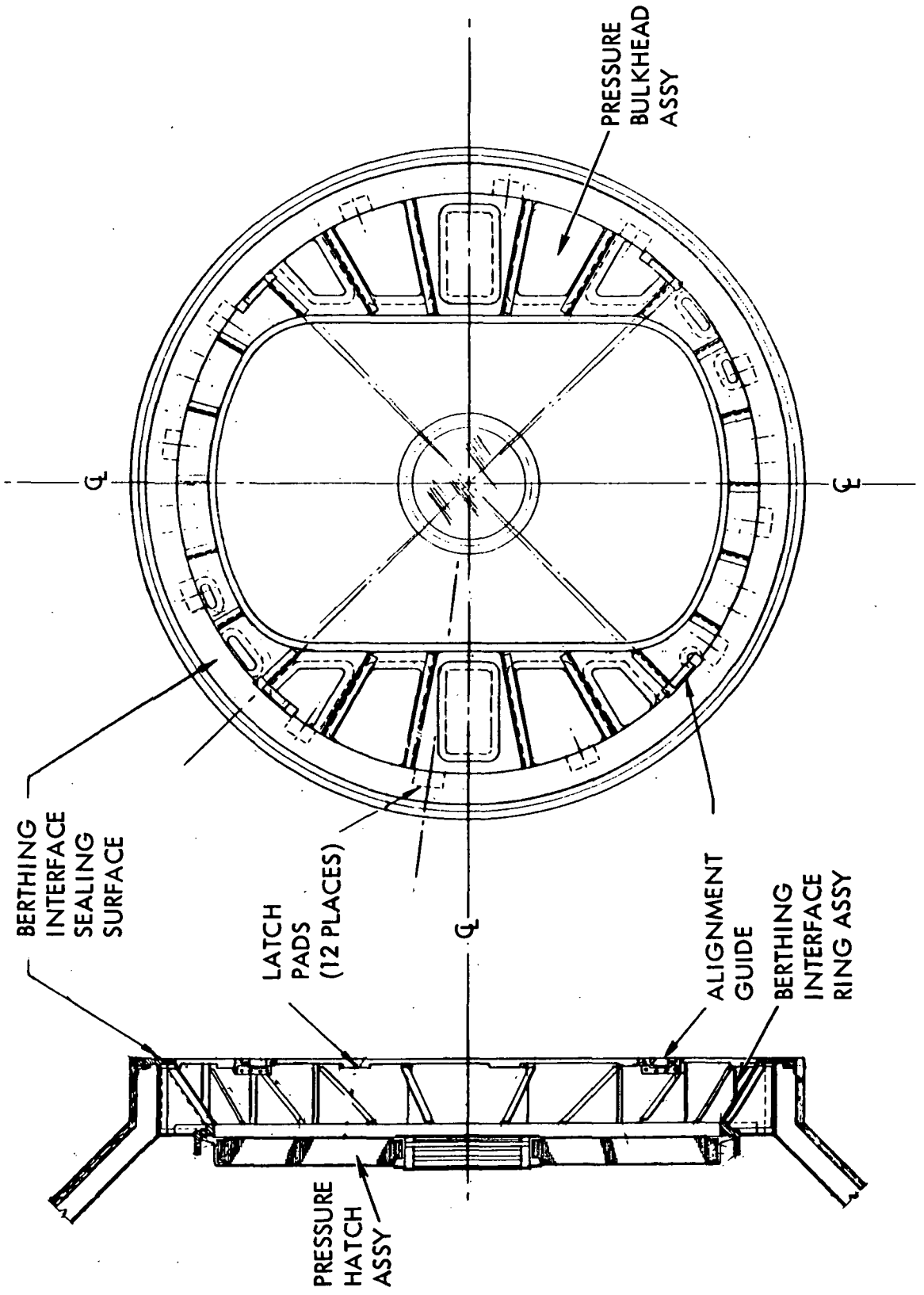


Figure 1-69. Passive Berthing Port Assemblies

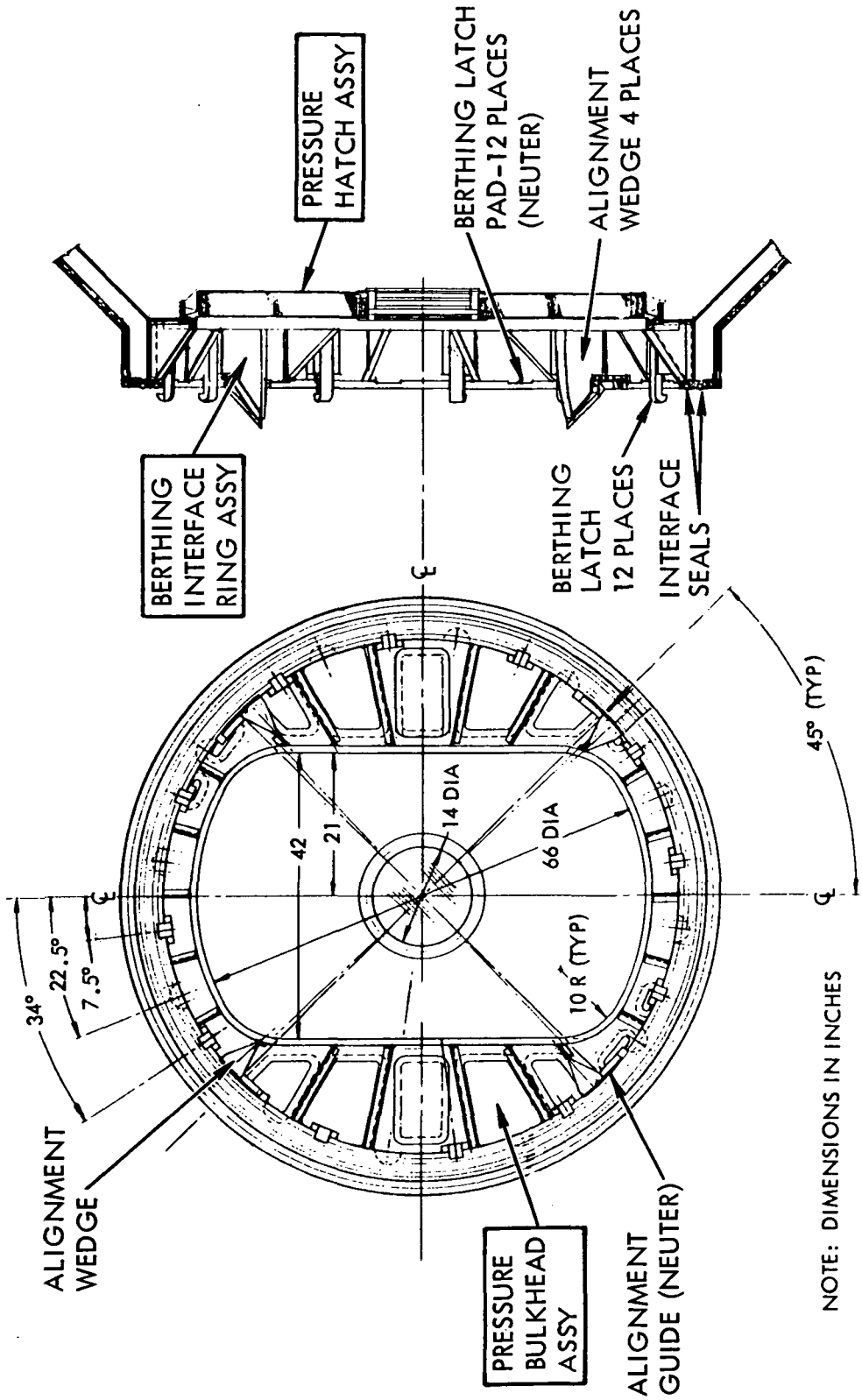


Figure 1-70. Active Berthing Port Assemblies

Individual plates to which the utility connections are mounted are sized to fit between the structural ribs of the pressure bulkhead. This arrangement provides the flexibility to accommodate any combination of utilities required for any particular berthing port.

The pressure hatch is identical for all ports and contains a 14-inch-diameter clear window in the center of the hatch for berthing alignment and visual assessment where required. The hatches have the capability to be opened from either side.

Structure

The berthing ports and their backup structure are designed to support all loads due to berthing, pressure differentials, and/or loads from station or shuttle maneuvers.

The berthing ring is a 2219-T87 aluminum-forged ring approximately 12 inches deep by 5 inches thick by 7 feet in overall diameter. The port bulkhead is a 2219-T87 aluminum-forged plate 5 inches thick by 82 inches overall diameter. These two forgings are rough-machined, welded at the approximately 80-inch diameter, and then finish-machined into the active ring-pressure bulkhead configuration or the passive ring-pressure bulkhead configuration. Both configurations are identical except for the berthing interface seal grooves. The bulkhead accommodates the pressure hatch and the utilities feed-through plates. Structural gussets between the ring and the bulkhead provide the bulkhead pressure reaction and also act as separators between the adjacent utilities. Preliminary design drawing V030-942004, berthing port assembly, defines the configuration.

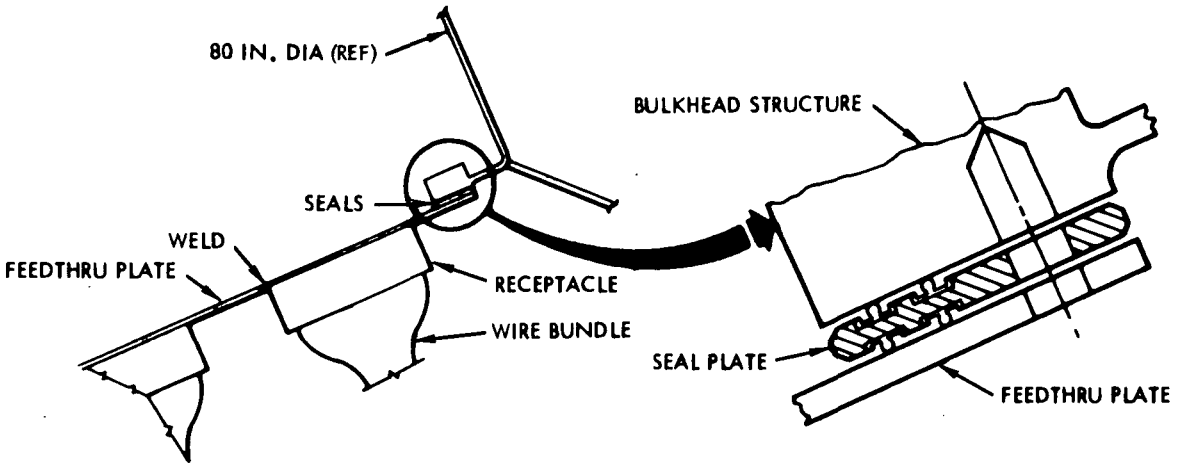
Berthing Interface Seals

Sealing of the berthing interface is accomplished with dual seals in the face of the active berthing ring. The passive berthing port ring provides the berthing seal surface. The seals are the only components of the berthing design that are not accessible in a shirtsleeve environment. Consequently, these seals are provided on the active berthing port of the module to be assembled to the space station. This arrangement permits inspection on the ground before launch to assure a quality seal.

The various connectors -- electricl, fluid, and gas -- are mounted into individual plates that are shaped to fit the particular pressure bulkhead opening. These plates are then bolted to the bulkhead along with a sealing plate of the same shape. The sealing plate provides the pressure seal. Figure 1-71 illustrates a typical installation.

Alignment

The berthing alignment operation for any module attaching to the space station is accomplished by the shuttle manipulator crew. A closed-circuit television camera is mounted on the centerline of the berthing port behind the hatch window of the port to which the berthing is to take place. An alignment target is located on the centerline of the berthing module behind



SECTION A - A

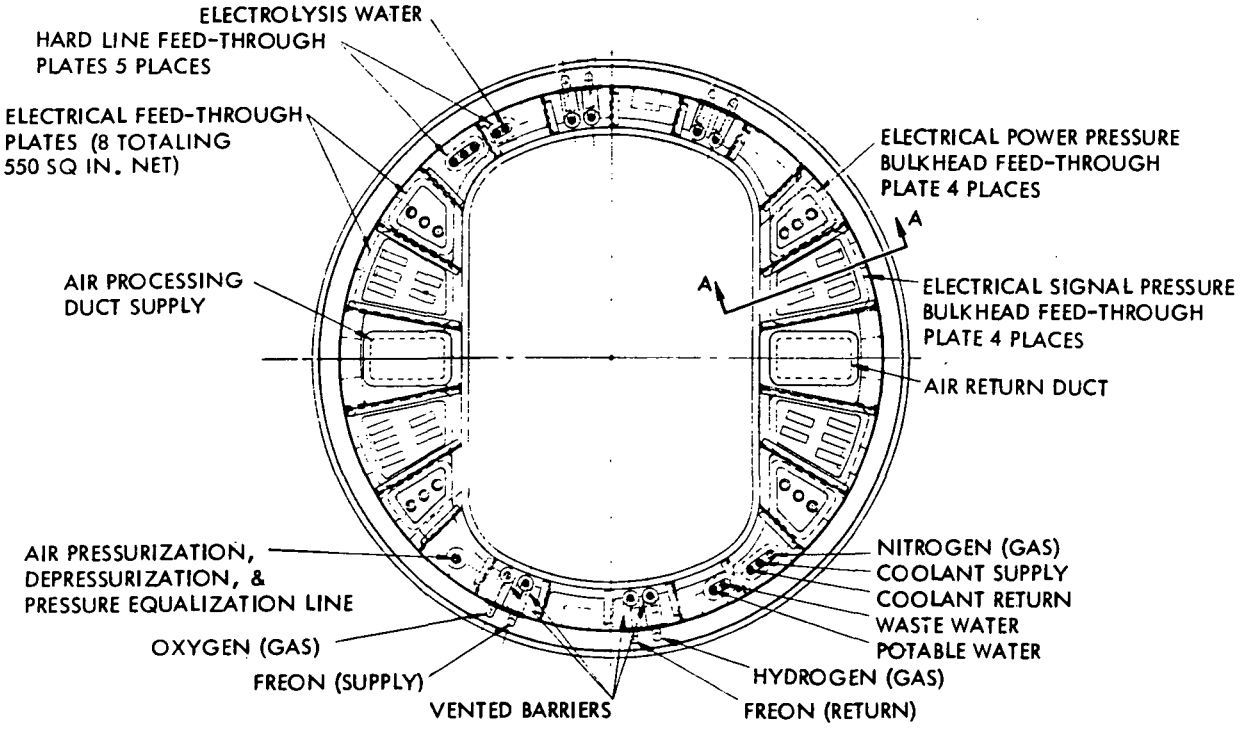


Figure 1-71. Berthing Port Utilities Arrangement

its hatch window. The manipulator operator aligns the module with the aid of the closed circuit television camera. Four lights on the core module berthing port illuminate the berthing module port and target. Figure 1-72 illustrates the alignment concept.

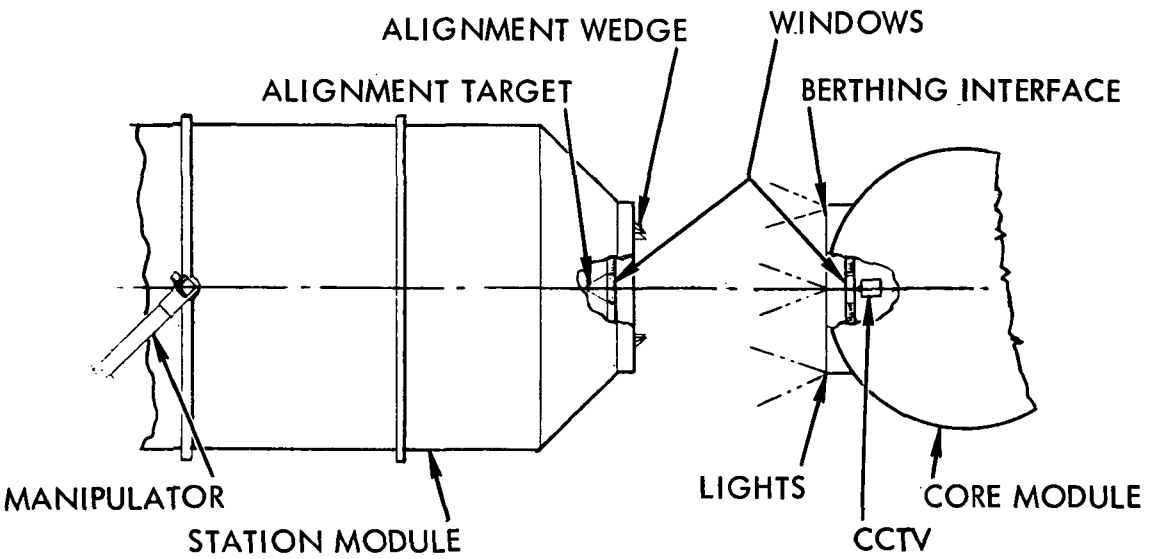


Figure 1-72. Berthing Alignment Concept

Mating

The mating portion of the berthing operation consists of the guiding of the module to its final position and latching the module to effect a structural attachment and a pressure seal.

The active port has alignment wedges and alignment wedge guides, while the passive port has alignment guides only (Figures 1-69 and 1-70). The alignment wedges act as fingers that are tapered so that the approaching ring's alignment guide will mesh with it. The intermeshing, tapered wedges and guides provide radial and angular indexing capability. The wedges and guides also provide final alignment and shear capability.

The active ring (Figure 1-70) contains 12 independently operating, automatic berthing latches. The latches are tripped upon contact of the two berthing rings. The latches provide the pull-down and clamping force necessary to accomplish the final sealing and structural continuity between the two modules. For module separation, the berthing latches are individually power-released and automatically reset for the next berthing engagement.

Utilities Interface

The utilities interface connections are located around the berthing port bulkhead and include electrical signal and power lines, and air processing ducts. The arrangement of the utilities through the bulkhead are shown in Figure 1-71. Space has been provided between the berthing ring and the hatch opening to accommodate 52 total umbilical connections. There are 18 plumbing lines (water, nitrogen, hydrogen, oxygen, freon), 2 air processing ducts, 20 electrical signal connections, and 12 electrical power connections that can be made across the interface. Not all of these connections are made at every interface. However, dedicated locations for the specific utility interface is common at all berthing ports. These connections are manually installed across the berthing interface by the crewman after berthing, sealing, and pressurization have taken place. Manual connection of the umbilicals has been utiltized to take advantage of the crewman's ability and to minimize system complexity.

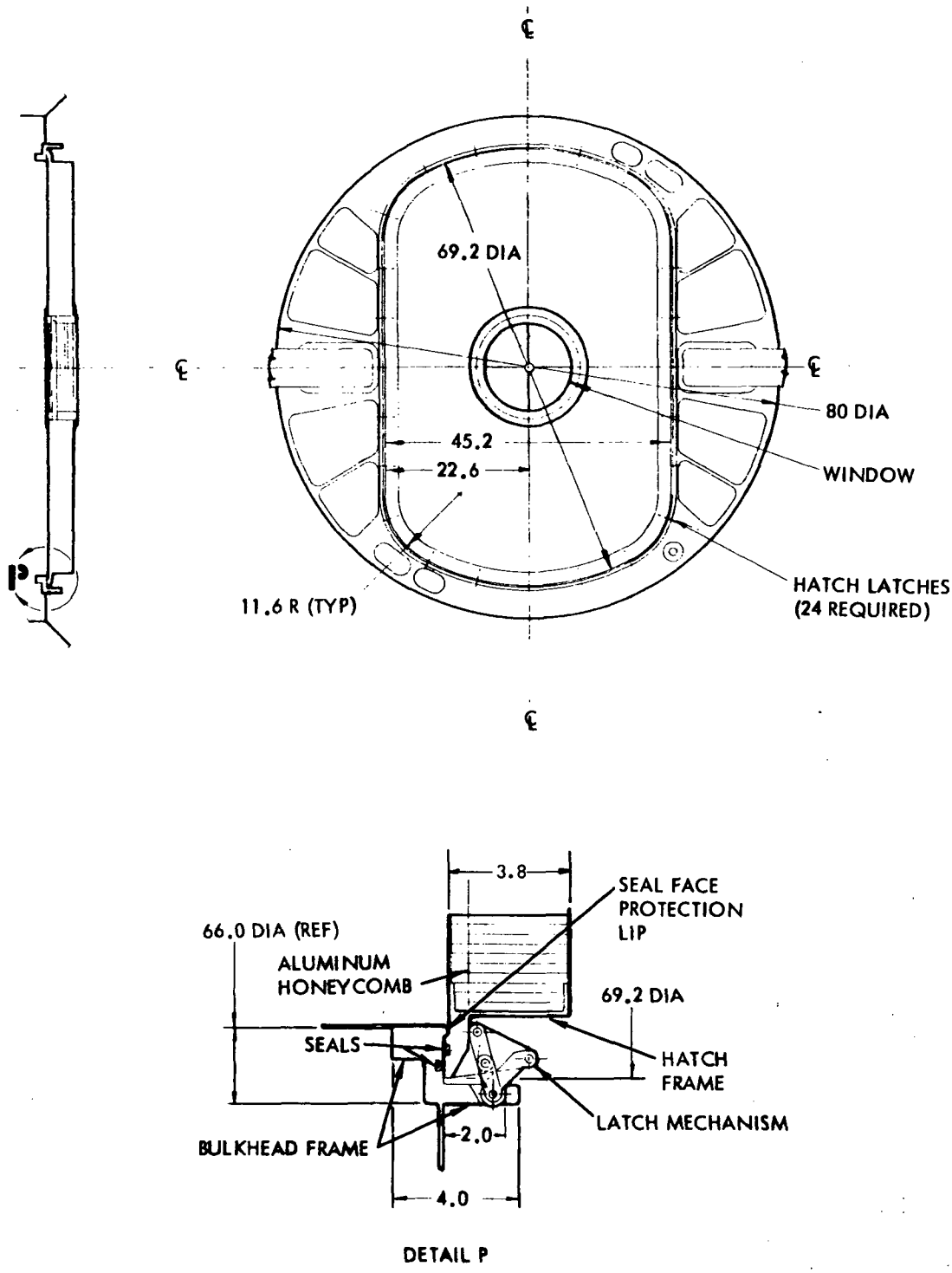
The water (potable, waste, cooling and electrolysis), oxygen, and nitrogen lines are connected directly between the pressure bulkheads of the berthing ports. The hydrogen, oxygen and freon lines, however, are double-walled lines with the outer space vented overboard. The hydrogen and freon line connections penetrate the outer, or pressure, wall of the berthing port between the bulkhead and the berthing ring. These fluid and gas lines are routed outside of the pressure hull where possible, with only the short connection across the interface being within the habitable area. This arrangement minimizes the probability of contamination to the station atmosphere.

The electrical signal connections are separated from the power connections to eliminate any unwanted signal contamination. Each of the 20 signal connectors can have up to 104 pins, thereby providing a total of 2080 individual connections at any port.

Hatches

All of the berthing port pressure bulkheads provide a 42- by 66-inch clear opening in order to accommodate the 40- by 40- by 50-inch package size. Each opening is covered and sealed by identical hatches.

Figure 1-73 defines the common pressure hatch utilized at all of the berthing ports. The berthing port is sealed from the remainder of the module by the pressure hatch. After berthing of the modules has been accomplished and pressurization has taken place, the hatch or hatches are opened to provide crew or cargo passage. The hatches are all supported to allow controlled manual opening in order to minimize seal wear and to prevent possible damage to the module, hatches, and seal. The latch and lock mechanisms are located on the pressurized side of the hatch to allow the observance, maintenance, and/or replacement of the mechanism. The hatches are capable of being opened



ALL MEASUREMENT ARE IN INCHES

Figure 1-73. Berthing Port Hatch

from either side. A 14-inch diameter clear opening window is provided in the center of the hatch. Mounting provisions for the closed circuit television camera or alignment target are also provided. Individual hatch assemblies, hatch mechanisms, and the window are all replaceable.

The basic hatch structure is an aluminum honeycomb sandwich with a peripheral edge number. The edge member accommodates one of the redundant seals with the other seal being mounted in the bulkhead hatch jamb. The edge member also has mounting provisions for the 24 over-center latches. Each latch is individually adjustable and/or replaceable.

Maintainability

A major feature of the berthing design is the shirtsleeve accessibility to all its components after the modules are mated. This provides complete accessibility for service, maintenance, and replacement of all components except the berthing ring seals. The same component accessibility is available for the utilities interface umbilicals. All critical components are capable of crewman disengagement and replacement in case of any failures of the machanisms. In addition, all mechanisms such as latches, windows, hatches, and utilities umbilicals are identical throughout the MSS.

Direct Docking

The berthing ports have the capability to accept a direct docking station assembly mode in lieu of a shuttle manipulator assembly mode. This capability is provided with the addition of an adapter that contains an active attenuation system as illustrated in Figure 1-74. This adapter would be bolted directly to the berthing interface ring. The utilities interfaces and hatch would not be affected. Each docking module would, therefore, be approximately 2 feet longer due to the addition of the adapter.

1.5.7 ANTENNA PACKAGE

The antenna package is an integrated structure, mechanism, and electronic components unit that provides VHF, S-band, and K-band communications in a single package. The external communications assembly is contained in the two packages to provide the full, specified antenna coverage for the MSS. Each antenna package contains the VHF, S- and K-band antennas and their transponders, and the K-band antenna drive motors and gearboxes. These packages are mounted on the outboard end of station modules 1 and 4 and are launched with the modules. An active berthing ring is provided on the package to provide replacement capability. Shirtsleeve maintenance of all components is provided except for the K-band parabolic antenna and antenna-mounted electronics. The physical and functional characteristics of the antenna packages are described in the Information Subsystem section of SD 71-215-4. Preliminary design drawing V030-942002 defines this antenna package configuration.

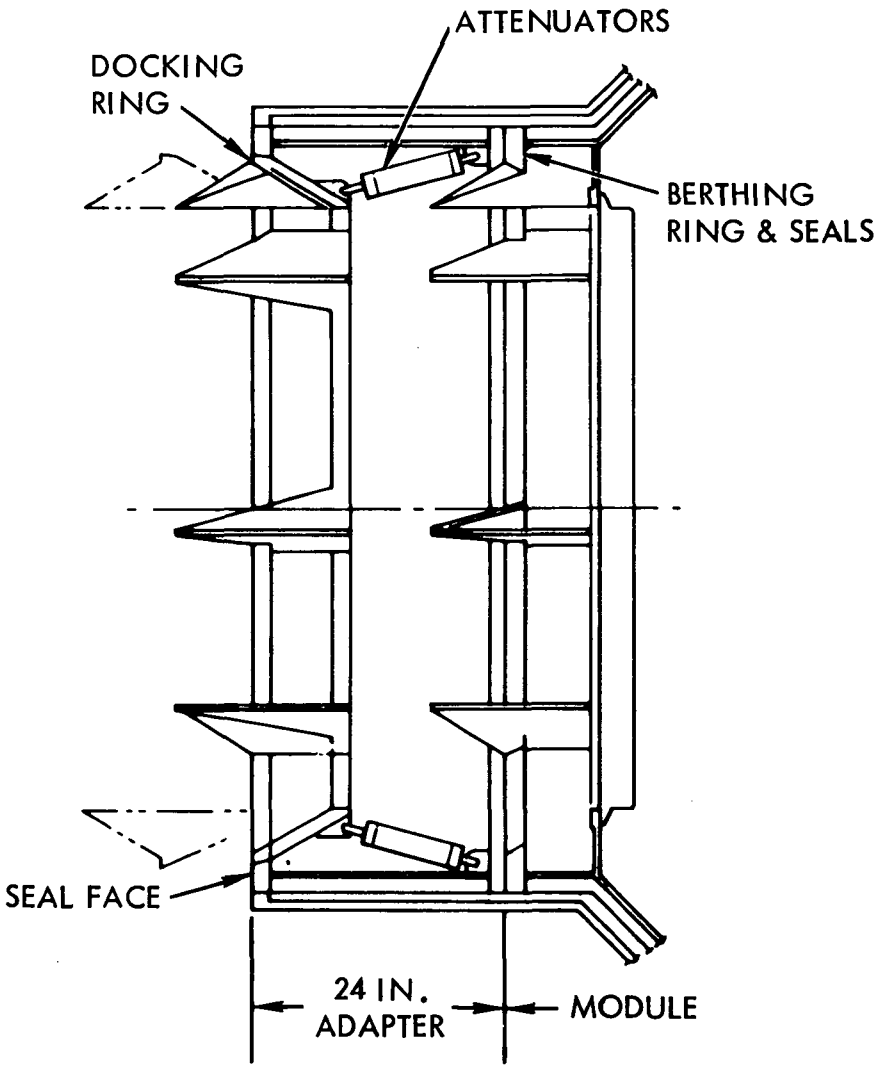


Figure 1-74. Direct Docking Adapter

Design Requirements

The design requirements for the antenna package were: (1) to provide two identical packages, (2) to provide a sealed volume for a shirtsleeve environment for maintenance, and (3) to provide a completely replaceable unit.

The performance requirements of the antenna package were: (1) to provide the specified antenna coverage, (2) to provide antenna coverage at or prior to the specified time of use, and (3) to provide redundant components in systems not shirtsleeve-maintainable in orbit.

The required antenna coverage is shown on Figure 1-75 by the solid line while the cross-hatched area represents the coverage provided.

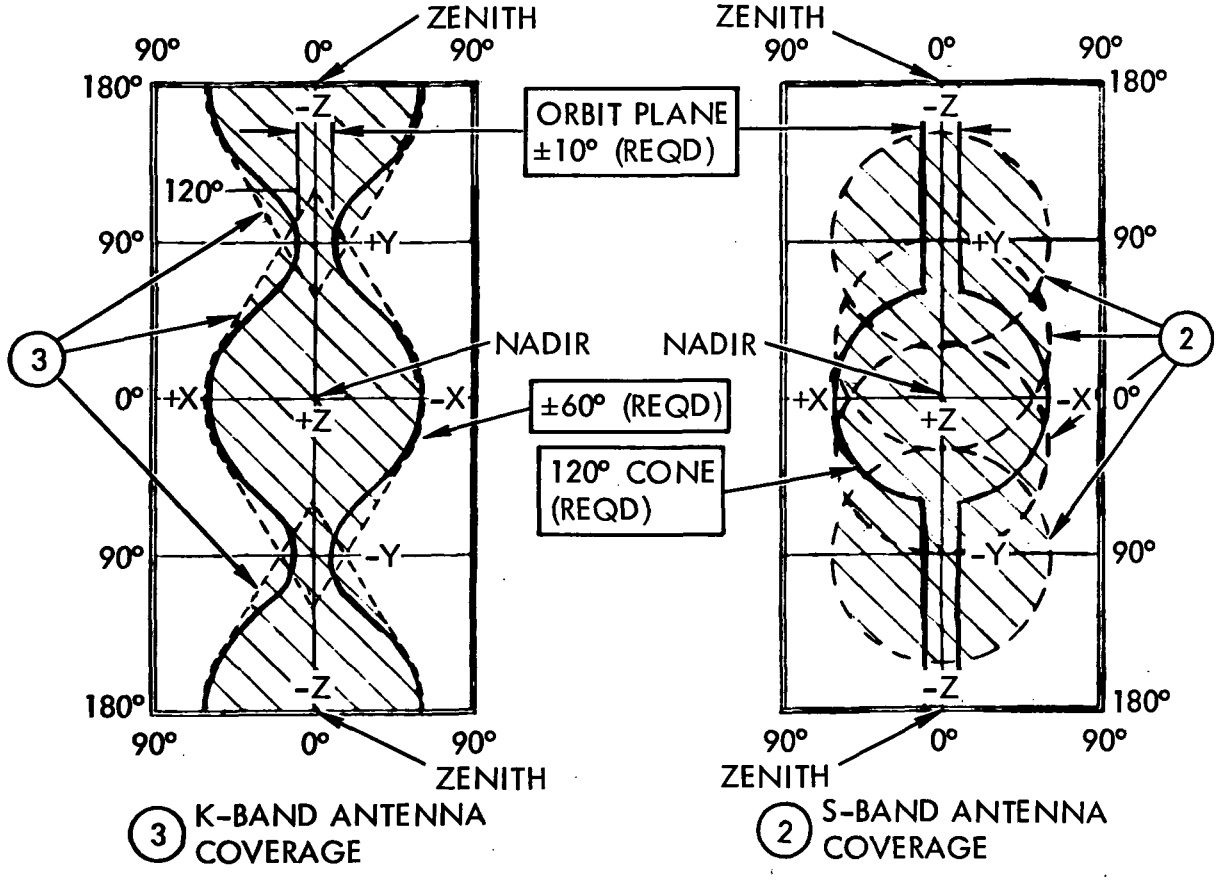


Figure 1-75. Antenna Coverage

Design Description

The antenna packages are located on the +Z and -Z ends of station module 1 and station module 4, respectively. They are installed, checked out and launched with these modules. Figure 1-76 illustrates the installation and the antenna viewing angles provided.

The antenna package structure is a truncated, cone-shaped pressure hull containing an active berthing port and covered with an environmental shield. A rotatable mount for the K-band antenna and transponder is located in the flat end. Two S-band window hemispheres are located in the cone sides. Two VHF whip antennas are located in the cylindrical berthing ring area.

Inside the structure is located the S-band antennas, the VHF and S-band transponders, and the K-band rotatable mount drive motors and gearboxes.

Antennas

In order to accommodate the K-band antenna with a 120- by 240-degree field of view, a two-axis rotation mount was provided. The antenna rotates about the Z-axis between 360 and 720 degrees and rotates 180 degrees about its axis in the XY plane. Figure 1-77 illustrates this arrangement. Combining these two axes allows 66 percent spherical coverage centered about the local Z-axis and vectored away from the MSS. The 5-foot dish antenna is coupled to redundant electronics that also act as its counter balance. The antenna and its support are driven by gear motors located within the antenna package pressure hull.

The S-band antennas are fixed-mounted inside the pressure structure and are positioned to provide the 120-degree field of view. The antennas' coverage differs between the +Z (nadir) and the -Z (zenith) installation. On the +Z installations, the antenna centerlines are oriented 30 degrees either side of the +Z-axis, while on the -Z installation the antenna centerlines are oriented on the Y-axis. Figure 1-78 illustrates the two positions of the antennas utilizing identical bracketry designed to accommodate either antenna position. The two transponders are in the interior cone section of the pressure hull adjacent to the antennas.

The two VHF band antennas possessing spherical coverage are mounted outside the pressure hull. These 24-inch-long whip antennas are mounted diametrically on the Y-axis in the cylindrical berthing port area. Consequently the two antennas in each package provide the spherical redundant coverage. Their transponders are mounted in the interior cone section of the pressure hull also adjacent to the antenna (Figure 1-78).

Structure

The structural arrangement consists of a series of primary subassemblies welded together to form the pressure hull. Other subassemblies are bolted or bonded to the pressure hull to make up the antenna package structural assembly (See Figure 1-79).

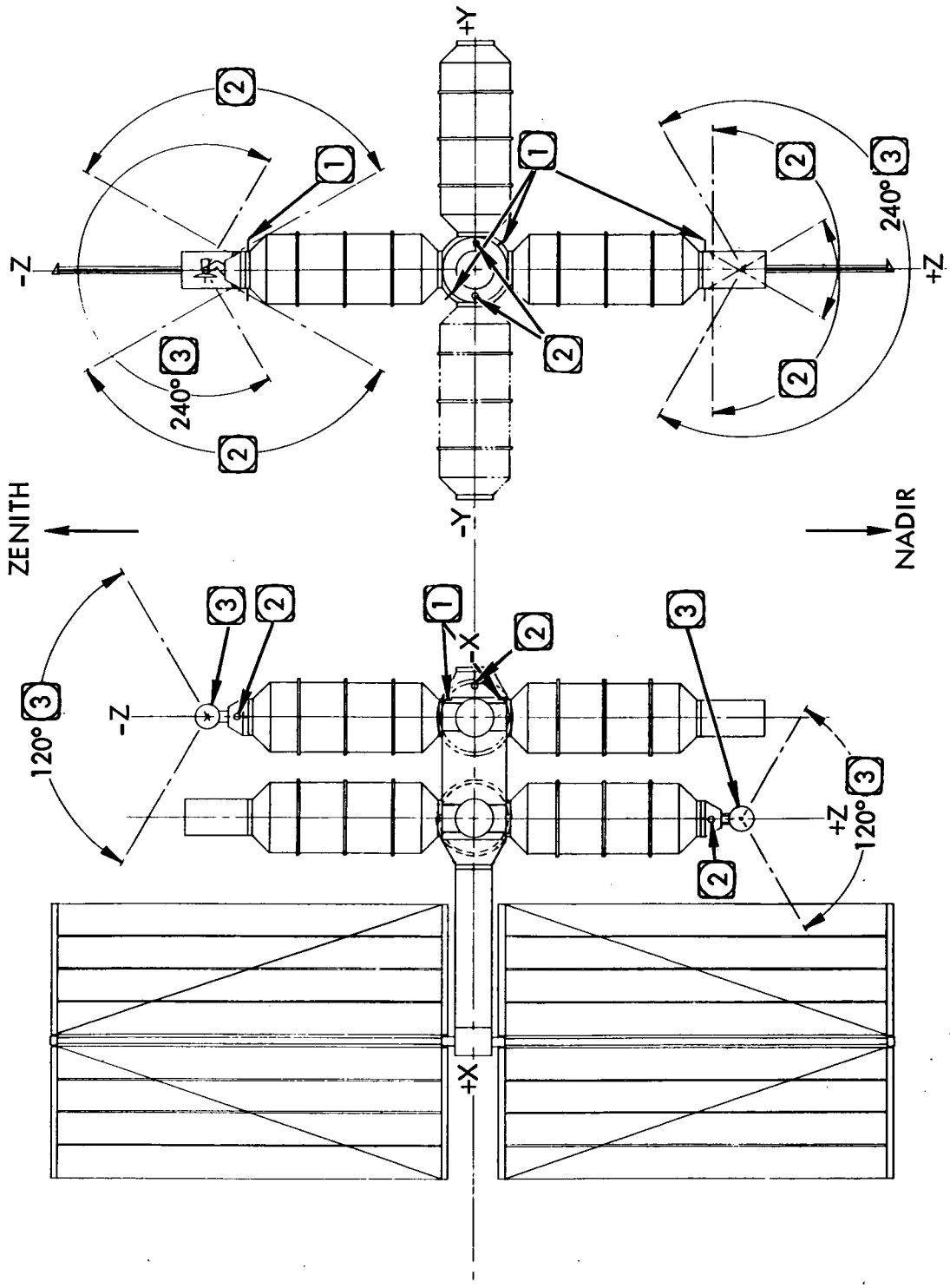


Figure 1-76. Antenna Location

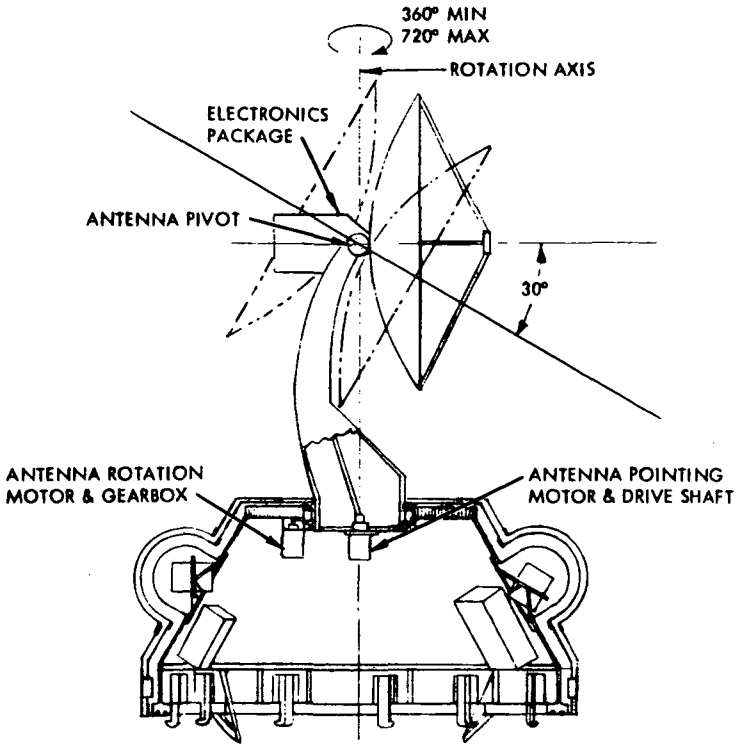


Figure 1-77. K-Band Antenna Arrangement

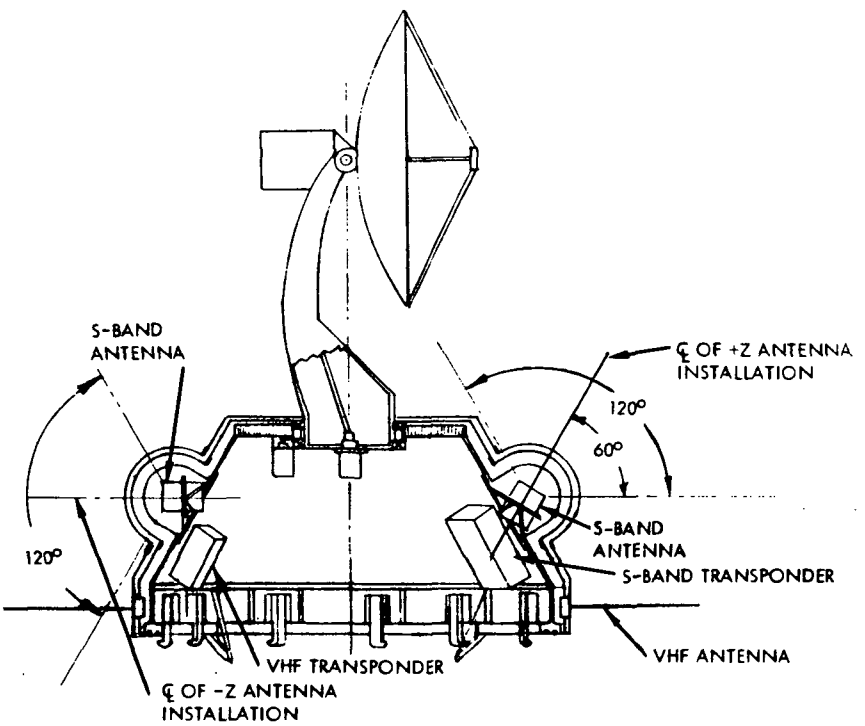


Figure 1-78. S-Band and VHF Antenna Arrangement

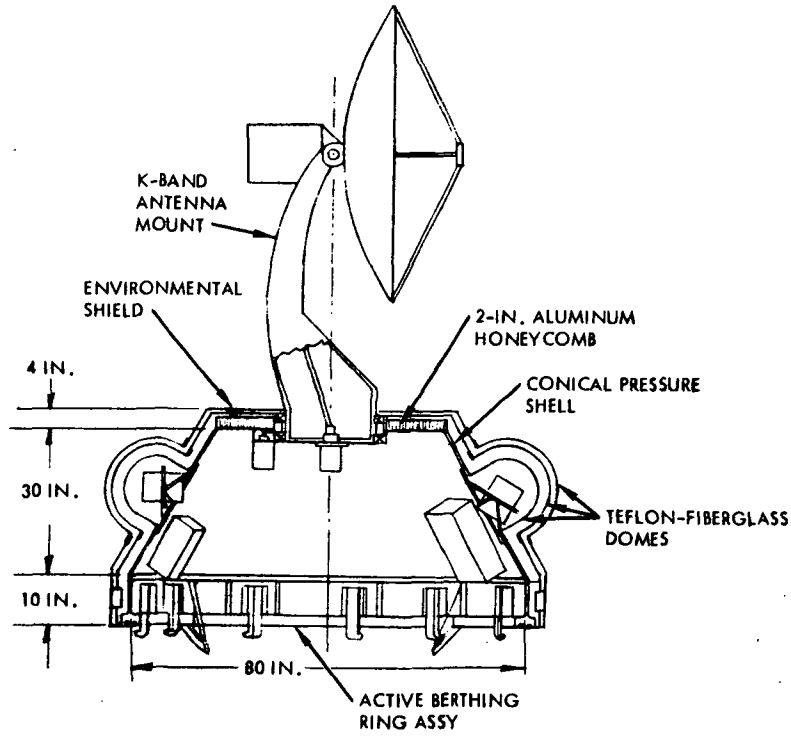


Figure 1-79, Structure Arrangement

The antenna package pressure hull subassembly is a pure monocoque structure of three basic sections. In the center is a 60-degree truncated cone, 30 inches long, constructed of 0.145-inch 5052-H34 aluminum. One end of it is welded to a 10-inch-long, 80-inch-diameter cylindrical berthing ring that was machined from a 2219-T87 aluminum ring forging. The other end is welded to the edge frame of a 2-inch-thick bulkhead of aluminum honeycomb sandwich construction. In the center of this bulkhead is the frame that holds the bearings and seal for the rotatable antenna mount.

The environmental protection subassembly is made up of a meteoroid bumper, an insulation blanket and a closeout liner/secondary bumper supported by fiberglass insulation/isolation brackets bonded to the pressure hull. The meteoroid bumper is 0.030 fiberglass laminate. The insulation blanket consists of approximately 60 layers of aluminized mylar separated by loose woven nylon. The closeout liner and secondary bumper is 10-mil Kapton.

Two hemispherical S-band antenna windows are provided in the cone area. Each consists of three concentric domes. Two domes of teflon-fiberglass are provided for meteoroid protection in the environmental shield. One dome of teflon-fiberglass is attached to the pressure hull to provide a pressure tight installation.

The K-band antenna mount support is located in the end bulkhead center frame. The antenna mount utilizes an aluminum box construction. This mount supports the K-band antenna and transponders approximately 50 inches outboard of the end bulkhead. The mount rotates in bearings in the bulkhead frame. An inflatable seal allows pressurization of the antenna package for shirtsleeve maintenance. The Z-axis rotation drive motor and gears are mounted to the bulkhead. The XY-axis drive motor and gearbox is located on the base of the antenna mount. The XY-axis drive motor drives the antenna by shafting through the mount to another gearbox on the XY-axis. This feature allows maintenance and/or replacement of both drive motors.

1.5.8 EXPERIMENT AIRLOCK

The experiment airlock is an integrated structure and mechanism that provides a pressurizable unit from which experiments can be exposed to space. Experiments can be mounted on the outer hatch or on pallets deployed from the airlock. A nadir pointing airlock attached to station module 2, and a zenith pointing airlock attached to station module 3 is provided. Preliminary design drawing V030-942005, Experiment Airlock - Modular Space Station, defines the configuration.

Design Requirements

The design requirements of the experiment airlock were: (1) to provide two identical airlocks, (2) to provide utilities interfaces to support the experiments, (3) to provide a means for loading the airlock, (4) to provide 14-inch-diameter clear windows on both ends of the module, and (5) to have the capability to be replaced. The clear inside dimensions were to be 80 inches in diameter and 12 feet 6 inches long with an external hatch capable of exposing the total 80-inch diameter.

Design Description

The experiment airlocks are located on the +Z and -Z ends of station module 2 and station module 3, respectively. They are installed, checked out, and launched with these modules. Figure 1-80 illustrates the arrangement as installed on the initial station.

The airlock structure is a cylindrical pressure hull with an active berthing port configuration on the end attached to the station modules and hinged to the outboard end is a deployable hatch with a window and an outer environmental shield. The total package is covered with an environmental shield.

Structure

The structural arrangement consists of a cylindrical pressure shell, two berthing rings, and a hatch. Other subassemblies are bolted or bonded to the pressure shell. Figure 1-81 illustrates the general arrangement of the airlock.

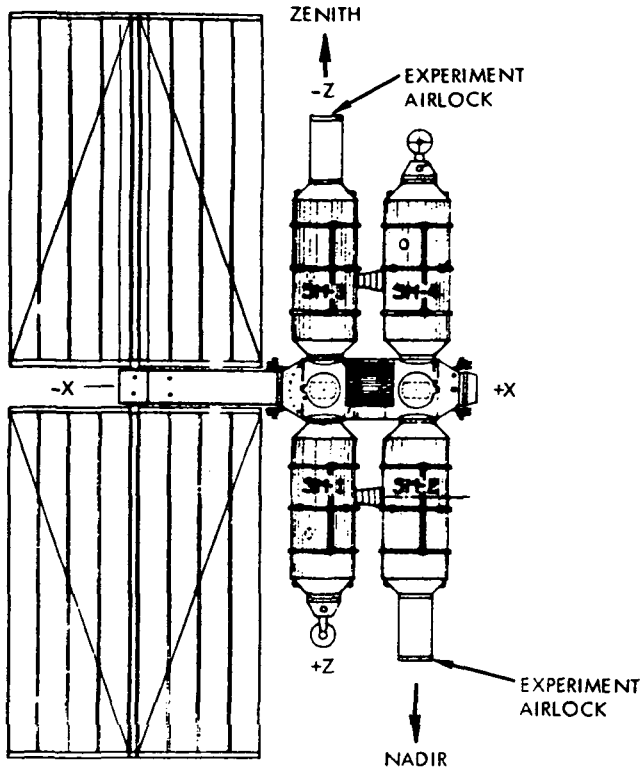


Figure 1-80. Experiment Airlock Location

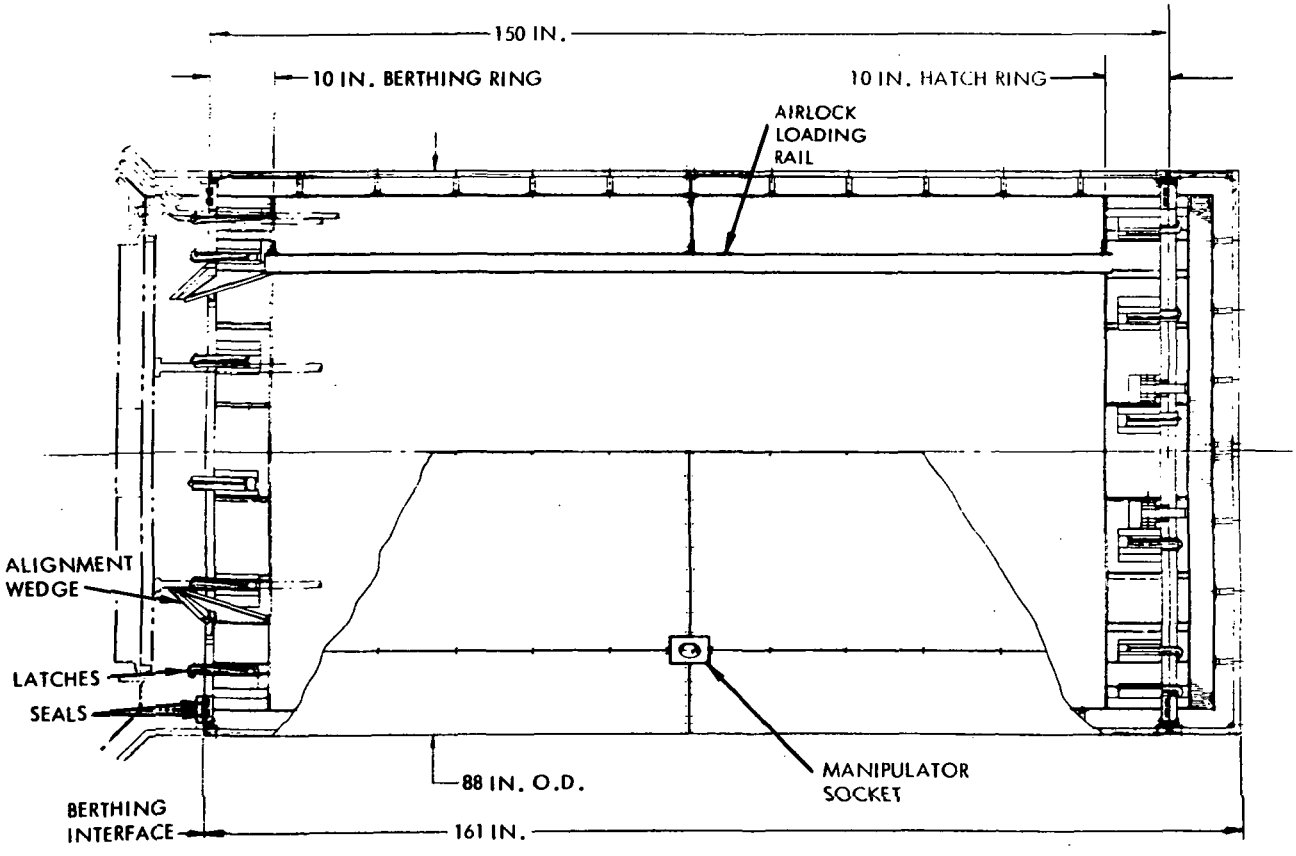


Figure 1-81. Experiment Airlock Arrangement

The experiment airlock pressure shell utilizes a pure monocoque structure. On each end of the pressure shell is a 10-inch-long, 80-inch-diameter cylindrical berthing ring that is machined from a 2219-T87 aluminum ring forging. The inner end is machined as a standard active berthing ring with seals, alignment guides, and wedges. The outer end is identical except that no alignment guides or wedges are provided, but there are mounting provisions for the hatch hinge mechanism. The cylindrical shell is an 80-inch internal diameter by 0.145-inch-thick aluminum tube constructed of 5052-H34 aluminum. The construction of this cylindrical section is identical to that used for the power module pressure shell. At the center of this length, on the outside of the pressure bull, is bonded a ring frame of 2219-T87 aluminum having a 3-inch-deep web and 2-inch-wide flanges. Attached to this ring frame are the four manipulator sockets that are provided for airlock replacement.

The experiment airlock outboard hatch subassembly is composed of an aluminum honeycomb sandwich with an outer frame and window frame. Figure 1-82 illustrates the outer hatch configuration. The outer frame, machined from a 2219-T87 aluminum berthing ring forging, is similar to a passive berthing ring with only a sealing face and latch pads, and no alignment guides. The window installation is the same as utilized throughout the station for the 14-inch-diameter window. A thermal control cover is also provided over the window.

The airlock loading rail is a 3-inch-deep web by 2-inch-wide flange I beam. This standard rail is used for experiment pallet handling and deployment, and is located at the top of the airlock clearing the hatch opening into the station module loading area.

The environmental protection subassembly is made up of a meteoroid bumper, an insulation blanket, and a closeout liner/bumper supported by fiberglass insulation/isolation brackets bonded to the pressure hull as shown in Figure 1-83. The meteoroid bumper is 0.030-inch fiberglass laminate. The insulation blanket is made up of approximately 60 layers of aluminized mylar separated by loose woven nylon. The closeout liner/secondary bumper is of 10-mil Kapton.

1.5.9 BERTHING ADAPTER

A berthing adapter, as illustrated in Figure 1-84, is required for shuttle berthing to the modular space station. The adapter provides the transition between the shuttle airlock interface ring (60-inch diameter) and the berthing interface ring (80-inch diameter) of the station modules. The length of the adapter (32 inches) provides clearance for the outboard opening hatch of the shuttle airlock. An active space station berthing ring is provided on one end with a reduced diameter active berthing ring on the other end. The pressure shell utilizes a monocoque construction with the environmental protection located 4 inches outboard of the primary structure.

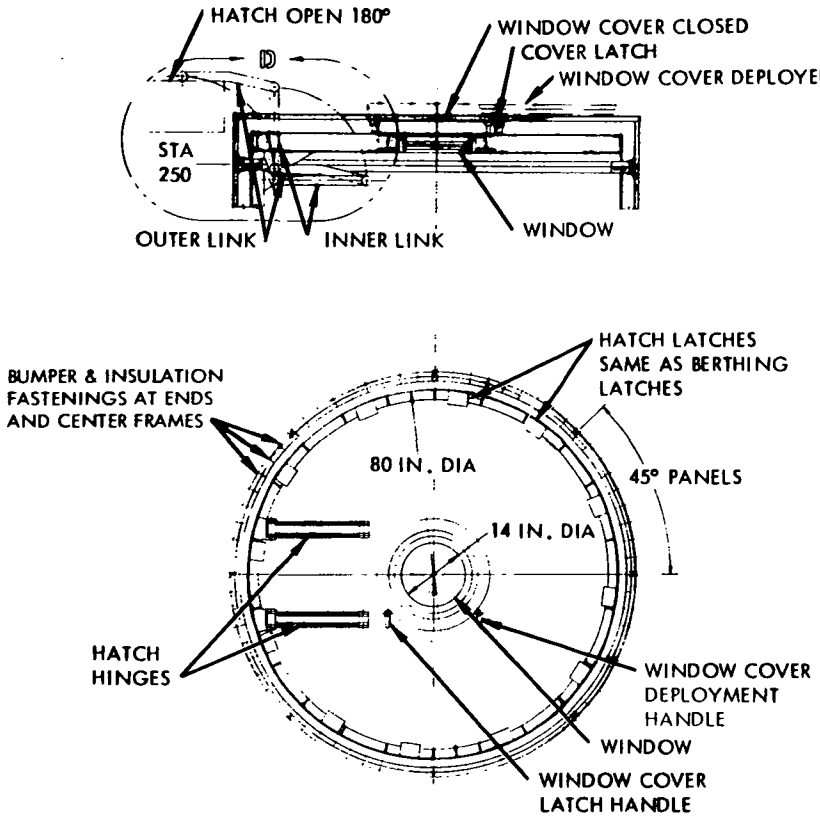


Figure 1-82. Outer Hatch Configuration

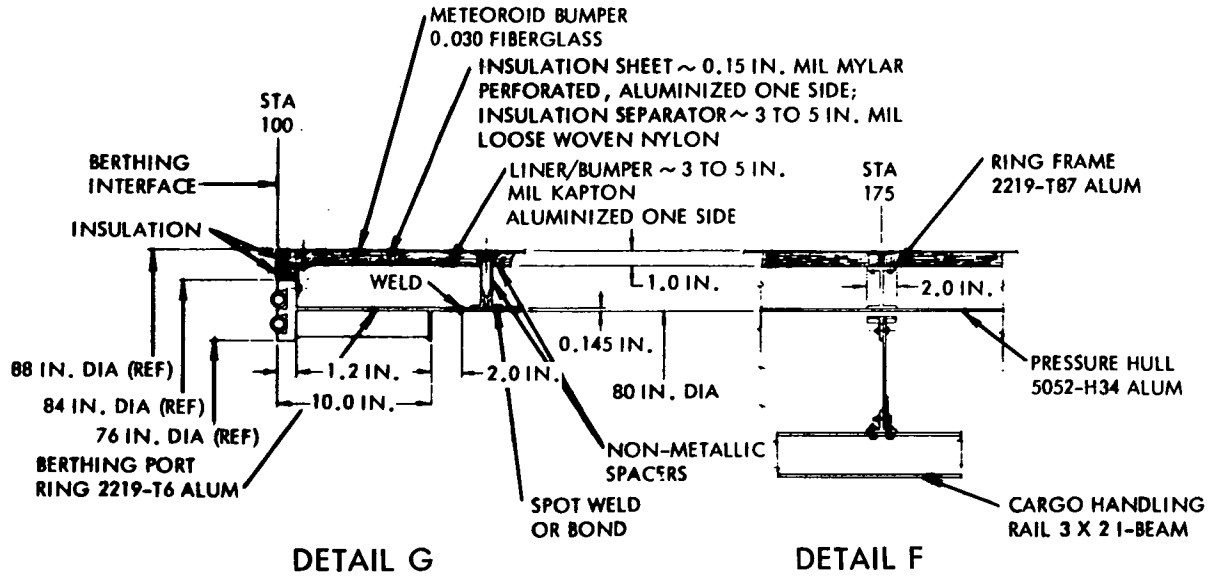


Figure 1-83. Pressure Shell and Environmental Shield

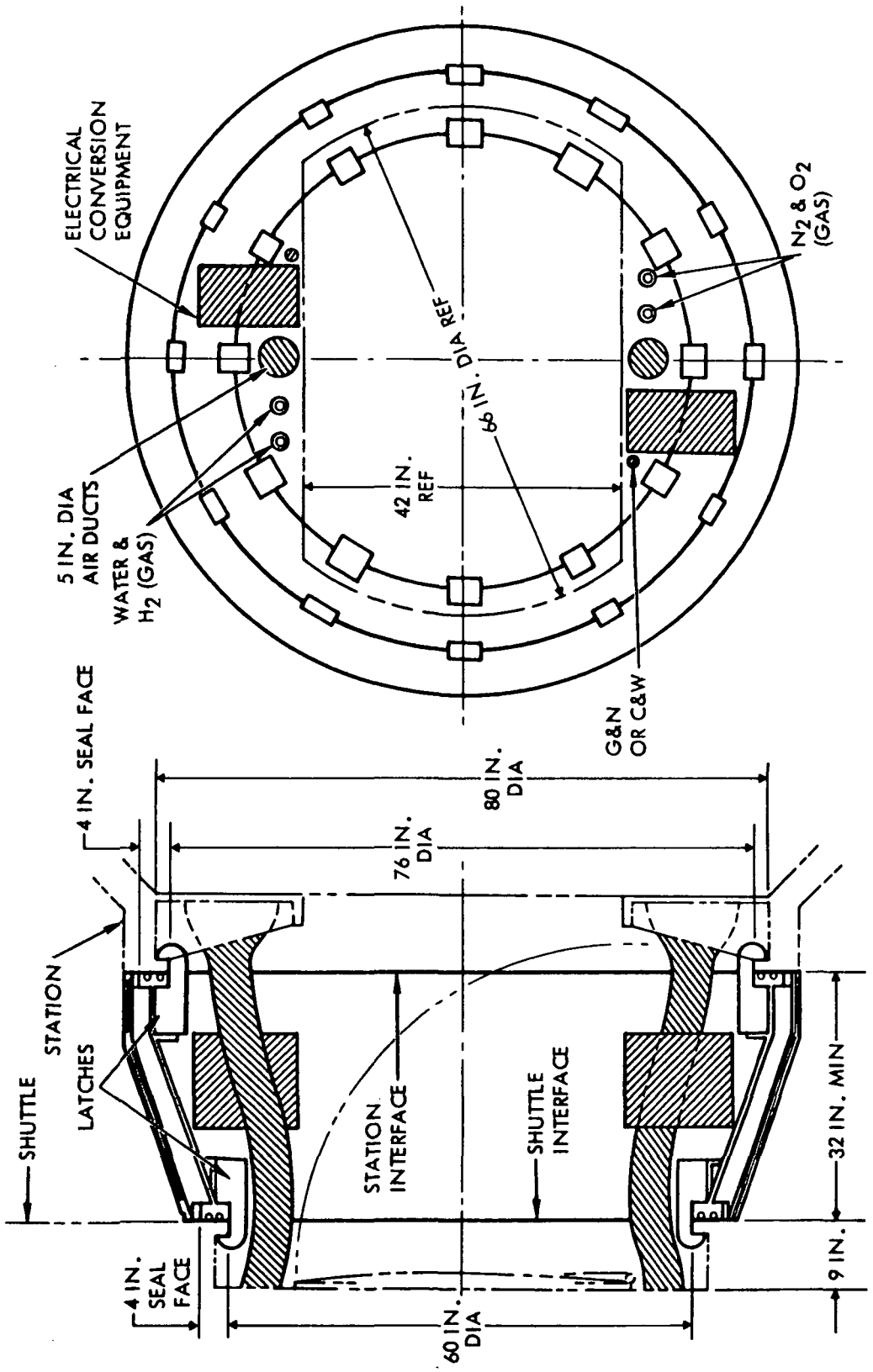


Figure 1-84. Station/Shuttle Berthing Adapter

In addition to the physical interface, there are certain utilities interfaces that must be accommodated. These include the air distribution, gaseous and liquid lines, and electrical power and data lines. Electrical conversion equipment is mounted in the adapter which conditions the shuttle power to be compatible with the station power. A 42-inch-wide clear opening is provided through the adapter.

In the normal station operations, the adapter is attached to the end port of the core module. The end of the adapter that interfaces with the shuttle is indexed to align the shuttle in a 45-degree orientation as illustrated in Figure 1-85.

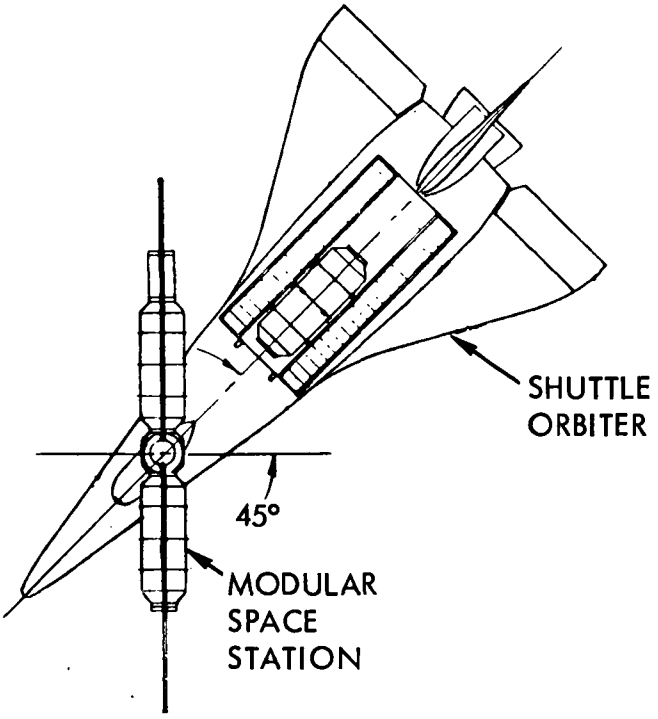


Figure 1-85. Station/Shuttle Berthed Orientation

1.5.10 MANUFACTURING ASSEMBLY

Three different module assemblies are fabricated for the modular space station configuration defined in this Phase B study effort. The manufacturing assembly and equipment installation sequences are similar in all three module configurations. The module configurations referred to are the core module, the power boom, and the common modules. The core module is unique with a 12-foot-diameter cylinder of skin and stringer construction and 10 passive berthing ports. The power boom is an 80-inch-diameter monocoque cylinder with an active and a passive berthing port. The common modules are 13-foot, 8-inch cylinders of monocoque construction that contain an active and a passive berthing port. Figures 1-86, 1-87, and 1-88 illustrate the manufacturing assembly sequence for the core module, the power boom, and the common modules, respectively. The manufacturing assembly sequence detail drawings V030-942104 (core module), V030-942103 (power boom), and V030-942204 (common module) are in DRL 67, SD 71-216 Modular Space Station Drawings.

The 10 basic steps of the manufacturing cycle for the three module assemblies are: (1) material procurement, (2) detail fabrication, (3) minor and major subassembly, (4) final structure assembly, (5) structures test, i.e., pressure, leak, radiographic, etc., (6) installation of secondary structures, (7) installation of subsystems, (8) in-process test, (9) final acceptance test, and (10) package and ship.

The details will be fabricated utilizing standard manufacturing practices developed during the Saturn S-II and Apollo programs. No new technologies are anticipated for the structural fabrication.

A forging and machining fabrication concept for the berthing rings has been selected because of the economies associated with the production quantity of berthing rings that are common to all modules to be produced. Welding has been selected as the joining method because it will provide the most reliable and airtight pressurizable volume, and the aluminum materials to be used are readily weldable.

Core Module

The fabrication of the structural portion of the core module consists of joining the cylinders and bulkheads to provide three pressurizable volumes (see drawing V030-942104). Volumes 1 and 2 are fabricated identically as follows: The end bulkheads are assembled from preformed gore segments, a berthing port assembly, a T-shaped ring for attaching the internal support bulkheads, and preformed stringers bonded to the welded bulkhead assembly. The berthing port cylinder assembly consists of four premachined and formed quarter panel segments, and four forged/machined berthing port assemblies. The berthing port assemblies are welded to the panels; and then the panels are welded to each other to form the completed berthing port cylinder assembly. The spacer cylinder consists of four premachined and formed quarter panels welded together. The flat pressure bulkheads are standard honeycomb construction. The airlock cylinder assembly consists of four preassembled

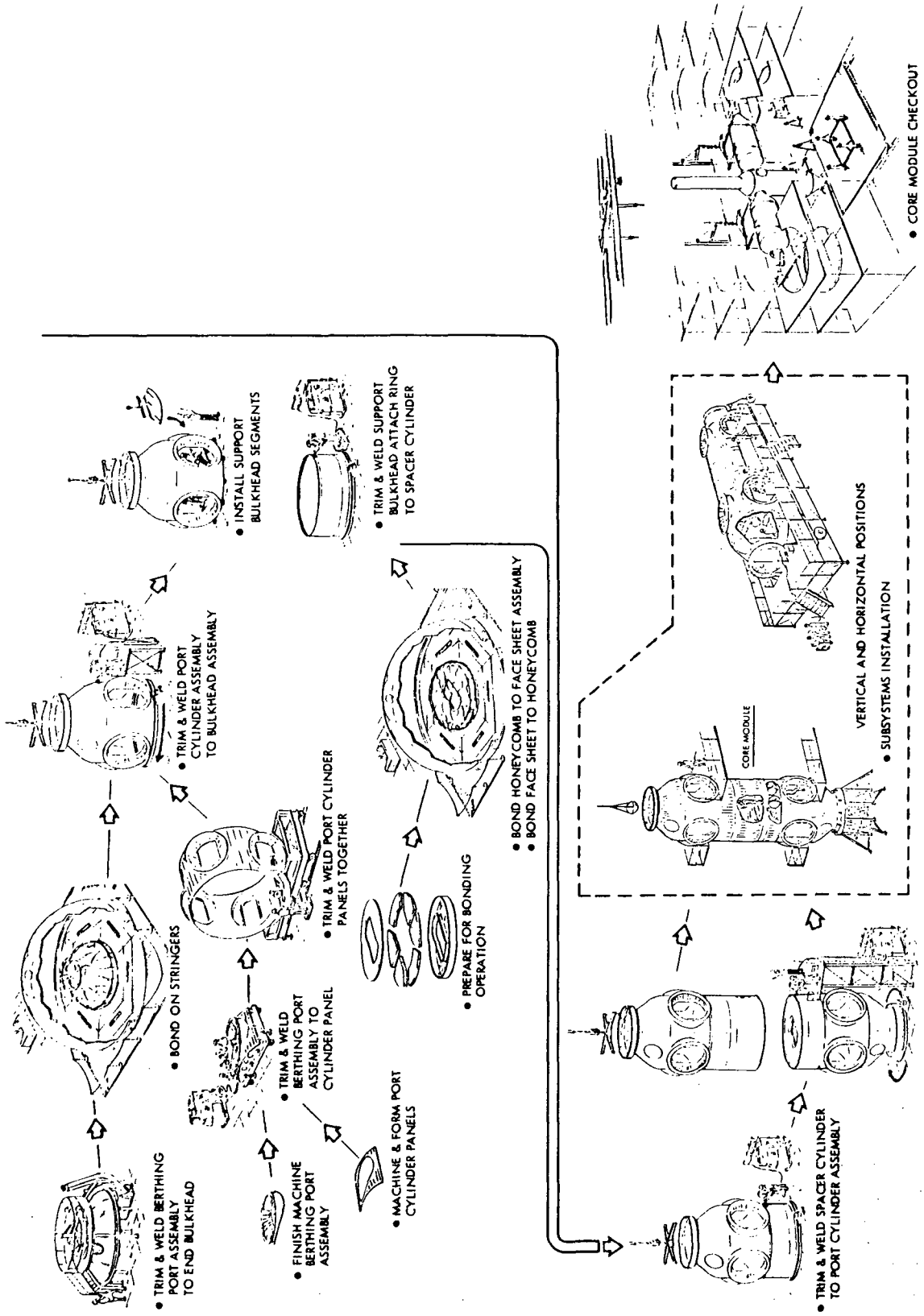


Figure 1-86. Core Module Manufacturing Assembly Sequence

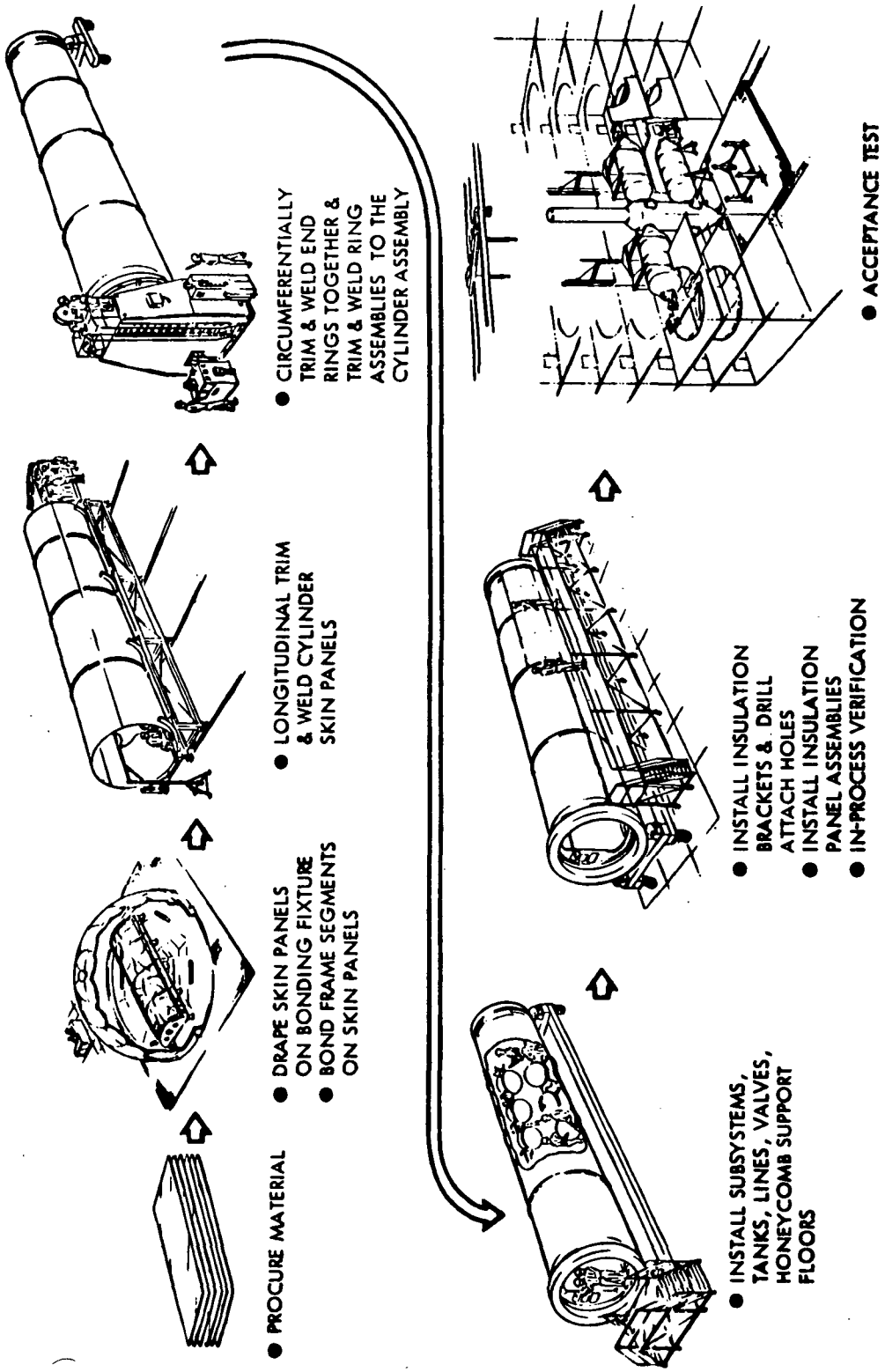


Figure 1-87. Power Boom Manufacturing Assembly Sequence

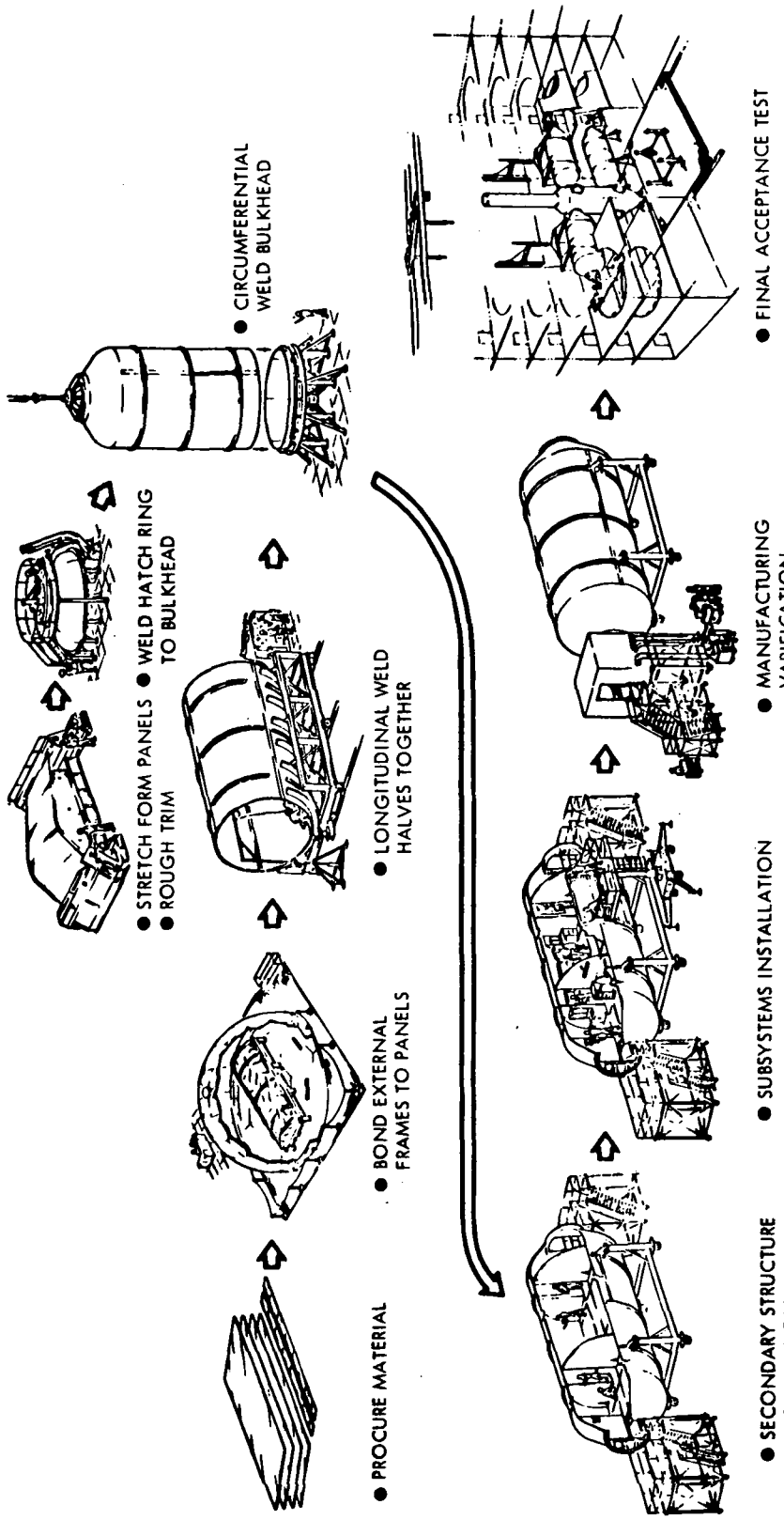


Figure 1-88. Station Module Manufacturing Assembly Sequence

quarter panels welded together. The above assemblies are circumferentially welded together in the vertical position. This position was selected to provide maximum accessibility with minimum tooling and support equipment requirements. Following structural assembly, the core module is pressure-tested.

After pressure-testing, the core module is ready to accept the secondary structures and subsystem installations. To facilitate these operations, two module positions have been selected, vertical and horizontal. The vertical position is utilized for initial installations (large storage tanks, etc.) because of the transverse bulkhead locations.

A special rotating fixture will be provided that will support the module in a horizontal position, thus allowing the module to be rotated. This fixture will allow manufacturing personnel to enter the module from either end for the installation operations. Placing the core module in the horizontal position also provides ground level access for installation operations. The rotating module also facilitates the installation of the internal and external secondary structures and bracketry, as well as the overall subsystems installations such as the installation of the environmental shield and radiator components.

The power boom and common modules assembly procedures are very similar.

Power Boom

The assembly of the power boom cylinder consists of joining preformed and preassembled panel segments together, using longitudinal welds to form the cylinder. The two end berthing rings are machined and assembled from forged aluminum rings then joined to the cylinder by circumferential welding.

Common Module

The assembly of the common module cylinder consists of joining preformed and preassembled panel segments together using longitudinal welds to form the cylinder. The bulkheads are assembled by welding the preformed bulkhead gore segments together. The two end berthing port assemblies will be fabricated from forged aluminum rings and then joined to the bulkheads by circumferential welding. This assembly (bulkhead/berthing port) will then be joined to the cylinder assembly by circumferential welding. Following their structural assembly, the modules are pressure-tested.

After pressure-testing, the modules are ready to accept the secondary structures and subsystem installations. To facilitate these operations, special rotating fixtures are provided that support the modules in a horizontal position and allows the modules to be rotated. These fixtures allow manufacturing personnel to enter the module from either end for the installation operations. Placing the modules in the horizontal position provides easy access from the ground level for installation operations. The rotation also facilitates the installation of the internal and external secondary structures and bracketry, as well as the overall subsystems installations.

Overhead installation of equipment is minimized. However, in the case of the power boom, the installation of the large storage tanks by carefully lowering them into the module, utilizing the boom's cargo transport rails as a guide, may be advantageous.

The installation of secondary structures and equipment in the horizontal position for the common modules, however, is more advantageous, such as the installation of the longitudinal floor through the berthing port hatch.

When the core module, power boom, and common module assemblies are complete, final in-process checks are performed. The completed modules are then sent to the integrated checkout area for final checkout and acceptance. Integrated checkout is the last major event prior to the preparation for shipment. Shipment of the modules are in a horizontal position that is also compatible with the method of loading the modules into the shuttle.

1.6 GROWTH STATION MODULES DESIGN DESCRIPTION

Figure 1-89 depicts the space station growth configuration. Only the items that are added or changed from the initial station are described. These items are: (1) the solar array assembly changes from the 7000-square foot array of the initial station to the 10,000-square foot array for the growth station, (2) station modules 5 and 6 are added, and (3) core module 2 is added. Design concepts of these items will be described as no preliminary design effort was performed. SD 71-216 does not contain any growth configuration design drawings.

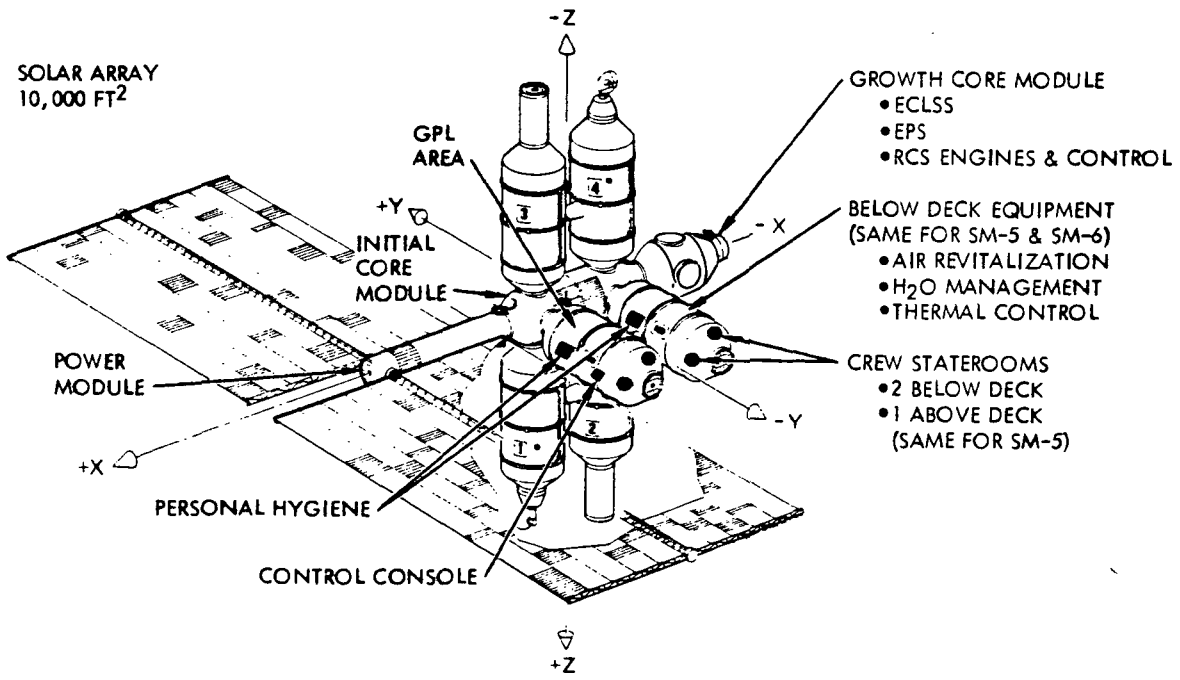


Figure 1-89. Growth Station Configuration

1.6.1 CORE MODULE 2

The growth station core module serves primarily as an additional bank of berthing ports. These additional ports are required for the growth station in order to accommodate the two additional common modules, SM-5 and SM-6, and three RAM's in lieu of the two RAM's of the initial station. This module also contains two RCS quad assemblies, additional EPS bus equipment, ECLSS sensible and humidity duct components, communications, an emergency G&C control unit, and crew equipment required for growth station operations. Figures 1-90 and 1-91 define core module 2.

Design Requirements

Core module 2 is required to provide three additional berthing ports to accommodate the RAM provisions because the growth station modules and cargo modules utilize the full berthing port capacity of core module 1. The 5-foot clearance between modules is also required to provide the capability for direct docking. The assembly of the module is by shuttle manipulation. An active berthing port is required on the end of the module attaching to core module 1.

Additional subsystems are required for the growth station and are allocated to this core module. These items are listed in Table 1-14.

Design Description

Core module 2 is identical to core module 1 in construction. The structural shell diameter is 144 inches with a length of 20 feet. The radial and -X berthing ports are passive with the +X berthing port being active. The entire assembly is enclosed by an environmental shield extending to 152 inches in diameter. This core module also contains the various elements of the electrical power subsystem (EPS), guidance and control subsystem (G&C), reaction control subsystem (RCS), information subsystem, crew habitability subsystem, and the environmental control/life support subsystem (ECLSS).

External Arrangement

The environmental shield covers the entire exterior of the module. The shield is penetrated by the acquisition light and the manipulator pickup and shuttle pickup fittings. The environmental shield provides both thermal and meteoroid protection and is of the same construction and attaches to the primary structure the same as core module 1.

Environmental covers are provided for all of the radial berthing ports. The cover design is identical to those utilized on the $\pm$Y-ports of core module 1.

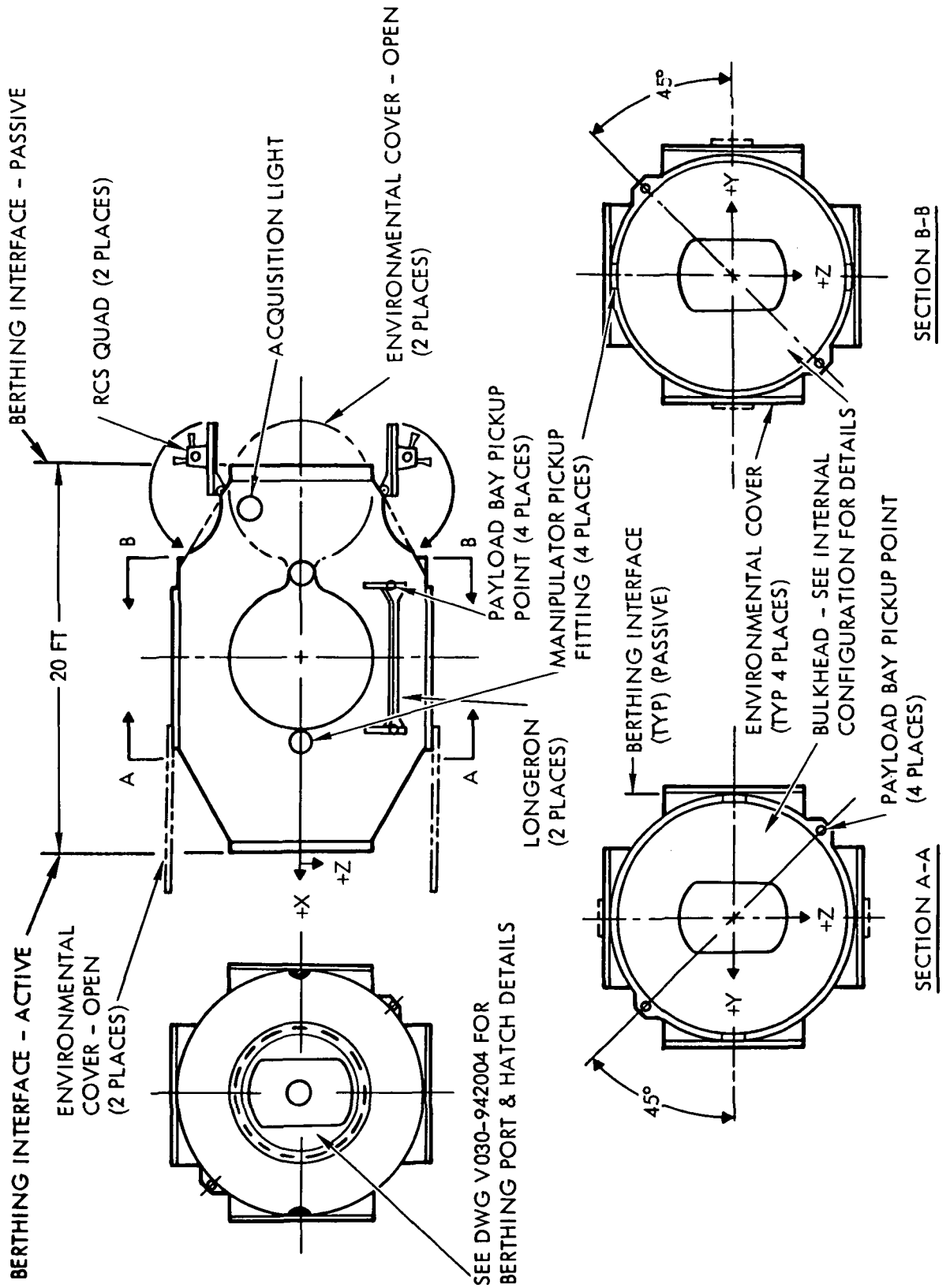


Figure 1-90. Core Module 2 External Configuration

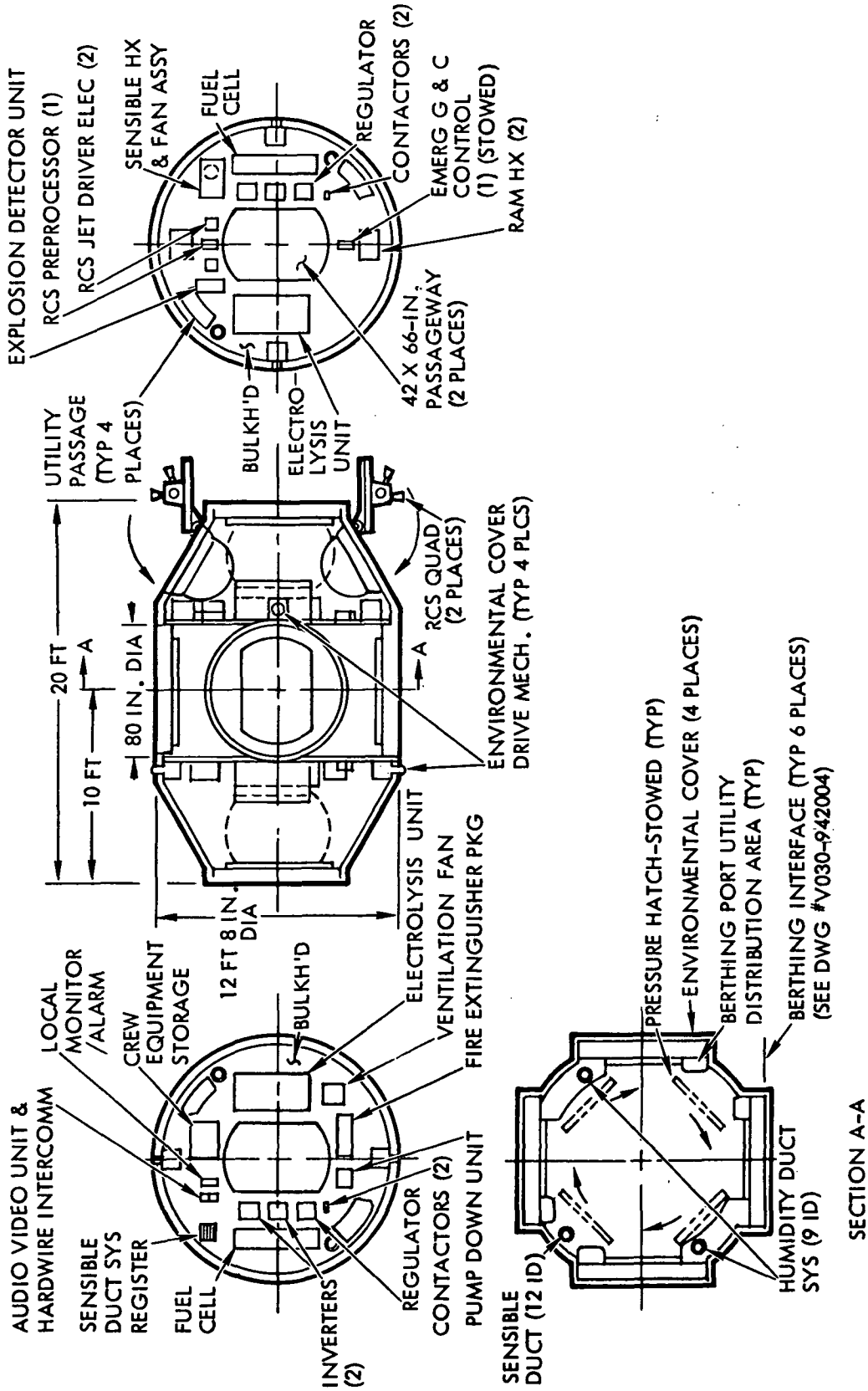


Figure 1-91. Core Module 2 Internal Configuration

Table 1-14. Core Module 2 Design Requirements

Item	Requirement
ECS	
Gaseous storage	Pumpdown
Atmospheric control	Humidity ducting, ventilation fan assembly, sensible Hx and fan assembly, explosion detector
Thermal control	RAM Hx's
Special life support	Fire extinguisher package and detector
EPS	
Energy storage	Fuel cells, electrolysis units
Power conditioning	Inverters, regulators
Distribution control and wiring	Contactors
G&C	
RCS electronics	Jet driver elect, preprocessors
RCS	
Engines	Quad assemblies (2)
ISS	
Command/control and monitoring	Emgerency G&C control, local monitor/ alarm
Internal communications	Audio/video unit, hardwire intercoms
Crew and habitability	
General/emergency equipment	Portable lights, emergency oxygen masks, mobile aids and restraints, first aid kit

Structural Arrangement

Core module 2 utilizes the same semimonocoque (0.040 skin and stringer) construction as core module 1. The module utilizes the Cassinian curve to fair into the cone ends. An active berthing port assembly is located on one end with a passive berthing port assembly on the other end. The four radial ports are also of the passive assembly configuration. Two interior stiffening bulkheads are also utilized for equipment mounting. A short drag longeron is placed on the exterior surface of the shell between these bulkheads to react the shuttle launch loads. Four shuttle pickup points are located at the intersection of the drag longeron and stiffener bulkheads. Four manipulator sockets are attached to one of the stiffener bulkheads.

An asquisition light is located on the -X end of this module. The design and installation of this light is the same as the light installation of core module 1. For growth station operations, this light will be utilized in lieu of the light located at the -X end of core module 1.

Interior Arrangement

The two RCS quad assembly locations are shown in Figures 1-90 and 1-91. The quad assemblies are retracted during shuttle delivery. These locations are the same as two of the four locations of core module 1. Because of this, the engine quad mounting structure, hatch covers, engine covers, and associated hardware are common with those items in core module 1, minimizing cost and spares requirements. Shirtsleeve service and replacement access is provided by rotating the quad assembly into its well, pressurizing the engine cover, and removing same. The associated electronics equipment is bulkhead-mounted adjacent to the quad assemblies. An additional emergency G&C controller is connected to the RCS electronics equipment and stowed nearby.

The additional bus and energy equipment required for the growth station is located in this module. This equipment is physically separated, for safety and redundancy, into the two systems required to expand the systems located in core module 1. The hydrogen lines routed through the core module are double containment. Where possible, the hydrogen lines are routed on the exterior of the pressure hull.

The core module atmospheric control sensible duct system consists of a supply duct and sensible heat exchanger fan assembly. The return air is circulated through the module. The atmospheric control humidity duct system is a continuation of the system in core module 1. The core module 2 system consists of a duct system interconnecting the four radial berthing port and -X berthing port interfaces with core module 1 interface. One ventilation fan is located in the module. The necessary pressure control and explosion detection systems are also provided.

Two RAM heat exchangers are located adjacent to the RAM berthing ports. A pumpdown unit is stowed near the radial berthing ports. This unit is portable and is attached to the pumpdown valve at the interface of the module to be pumped down.

The special life support equipment provided consists of a fire detection system and a stowed fire extinguisher package.

The items of crew equipment located in the core module fall under the category of general/emergency equipment. A storage locker is provided for the following items of equipment:

Item	Quantity
Portable light	1
Emergency oxygen mask	3
Mobility aids and restraints	1 set
First aid kit	1

Dual utility runs are provided throughout the core module. These runs are redundant and located on opposing sectors of the module diameter for safety.

1.6.2 POWER MODULE ASSEMBLY

The growth power module configuration consists of the initial station power boom and a solar array assembly with 10,000-square foot solar arrays. A structural adapter is provided between the orientation drive and power transfer assembly and the power boom to retain the solar array clearance with the core module. Figure 1-92 depicts the growth assembly and its relationship to the initial station configuration.

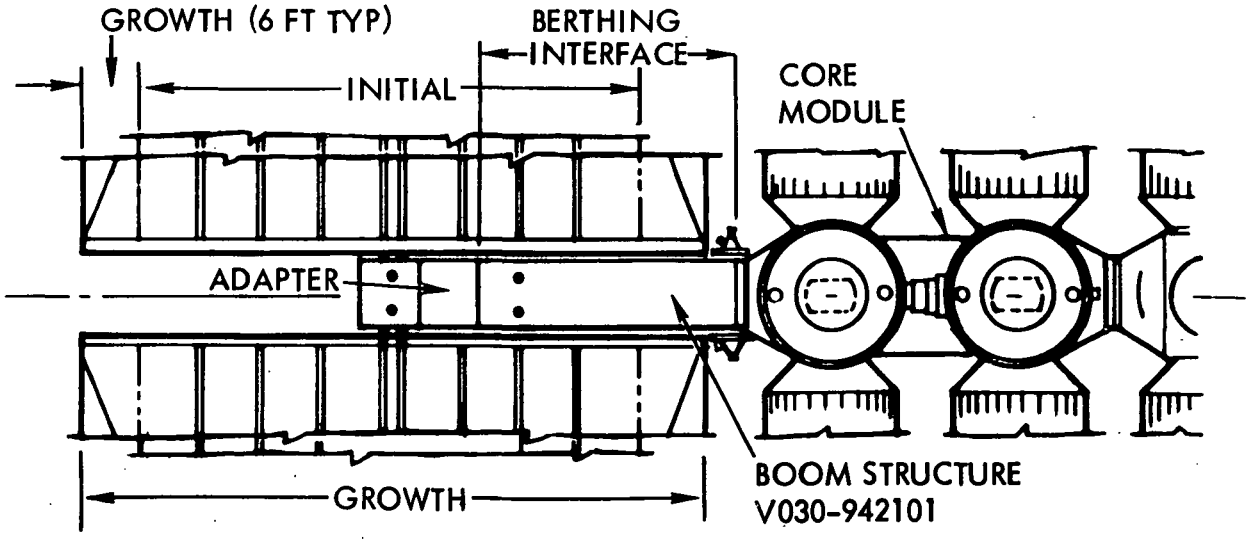


Figure 1-92. Power Module Configuration

Design Requirements

Only one basic requirement is imposed, replace the initial station solar array assembly containing 7000 square feet of solar array with the growth solar array assembly containing 10,000 square feet of solar array. The growth solar array panel dimensions are increased in width by 6 feet and the length by 11 feet. The initial station power boom is to be retained on the station with only the solar array assembly to be replaced. The replacement operation will utilize the shuttle and shuttle manipulator.

Design Description

The growth solar array assembly consists of two subassemblies, an orientation drive and power transfer assembly, and an adapter assembly. The adapter is a 6-foot long assembly that interfaces with the power boom and provides the solar array clearance with the core module. The orientation drive and power transfer assembly is a vendor item; however, it is assumed to be identical to that utilized for the initial station.

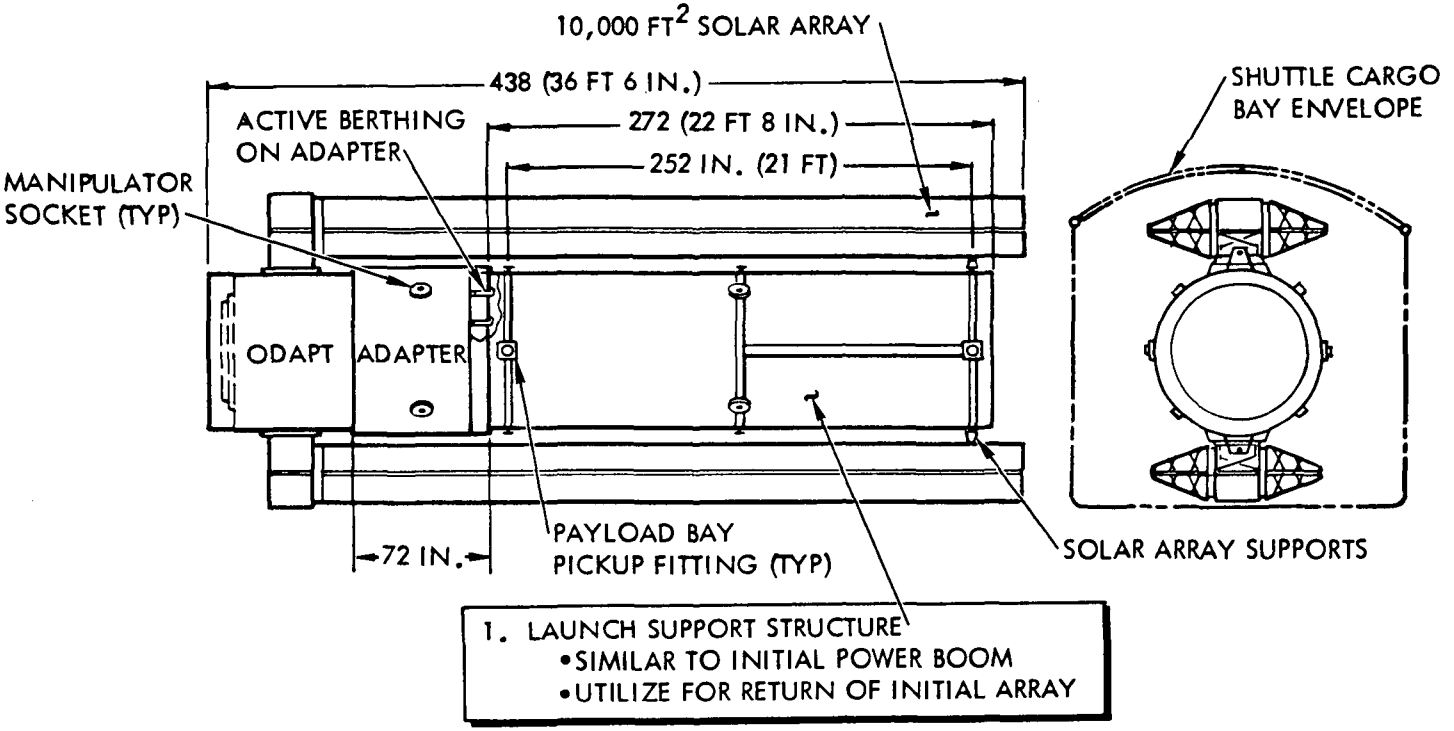
Adapter Assembly

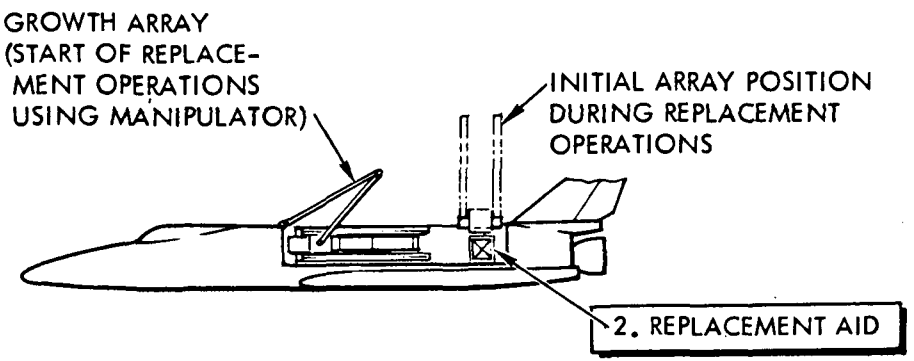
The adapter assembly is a part of the vendor solar array assembly package. The anticipated structural arrangement is similar to the power boom structure in order to utilize common hardware and facilities and to retain the boom stiffness. The adapter assembly is of monocoque construction utilizing 0.145-inch thick 5052-H34 aluminum alloy 80 inches in internal diameter and 6 feet long. One end of the adapter is permanently attached to the ODAPT while the other end contains an active berthing port ring assembly that provides the interfacing attachment to the power boom. A centrally located ring provides the attachment of the four manipulator sockets. The environmental protection assembly is identical to that utilized on the power boom and extends to an 88-inch diameter.

Solar Array Assembly Replacement

A possible replacement procedure will be described in the following text. This procedure requires two special pieces of equipment, a launch support structure and a replacement aid. The launch support structure is required to transport the growth solar array to orbit, and is also required to return the initial array assembly. The replacement aid provides a parking facility for the initial array during the on-orbit replacement operation. Figure 1-93 shows the launch support structure configuration and the replacement aid and its location in the shuttle payload bay.

The launch support structure has an overall length of 22 feet 8 inches (272 inches) and an external diameter of 86 inches. A monocoque structure identical to the power boom utilizes a 0.145-inch thick aluminum alloy shell with an internal diameter of 80 inches. Three aluminum alloy stiffener rings are bonded to the external diameter, one at each end and one in the center. Two aluminum alloy drag longerons, located 180 degrees apart, are bonded to the outside diameter for the launch load reactions. Two passive berthing





SOLAR ARRAY REPLACEMENT AIDS

1. LAUNCH SUPPORT STRUCTURE
   - SHORT POWER BOOM
   - SAME MONOCOQUE CONSTRUCTION
   - PASSIVE BERTHING PORT

2. REPLACEMENT AID
   - ACTIVE BERTHING PORT
   - MINIMUM STRUCTURE
   - ATTACHED IN SHUTTLE CARGO BAY

Figure 1-93. Solar Array Replacement Aids

Space Division
North American Rockwell

port rings are provided, one on each end of the cylinder. Four manipulator sockets are attached to the center stiffener ring. Four shuttle payload bay pickup fittings are also installed on the end stiffener rings.

The replacement aid is a short piece of structure installed in the shuttle payload bay. The exposed end of this structure contains an active berthing ring which provides the attaching structure for the replacing solar array assembly.

The procedure for replacement of the solar array assumes that the initial array has been folded into the configuration that is required for shuttle transport. The solar array replacement operation is listed below and schematically illustrated in Figure 1-94.

1. Shuttle picks up berthing adapter from aft end of core module
2. Shuttle berths to the initial station solar array/orientation drive and power transfer assembly (SA/ODAPT)
3. The SA/ODAPT disengages and shuttle separation occurs
4. Manipulator transfers SA/ODAPT to shuttle bay replacement aid
5. Manipulator picks up the growth station solar array/adapter/launch support structure assembly from the shuttle bay and transfers it to the berthing adapter
6. Manipulator transfers the launch support structure assembly from the growth array/adapter and attaches it to the initial station SA/ODAPT
7. Manipulator stows the initial station SA/ODAPT/launch support structure assembly in the shuttle bay for return
8. Manipulator captures the power boom
9. Shuttle berths the growth array/adapter assembly to the power boom
10. The shuttle separates and growth array checkout commences
11. The solar array is deployed on checkout completion

1.6.3 STATION MODULES 5 and 6

Station modules 5 and 6 provide the growth facilities to accommodate the additional six crewmen and to provide the additional air revitalization and additional water and waste management equipment. The two modules split the facilities between the station volumes V_1 and V_2 .

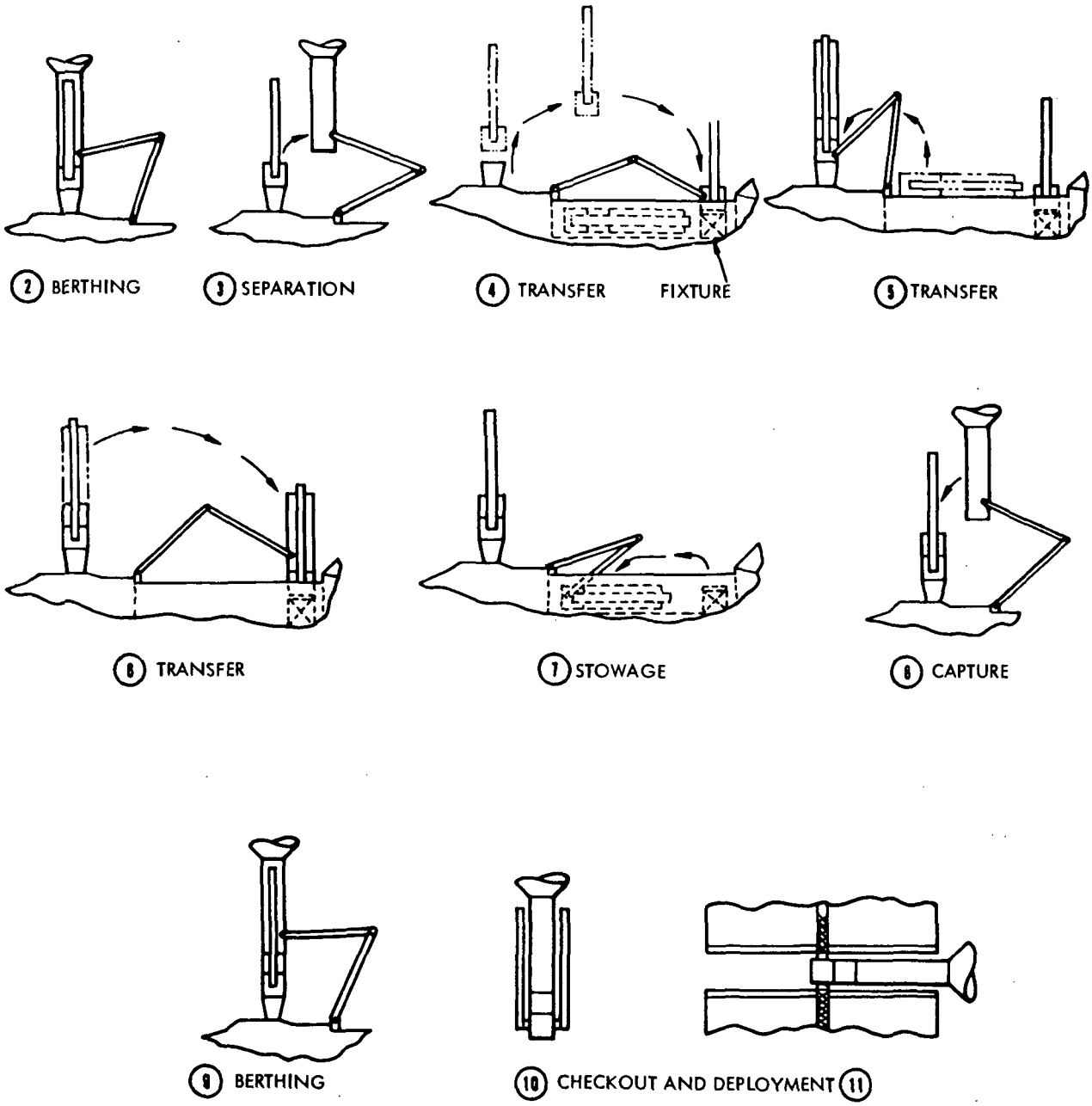


Figure 1-94. Solar Array and Turret Replacement

Design Requirements

The growth station requires accommodations for 12 crewmen split equally between the habitable volumes V_1 and V_2. Additional hygiene facilities are also required with one facility containing another shower unit. Additional GPL facilities to provide, as a minimum, the equivalent area allocated to this function in the 33-foot diameter station are required. Table 1-15 lists the subsystem equipment requirements for modules 5 and 6.

Design Description

These two modules utilize the identical split level floor arrangement of station modules 1 and 4. Two crewman quarters are located below deck and the total subsystem equipment. The upper deck contains a single crewman's quarters and a personal hygiene facility. A shower unit is provided in station module 6 only. An additional control center to accommodate the increased GPL facilities is provided in station module 5. The remainder of the area is allocated to GPL activities.

The external arrangement contains the identical radiator and environmental protection arrangement as utilized for the other station modules.

Interior Arrangement

Station Module 5

The split level area is used for the three-crewman staterooms (50 square feet each). Two are located below deck and one is located above deck. The unused upper floor area (approximately 50 square feet) is open and available for experiment equipment. The personal hygiene equipment (sink, urinal and toilet) is located on the upper deck. A control console is positioned on the upper deck adjacent to the crewman's stateroom. The balance of the upper deck area is utilized for GPL functions and associated equipment.

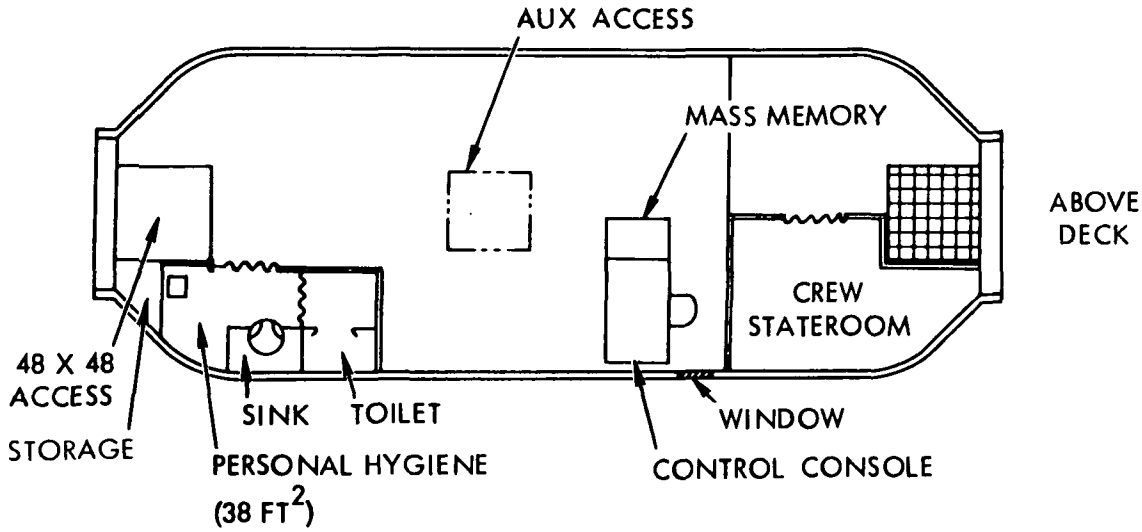
The below deck area is used for the subsystems equipment required for life support which includes: (1) CO_2 management, (2) atmosphere control, (3) water management, and (4) waste management functions. Figure 1-95 depicts the concept arrangement of the module.

Station Module 6

SM-6 is identical to SM-5 with the following exceptions: (1) a shower is added to the personal hygiene facility, (2) no control console on the upper deck, and (3) a trash compacter is added and is located on the upper deck adjacent to the personal hygiene facility. Figure 1-96 depicts the concept arrangement of the module.

Table 1-15. Station Modules 5 and 6 Design Requirements

Item	Requirement
Common Items	For equipment details, refer to DRL 66, Preliminary Performance Specification
ECS	
CO_2 management	CO_2 removal unit, CO_2 reduction unit, vent gas accumulator, accumulator pump, water electrolysis unit, water accumulator, V/C water feed pump, CO_2 sensor unit, H_2 and O_2 accumulators
Atmospheric control	Humidity ducting and fan assembly, ventilation fan assembly, sensible Hx and fan assembly, humidity control unit, pressure relief system, contaminant control unit, explosion and gas monitor detector
Water management	Water reclamation unit, vent accumulator and pump, potable water tank, purity monitor system
Waste management	Fecal collection, urine collection
Hygiene	Sink
Special life support	Fire extinguisher package, fire detector
EPS	
Distribution control	Secondary bus
ISS	
Internal communications	Audio/video unit, hardwire intercom, TV monitor - color
Station module 5	
ISS	
Command/control and monitoring	Operational control console, MSS memory rack
Station module 6	
ECS	
Waste management	Trash processor
Hygiene	Full body shower



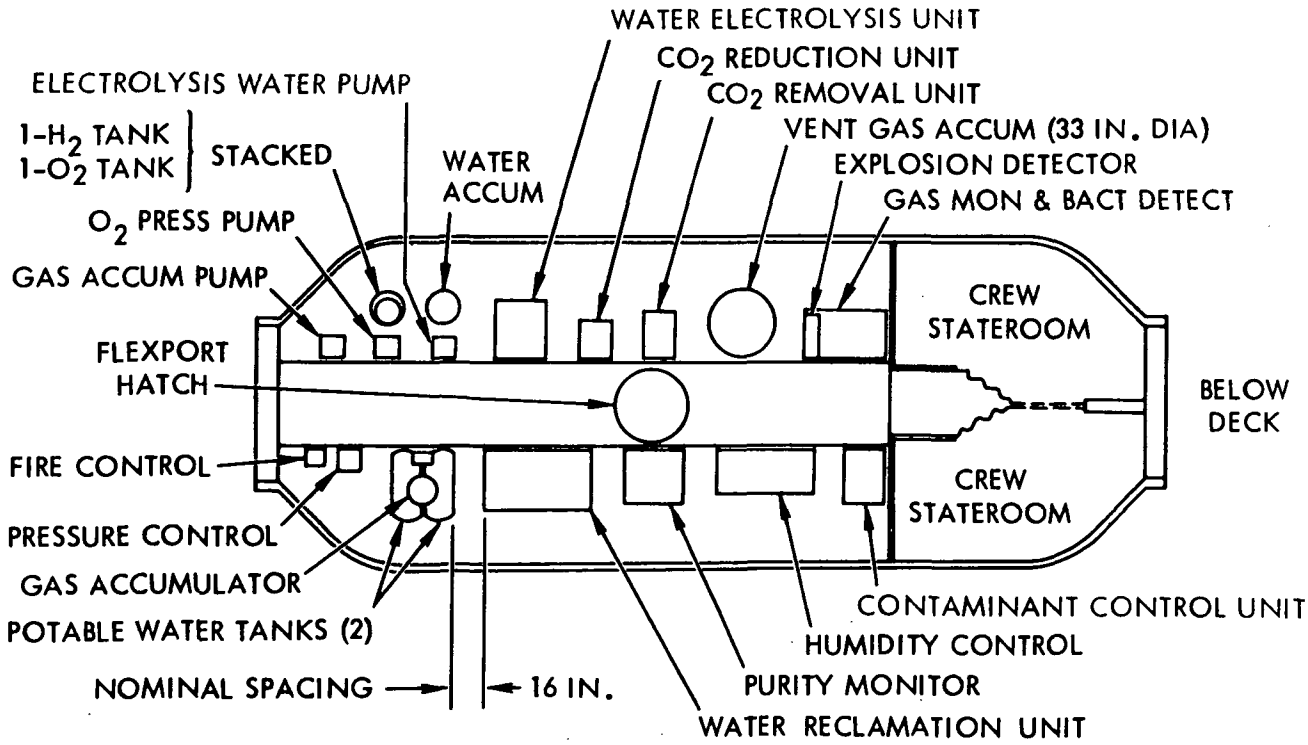


Figure 1-95. Station Module 5

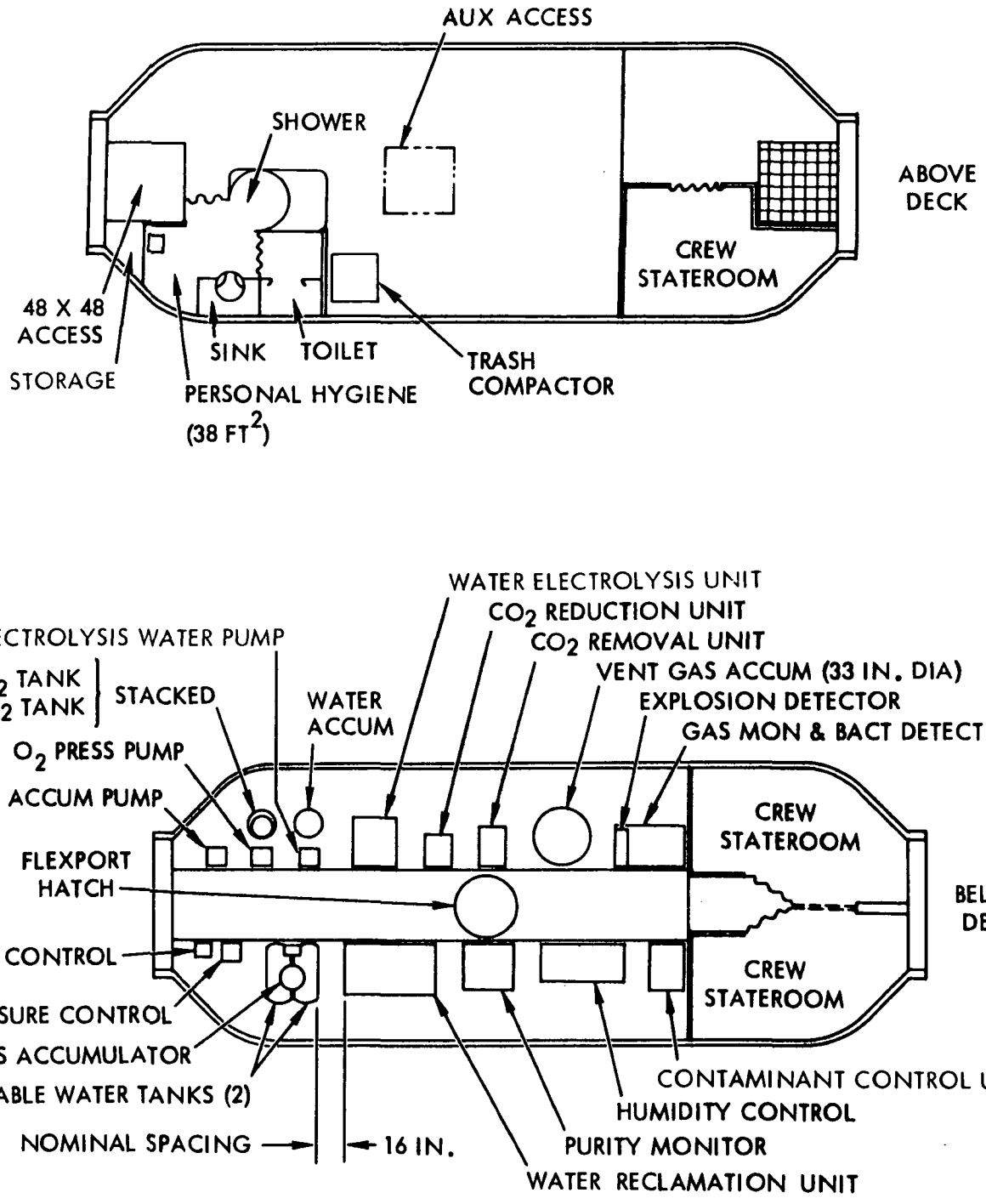


Figure 1-96. Station Module 6

2. ALTERNATIVE CONFIGURATION ANALYSIS

This study activity was directed toward establishing alternative module configurations and conducting analyses to define their functional and physical characteristics. Eight study configurations were developed with key issues as follows:

Study Configuration 1 - individual module features

Study Configuration 2 - lower volume utilization and module diameter evaluation

Study Configuration 3 - functional allocations

Study Configuration 4 - manipulator berthing or direct docking

Study Configuration 5 - subsystem selection drivers and module replacement impact assessment

Study Configuration 6 - special module configuration

Study Configuration 7 - split-level crew quarters evaluation and individual module configuration arrangement

Study Configuration 8 - preliminary design configuration

A list of configuration drivers with the alternatives considered with the study configurations is presented in Table 2-1.

The following paragraphs discuss the alternative configurations and the major considerations that lead into each subsequent study.

The Phase B reference configuration shown in Figure 2-1 was used as the starting point for this study. The major issues and characteristics defined for this configuration are as follows:

1. Major Issues

   a. Station modules underweight

   b. Requires module conversions (initial to growth stations)

   c. Direct docking only

Table 2-1. Configuration Drivers and Alternatives

Characteristics	Features
System sizing	Minimize conversion from 6 men to 12 men Optimize at 6-man level Provide capability >6 men and <6 men
Cargo operations	Up/down same launch Up/stay with fluid/gases transfer Up/stay without fluid/gases transfer
Dual shirtsleeve egress	Common module only Common module plus special modules All modules including RAM's
Module diameter	15 feet 14 feet <14 feet
Subsystem assemblies	Devoted modules (power, ECLSS, RCS) Dual RSM's (power/RCS/ECLSS) Distributed
Y plane modules	None Cargo only Station modules (common or special) RAM's Cargo plus RAM's
Pressure volumes	2 independent 3 with 2 out of 3 4 with 2 out of 4
RAM accommodations (initial station)	2 attached (both earth oriented) 2 attached (earth and zenith oriented) 2 attached plus 1 service port Accommodate 2 (attached or detached)
RAM sizing	Same as ØB (EL 107) Same as common modules
Crew quarters	6 in a single module Split between modules
ECLSS assembly sizing	6-man units initial and growth 6-man initial, 12-man growth Less than 6-man units

Table 2-1. Configuration Drivers and Alternatives (continued)

Characteristics	Features
Floor orientation (secondary structure)	Transverse Longitudinal Both
Internal arrangements (if longitudinal)	Single level Split level Selected facilities below deck
Berthing ports per module	Single end all common modules Dual ends all common modules Dual ends on selected modules
Experiment airlock location	Internal to GPL External single location External, movable External dual locations
RCS engines fuel location	In cargo module(s) On space station Split (station and cargo)
High-gain antenna location	On station special modules On station common modules Separate packages
Solar array location	Power boom single end Power boom dual ends Integrated with end-mounted SSM's
Initial buildup sequence	Core module/power module Power module/core module Common module/power module
Core modules	Single initial and growth Single initial, dual growth Dual initial and growth None
Manipulator	Shuttle only Shuttle and station None

Table 2-1. Configuration Drivers and Alternatives (continued)

Characteristics	Features
EVA/IVA airlocks	2 dual EVA/IVA EVA/IVA + EVA + IVA EVA + EVA + IVA + IVA 1 EVA/IVA, + EVA
Berthing port commonality	All common Separate for power Unique
Flexport operations	Normal crew passageway Emergency egress only
Aisle/passageway	Center Side Sub floor access
Module spacing	6 inches 12 inches 24 inches 48 inches

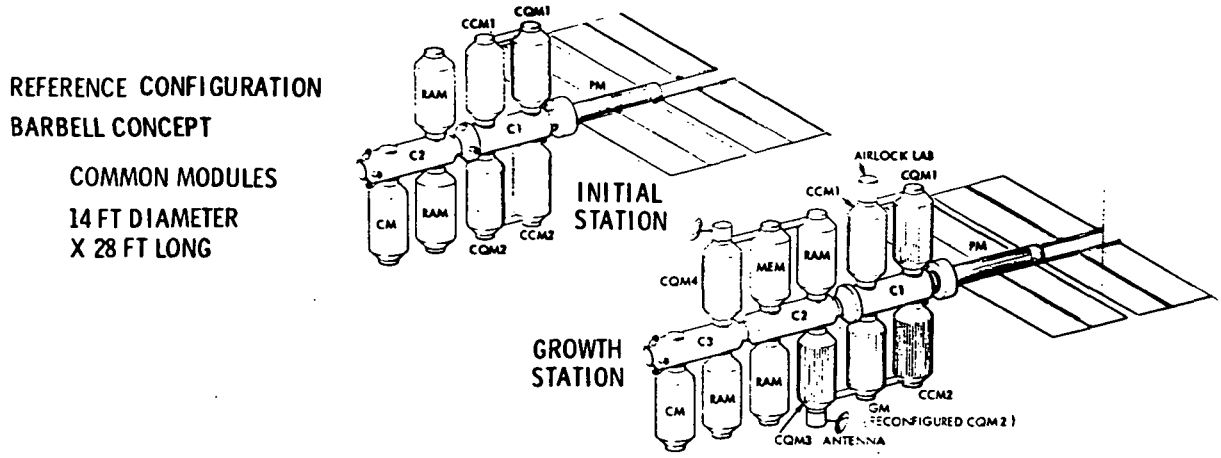


Figure 2-1. Reference Configuration (Starting Point)

2. Key Characteristics

   a. Station modules in single plane - four initial, seven growth

   b. Dual core initial, three for growth

   c. RAM in vertical plane away from solar array

   d. Cargo module in vertical plane

   e. Module spaceing, 2 feet - direct docking

   f. Cryogenics H_2, O_2, N_2

   g. Solar array battery and low-temperature radiator

   h. Launch sequence, core, power, CQM-1

   i. Control centers in station modules

2.1 STUDY CONFIGURATION 1

This study activity was directed toward accomplishing three objectives to resolve the issues identified in the reference configuration:

1. Add manipulator and berthing mode concept
2. Reconfigure station modules
3. Split core module

2.1.1 MANIPULATOR AND BERTHING MODE

A manipulator and berthing mode concept was considered to alleviate problems associated with station buildup and module replacement when using the shuttle direct docking mode. A separate trade study was initiated to resolve whether to use the shuttle manipulator or have an individual one on the station. In the interim, this study was to proceed with a station manipulator. The manipulator was to be mounted in a fixed position and permanently attached on the core module. The growth station core module would contain a second manipulator mounted on the opposite side and aft from the first one. This manipulator configuration was used for the station operational studies.

2.1.2 RECONFIGURING STATION MODULES

Since the station modules of the reference configuration were under the 20,000-pound target weight as depicted in Table 2-2, the goal was to increase the module weights to more nearly meet the target weight.

Table 2-2. Reference Configuration
(Common Modules Underweight)

Module		Target Weight, 20,000 lb
Crew quarters	CQM-1	12,950
	CQM-2	14,060
	CQM-3	12,570
Galley	GM	15,590
Control center	CCM-1	15,730
	CCM-2	15,460
Medical exercise	MEM	13,550

This objective would be accomplished by combining functions in the modules to increase module weight. Also, considerations would be given during combining functions for minimizing module conversions when configuring to the growth station.

Reconfiguring Crew Quarters Modules

The reference configuration had two modules for crew quarters (split crew 4 and 2) for the initial station. To convert to the growth station, crew quarters module 2 was changed by addition of a galley, dining, and recreation area which replaced the two crewmen staterooms, the initial galley, and crew care area. Two additional modules for a crew of four each are added for the growth configuration.

To eliminate the conversion of modules and increase module weight, a single module (crew of six) would be used for the initial station in configuration 1. A similar module would be added for the growth station. This configuration for the crew quarters module and its weight is illustrated in Figure 2-2.

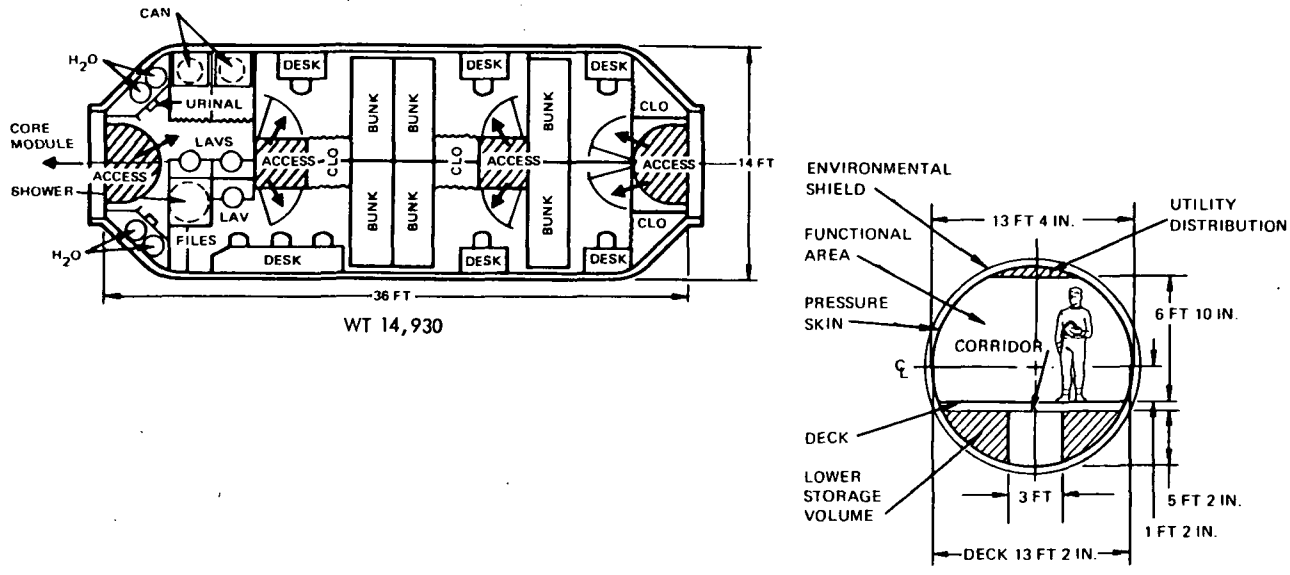


Figure 2-2. Crew Quarters Module No. 1 and No. 2 (CQM1 & CQM2)

The module utilizes the lower corridor access for passageway. Access to the stateroom is achieved by passing through the lower corridor to the vestibule which serves the selected stateroom.

This particular crew arrangement would eliminate one crew quarters module for a total of six station modules. The module weight was increased by approximately 2000 pounds over the reference configuration crew quarters module.

Reconfiguring Control Center Modules

The reference configuration as used previously had station module lengths of 28 feet. To maintain commonality between station modules for this study, a length of 36 feet was established. No new functions were added to these modules, but facilities were rearranged with the increased area. The arrangements and weights for the two control center modules for configuration 1 are illustrated in Figure 2-3.

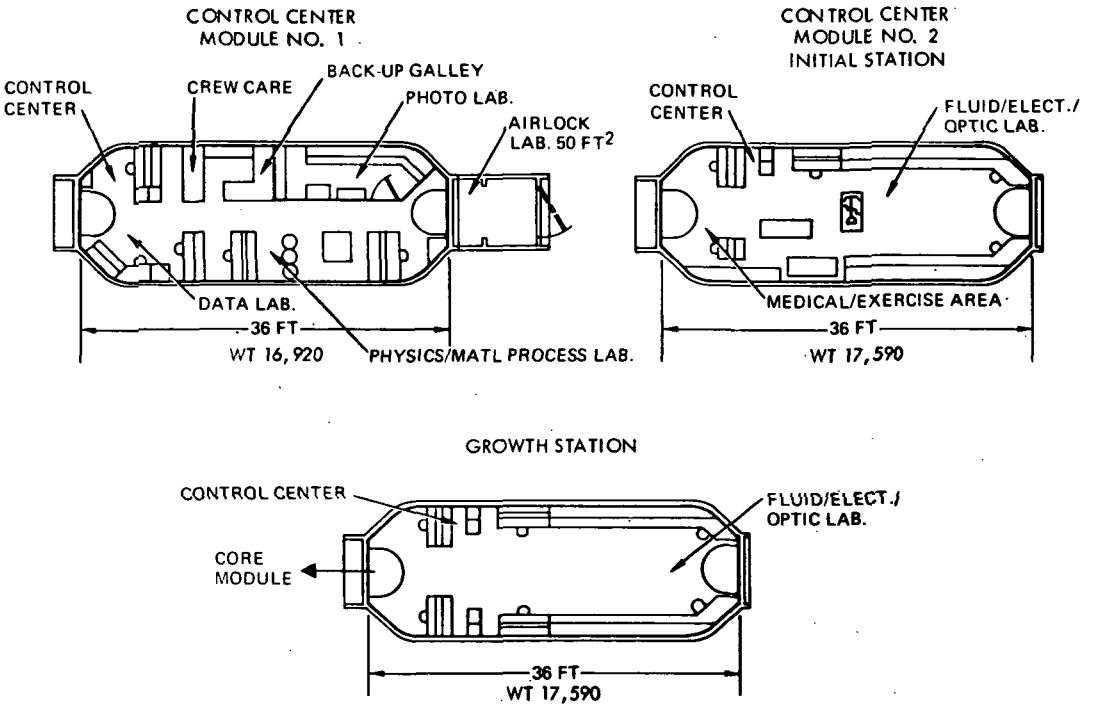


Figure 2-3. Module Arrangements

For the growth configuration, control center module 2 is reconfigured by removing the medical/exercise area and installing additional control center equipment.

Galley Module

For the reference configuration, the galley for the initial station was part of the crew quarters module. This module was converted into a galley module for the growth station. For configuration 1, the galley module was made one of the initial station modules less some growth equipment. The growth configuration for this module is achieved by adding additional dining and recreation facilities. These module configurations with their weights are illustrated in Figure 2-4.

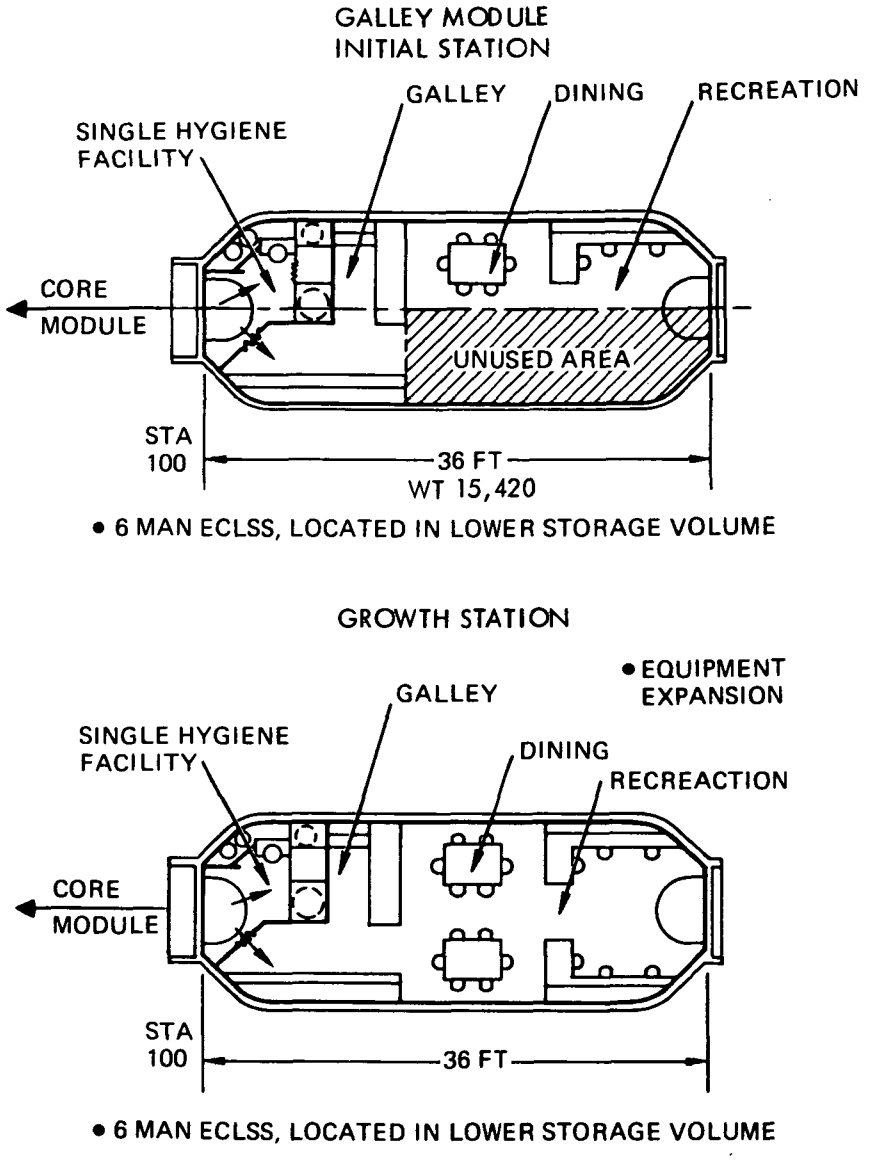


Figure 2-4. Galley Module

Medical Exercise Module

The medical/exercise module is used only for the growth station in both the reference configuration and configuration 1. The only difference between the two configurations is the module length. The reference configuration had common station module lengths of 28 feet while configuration 1 uses a common station module length of 36 feet. The medical/exercise module is illustrated in Figure 2-5.

2.1.3 CORE MODULE

Two core modules were required with the initial station for the reference configuration. In configuration 1, a split core module concept was conceived as illustrated in Figure 2-6. This particular configuration would utilize an adapter (1/2 core) attached to the power boom. Normally this adapter was required for high-pressure storage tanks equipment for station buildup and was enlarged to accommodate berthing ports in the Y-Z planes. Also, berthing ports were placed in the Y plane of the core module, departing from the barbell concept. The modules to be berthed in the Y plane would be either cargo or RAM modules. Station modules having a high traffic flow would be located in the Z plane, providing better capability for mounting flexports between modules to satisfy the dual egress requirement.

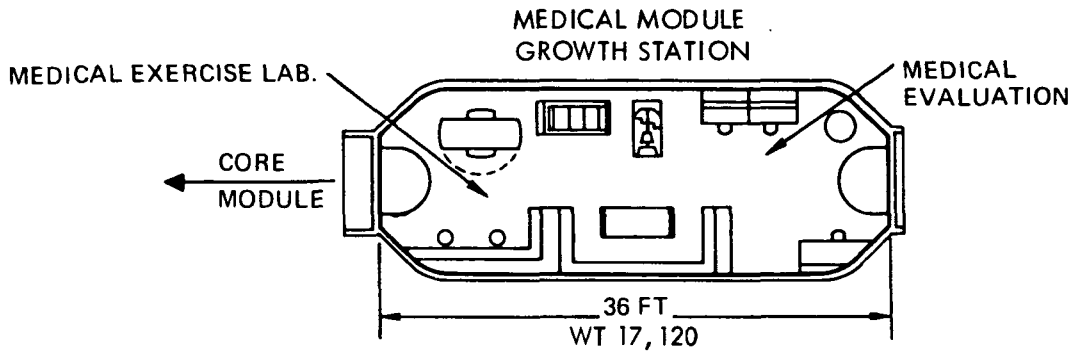


Figure 2-5. Medical/Exercise Module

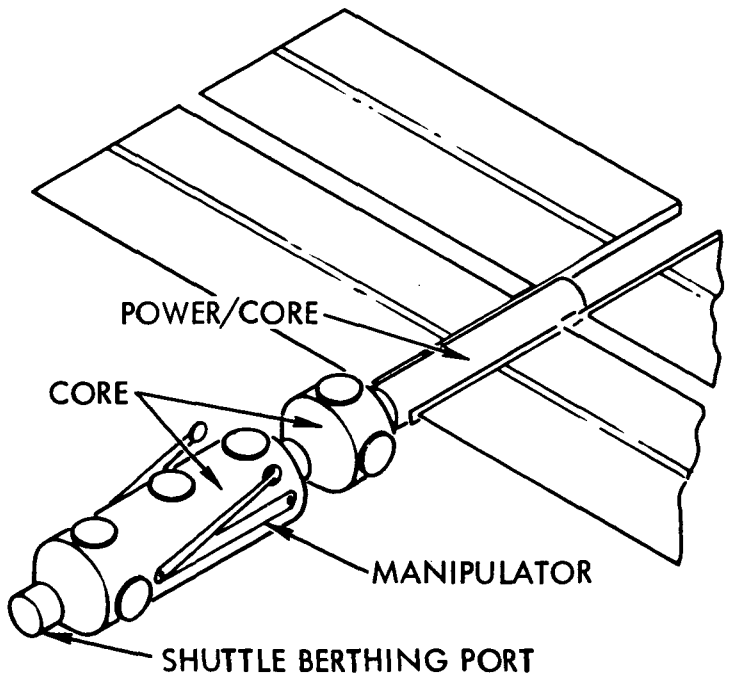


Figure 2-6. Split Core Module Concept

As a result of this study for reconfiguring modules, the module weights did increase as reflected in the previously identified figures with a decrease of one station module.

The initial station for configuration 1 is illustrated in Figure 2-7. Analysis of this particular configuration can be summarized as follows:

1. Same functional facility areas as Station A
2. All station modules in vertical plane (one less station module - six in study configuration 1, seven in reference configuration)
3. Only expansion of equipment for growth station (in two modules)
4. Greater use of shuttle performance capability (within target weight of 20,000 pounds)
5. Excess storage volume

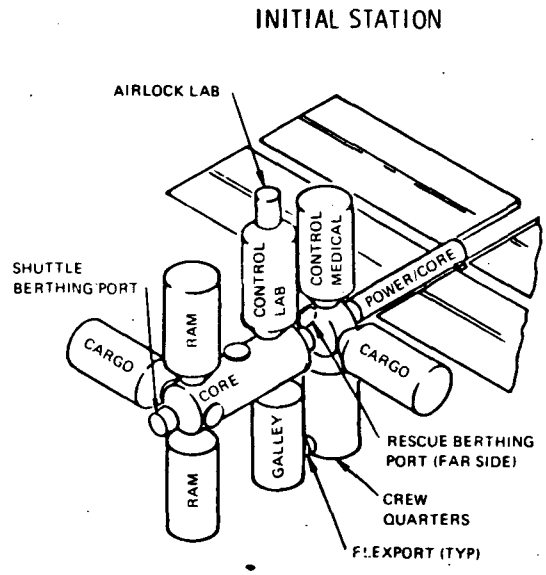


Figure 2-7. Study Configuration Concept No. 1

Study configuration 1 characteristics are as follows:

Station modules in single plane (4 initial, 6 growth)

1-1/2 cores initial, 1-1/2 for growth

RAM's in vertical plane away from solar array

Cargo module in horizontal plane

Module spacing, one foot, berth only

Cryogenic H_2, O_2, N_2

Solar array battery and low-temperature radiator

Launch sequence power, core, control

Control centers in station modules

2.2 STUDY CONFIGURATION 2

The activity for configuration 2 was directed toward accomplishing two objectives as derived from configuration 1:

1. Utilize lower deck volume for selected facilities
2. Conduct module diameter trade

2.2.1 LOWER VOLUME UTILIZATION

The major considerations that governed the analysis for lower volume utilization are as follows:

1. Start with study configuration 1
2. Retain crew quarters module

   6-man ECLSS
   Reclamation equipment
   Storage

3. Retain galley module

   6-man ECLSS
   Freezer
   Storage

   } Lower storage volume fully utilized

4. Combine functions of control modules (2) and medical exercise module into two integrated modules

A typical station module cross-section, 14 feet in diameter, is illustrated in Figure 2-8. To obtain the proper head height above deck, the floor is approximately one foot below the centerline. When a seated operational function is integrated into the lower deck volume, the head height is restricted. This is illustrated in Figure 2-8.

An alternative to eliminate excessive storage volume was to integrate the medical/exercise function into other station modules. The two control center modules were selected for this purpose. The medical facility was relocated into the control center 1 module by rearranging and removing some laboratory equipment and facilities. This new arrangement, identified as the control center and medical module, is shown in Figure 2-9.

The control center 2 module was rearranged to accept the other laboratory equipment and facilities. This configuration, identified as a control center and laboratory module, is illustrated in Figure 2-10.

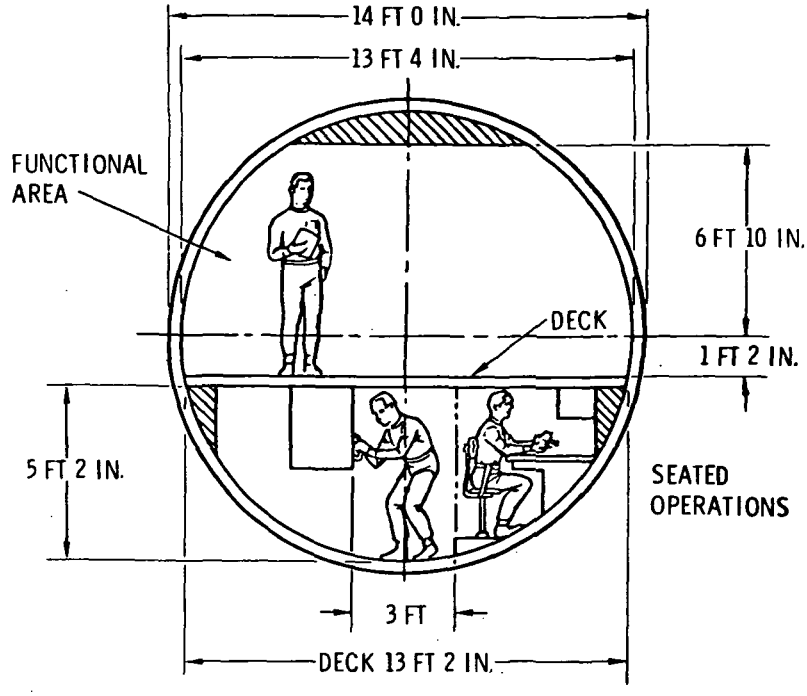


Figure 2-8. Typical Module Cross-Section

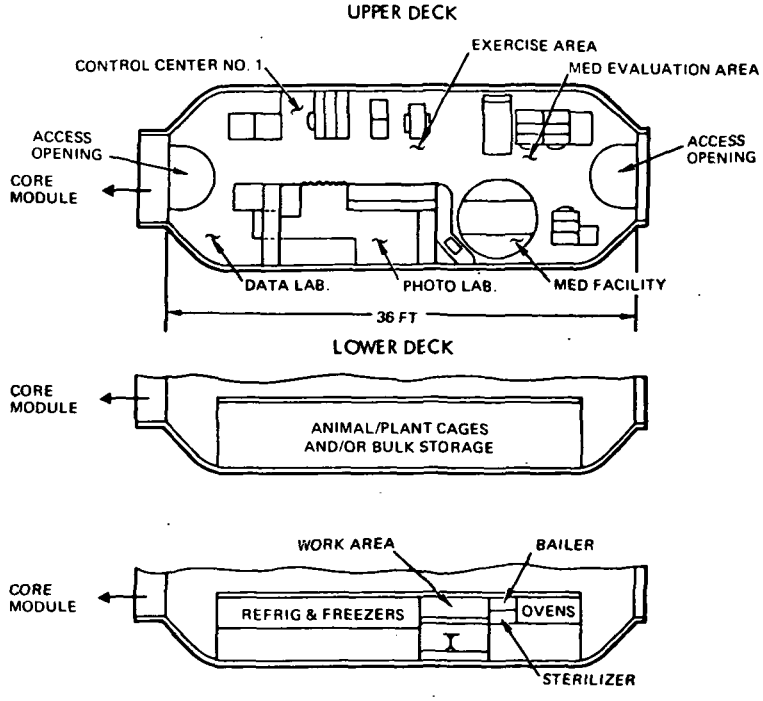


Figure 2-9. Control Center and Medical Module

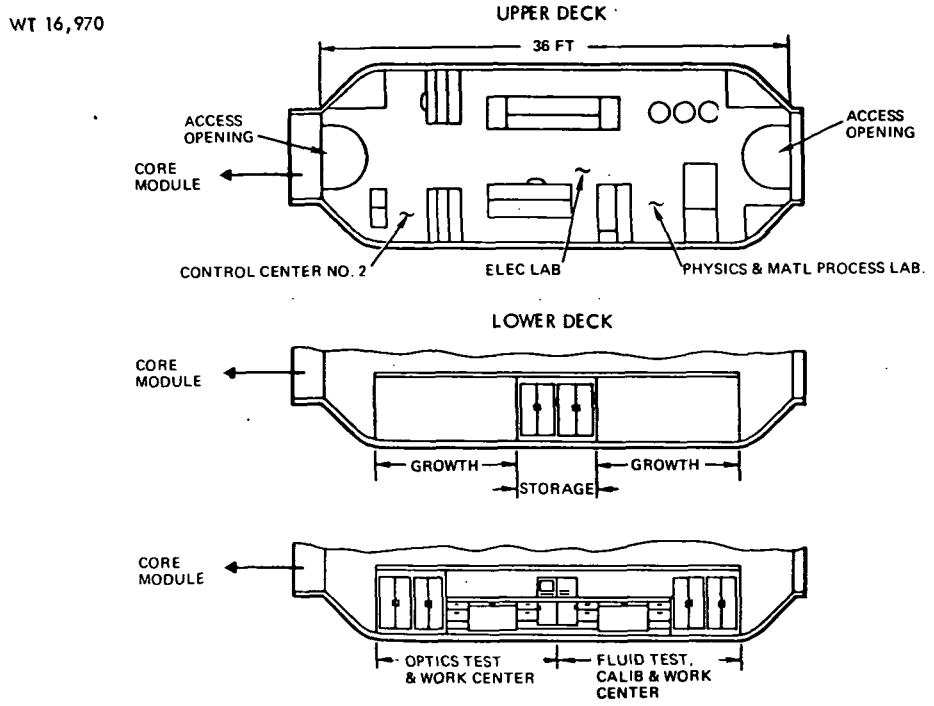


Figure 2-10. Control Center and Laboratory Module

Table 2-3 shows the reduction of the number of modules from seven in the reference configuration to six in configuration 1 and five in the configuration 2.

2.2.2 MODULE DIAMETER

Another possible alternative to reduce excessive storage volume was to investigate volume utilization efficiency by module diameter changes. This was a trade study performed as a separate task and is documented in Appendix A of this volume. The module diameters investigated, with a summary of their evaluation, are presented in Figures 2-11 through 2-14. The conclusion derived from this module diameter study is as follows:

Diameters below 13 feet are inefficient and produce penalties
15-foot diameters provide the least number of modules (within a 40-foot length)
14-foot (guideline diameter) requires only one more station module than 15-foot diameters
Continue configuration trades with 14-foot diameter modules

Table 2-3. Module Comparison Matrix

Module	Reference Configuration	Study No. 1 Configuration	Lower Volume Utilization Study No. 2
Crew Quarters	CQM1 CQM3 CQM4	CQM1 CQM2	CQM1 CQM2
Galley	GM	GM	GM
Control Center	CCM No. 1	CCM No. 1	
Medical	CCM No. 2	CCM No. 2	CCM/Lab
Laboratory	MEM	MEM	CCM/MEM
Total	7	6	5

Space Division
North American Rockwell

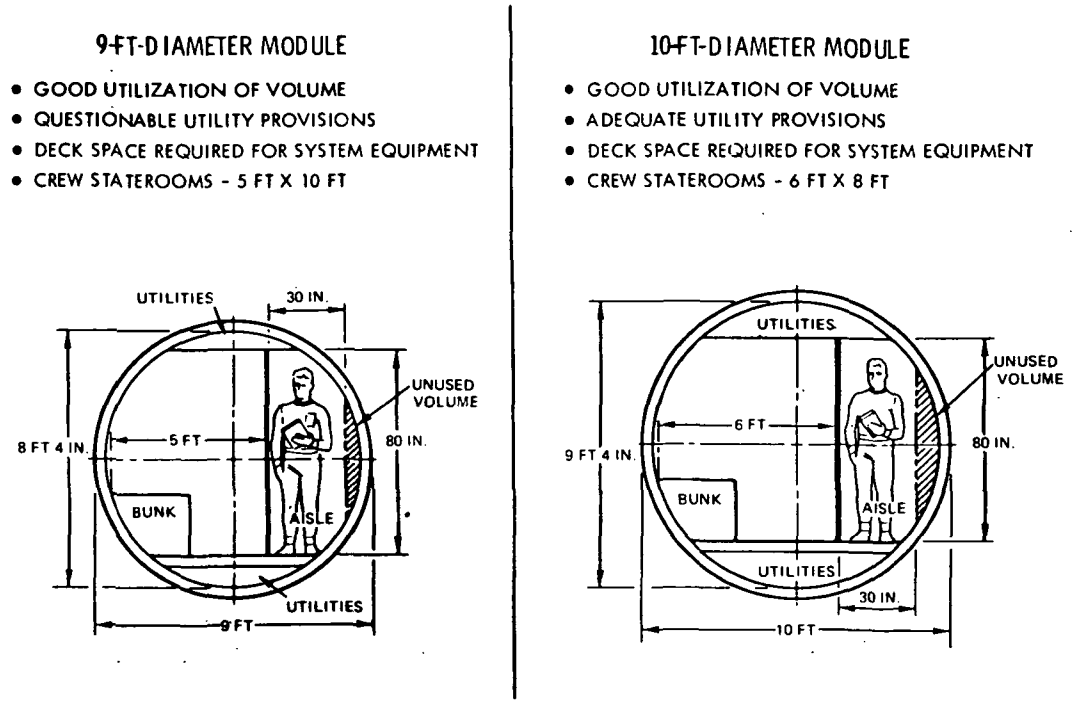


Figure 2-11. Module Diameters Evaluated (9 and 10 Foot)

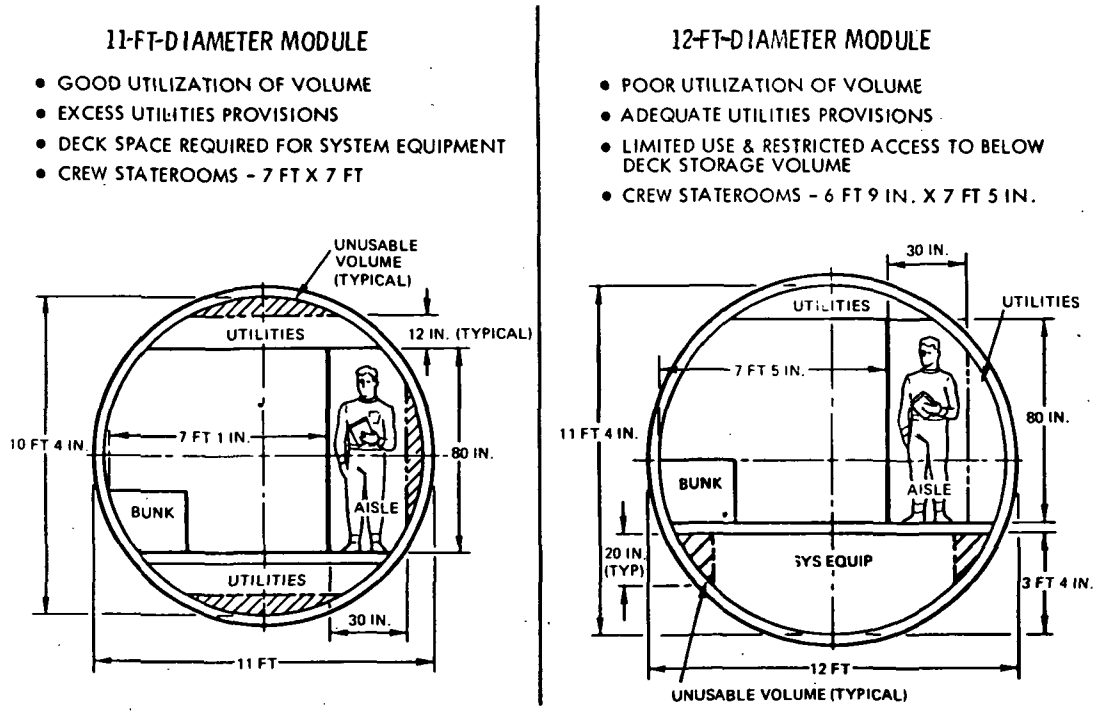


Figure 2-12. Module Diameters Evaluation (11 and 12 Foot)

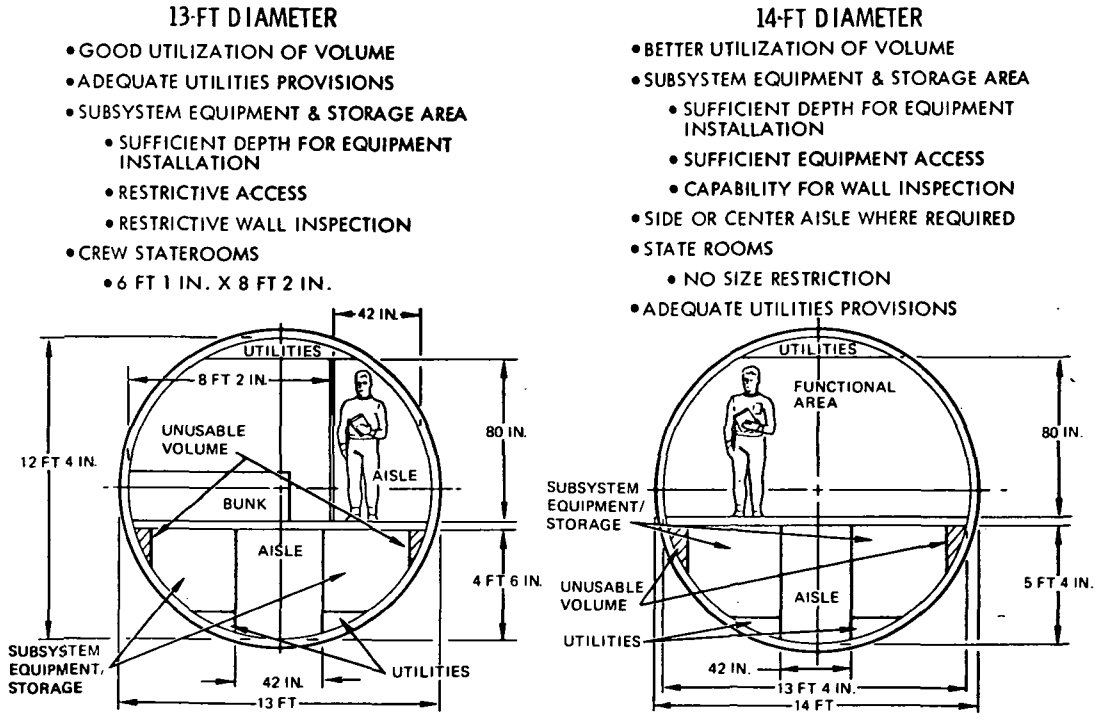


Figure 2-13. Module Diameters Evaluated (13 and 14 Foot)

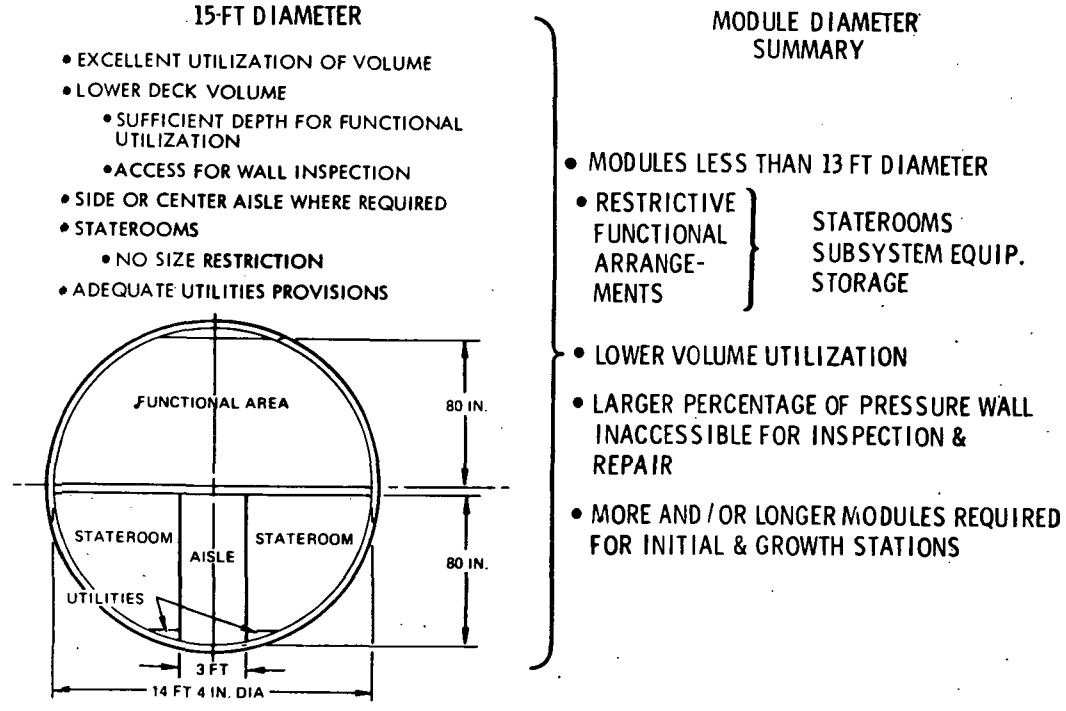


Figure 2-14. Module Diameters Evaluated (15 Foot and Module Diameter Summary)

The initial and growth stations for configuration 2 are illustrated in Figure 2-15 and the characteristics are presented in the following listing:

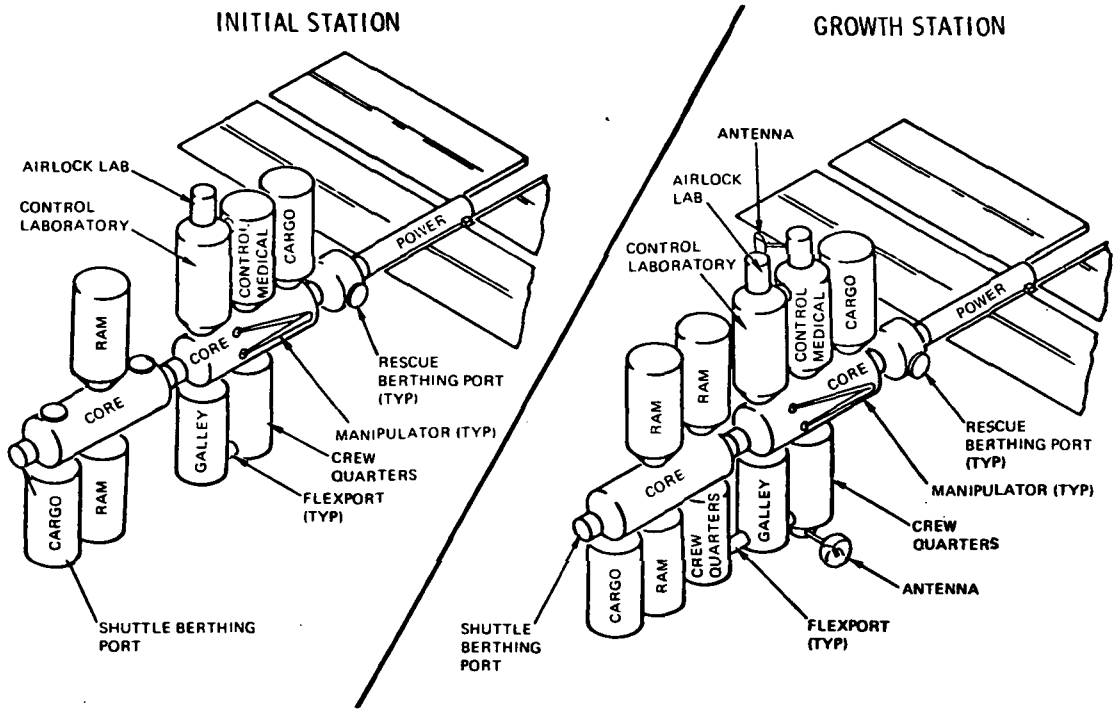


Figure 2-15. Station Configuration Study 2

1. Station modules in single plane: 4 initial, 5 growth
2. Dual core initial, same for growth
3. RAM in vertical plane away from solar array
4. Cargo module in vertical plane
5. Module spacing 1 foot, berth only
6. Cryogenic H_2, O_2, N_2
7. Solar array battery and low-temperature radiator
8. Launch sequence power, core, control
9. Control centers in station modules

The analysis of this configuration 2 study can be summarized as follows:

1. Reduce excess volume
2. One less module than study 1 configuration
3. Two less modules than reference configuration
4. Same functional facility areas as station A
5. Only expansion of equipment for growth station - three modules

Excessive growth scars

2.3 STUDY CONFIGURATION 3

The objective of study configuration 3 was to optimize station configuration at a six-man level to eliminate the excessive growth scars, i.e., area, equipment, and weight.

To optimize the station at a six-man level, a new functional allocation for the modules was in order. This task was a separate trade study and is discussed in Appendix A of this volume. To summarize this particular study, the merging and allocation process resulted in the preliminary facility sizing requirements listed in Table 2-4. Minimum floor area requirements represent minimums for design for the initial station. The maximum volumes listed for storage and allocated equipment occupies space on, above, or within the designated floor space. In other words, the floor space shown is not clear floor area but represents the merged facility floor space area with its associated equipment.

In general, more storage and equipment volume is required for the growth station than was required for the initial station. In several cases (such as the primary galley), this larger volume can be accommodated within the same initial station total floor space requirements without crowding or degrading the usefulness of the space. Additional work space has been provided for some merged facilities (such as the experiment control center) in the growth station because more crew members are simultaneously involved during work cycles.

The candidate facility groupings are listed in Table 2-5, with the upper two modules located in pressure volume 1, and the lower two modules in pressure volume 2. Staterooms, control centers, hygiene faciltiies, and galleys must be located in at least two pressure volumes to permit station operations to continue with double occupancy in staterooms when a loss of one pressure volume occurs.

Maintenance shops and laboratories should be in separate modules from the staterooms, galley and dining, and medical center, to remove maintenance activity discussion and noises. The airlock laboratory is also to be allocated to a separate module from the stateroom areas, primarily because of airlock noise disturbances to the staterooms.

The combination of offices and staterooms as well as galley and dining facilities in the same module results in general efficiency, space savings, and combines facilities where similar or related functions are performed. These facility groupings were arranged in modules as illustrated in Figures 2-16 and 2-17.

Table 2-4. Preliminary Facility Sizing (Initial Station)

Functional Area	Number Required		Area	Storage Volume
	V1	V2	Minimum Sq Ft per Facility	Cu Ft per Facility
General stateroom	2	2	50	30
Commander's stateroom/office backup control	0	1	90	55
Executive stateroom	1	0	90	
Personal hygiene				
With shower	0	1	54	30
Without shower	1	0	38	
Primary control center 2	1	0	50	50
Primary control center 1	0	1	50	TBD*
Primary galley	0	1	85	TBD
Backup galley	1	0	15	TBD
Dining/recreation	0	1	160	TBD
Prime crew care/exercise	1	0	190	140-190
Backup medical care/exercise	0	1	51	2
EVA/IVA airlock	1		35	0
GPL (physics)	0	1	34	
GPL (biomed/biolog)	0	1	34	
GPL (mechanical, electrical, optical maintenance)	1	0	232	490
GPL (photo lab)	0	1	33	TBD
GPL (data analysis)	0	1	95	TBD
Experiments operations (zenith airlock)	0	1	100	TBD
Experiment operations (nadir airlock)	1	0	168	TBD
Experiment airlocks	1	1	60	

*TBD - To be defined during Phase C/D

Table 2-5. Candidate Facility Grouping, Study No. 3

Crew quarters & control center module Experiment coordination and 2 crewm n Office and data analysis lab Control center Active recreation and backup galley Cargo storage V_1 Total 485 square feet	Crew care, physics lab, & ECLSS module Personal hygiene Crew care exercise med behav qual Physics material process and airlock lab Cargo storage Total 380 square feet V_1
V_2 Laboratory & ECLSS module Personal hygiene Fluid optics/electronics labs Backup crew care Photo lab Cargo storage Total 370 square feet	Crew quarters and dining module V_2 Commander and 2 crewmen Office and backup control Galley Dining and passive recreation Cargo storage Total 435 square feet

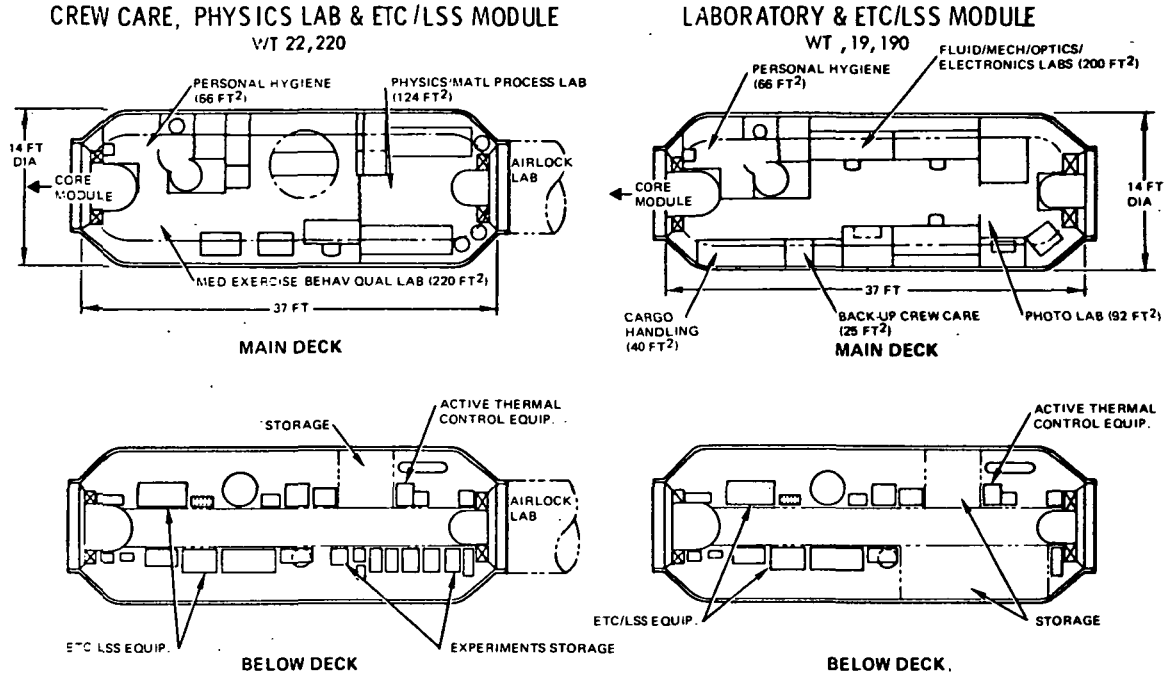


Figure 2-16. Module Arrangements

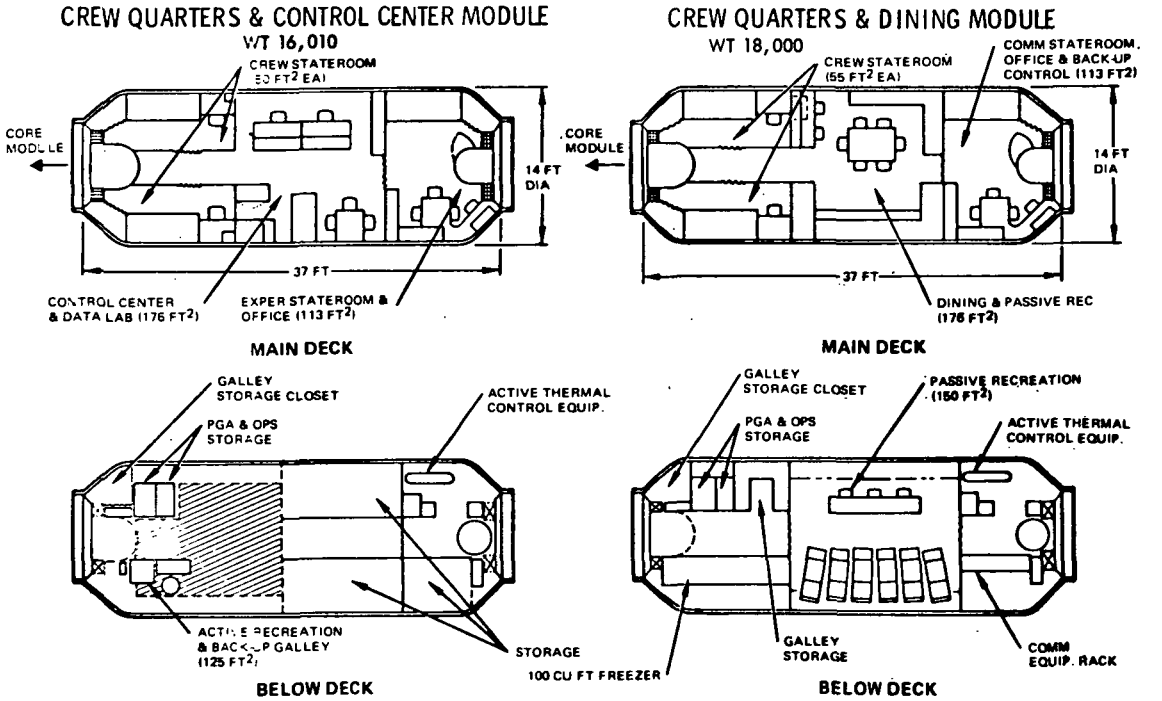


Figure 2-17. Module Arrangements

The initial station for study configuration 3 is illustrated in Figure 2-18 and its characteristics are listed below:

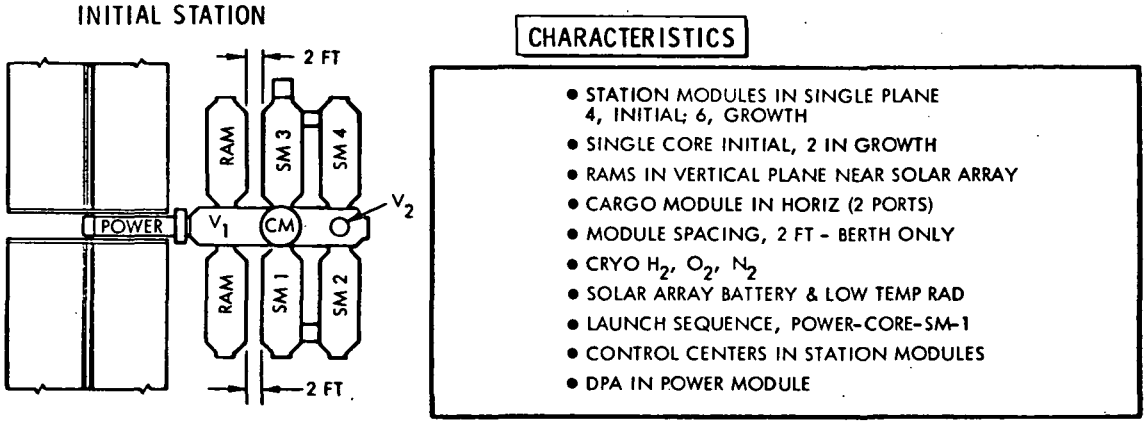


Figure 2-18. Station Configuration, Study 3

Station modules in single plane, 4, initial; 6, growth
Single core initial, 2 in growth
RAM's in vertical plane near solar array
Cargo module in horizontal (2 ports)
Module spacing, 2 feet - berth only
Cryogenic H_2, O_2, N_2
Solar array battery and low-temp radiator
Launch sequence, power-core-SM-1
Control centers in station modules
DPA in power module

The analysis of this study can be summarized as follows:

1. Four station modules for initial station
2. Lower deck volume utilized for active and passive recreation/ facilities, backup galley
3. Commonality
   - Length - 37 feet
   - Interior compartmentation
   - Subsystem equipment installation
4. Launch compatible length and weight

The functional groupings selected for this configuration are optimized for a six-man initial station.

2.4 STUDY CONFIGURATION 4

There were two key issues that evolved from the configuration 3 analysis: (1) berthing or direct docking (manipulator reach), and (2) core module overweight (exceeded target weight). The objective of study 4 was to resolve these two issues.

2.4.1 MANIPULATOR - BERTHING OR DIRECT DOCKING

Berthing or direct docking was a separate trade study that is documented in Appendix A of this volume. A summary of this study is presented in the following paragraphs.

Two concepts of station assembly are illustrated in Figure 2-19.

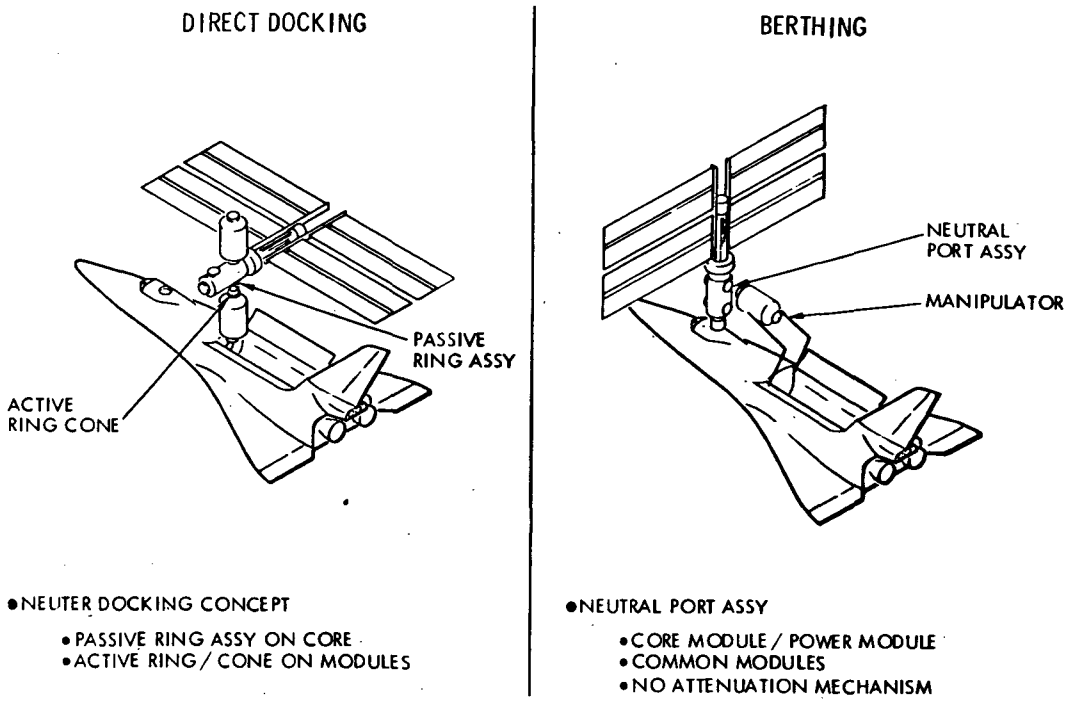


Figure 2-19. Docking and Berthing

Direct docking as utilized in the Phase A study uses the neuter docking concept with the passive ring assemblies located on the core module and the active ring/cone assembly on the attaching station modules. The active ring/cone assembly contains the latches and attenuation system.

The berthing concept utilizes either the shuttle or station manipulator for station assembly. A neutral port assembly is used on both the core module and the attaching modules. No attenuation mechanism is used. Berthing loads are attenuated by the structure.

A summary of mode selection considerations is presented in Table 2-6. The berthing mode was selected to be the prime mode of operations.

In the manipulator study, it was concluded that the shuttle manipulator would be used, and no requirements were identified for station manipulators. The conclusions of the manipulator analysis for module emplacement and replacement are summarized as follows:

1. Use shuttle manipulator only
2. Side berth shuttle
3. Module space, 24 inches minimum

Table 2-6. Mode Selection Considerations Summary

Considerations	Impact of Mode Selection	
	Berthing	Docking
Change in mode	Not possible	Will accommodate either
Manipulator design	Reach dependent	Independent
Core module penalty	None	a) Active port with attenuation b) 3-foot length
Common module penalty	None	Active port
Shuttle adapter	Sized to shuttle requirements	Sized to module length deltas

Mode Selection Recommendation

Recommendations	Rationale
• Retain berthing mode	• Allows deferrable option (Phase C)
• Make system/configuration compatible with direct docking - Module spacing, 5 ft - Scar weight = 384 lb	

2.4.2 CORE MODULE OVERWEIGHT

During the study configuration 3 phase, a requirement was imposed to have the RAM's located in the vertical plane. A single core module with 2-foot spacing between modules with the RAM's in the vertical phase require a longer core module. This additional length caused it to exceed the 20,000-pound target weight. For study configuration 4, the two-core module concept was selected for the initial station, which is within the target weight.

The configuration 4 initial station concept evolved from this analysis is depicted in Figure 2-20. Its characteristics are presented in the following listing:

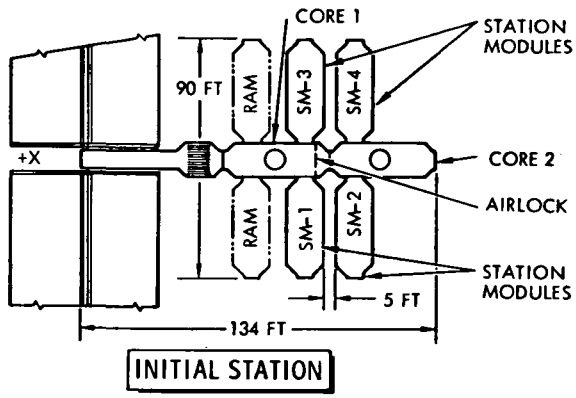


Figure 2-20. Station Configuration 4

1. Station modules in single plane: 4, initial; 6, growth
2. Dual core initial, 3 for growth
3. RAM's in vertical plane near solar array
4. Cargo module in horizontal plane (4 ports)
5. 5-foot module spacing (berth or dock)
6. Cryogenic O_2, H_2, N_2
7. Solar array battery and low-temperature radiator
8. Launch sequence power, Core 1, SM-1
9. Control centers in station modules
10. DPA in power module

2.5 STUDY CONFIGURATION 5

During the study of configuration 4, a separate subsystem trades and selection was conducted. This study was completed and it influences the equipment allocations and arrangements of the station modules for configuration 5. The subsystems analyses are documented in SD 71-217-4, Volume IV.

2.5.1 SUBSYSTEM SELECTION

To briefly summarize the results of the subsystem trades, the assignment of major assemblies to the various subsystems are portrayed in Figure 2-22. Since commonality existed between subsystems for gas usage, an integrated subsystem concept was utilized as reflected in Figure 2-21.

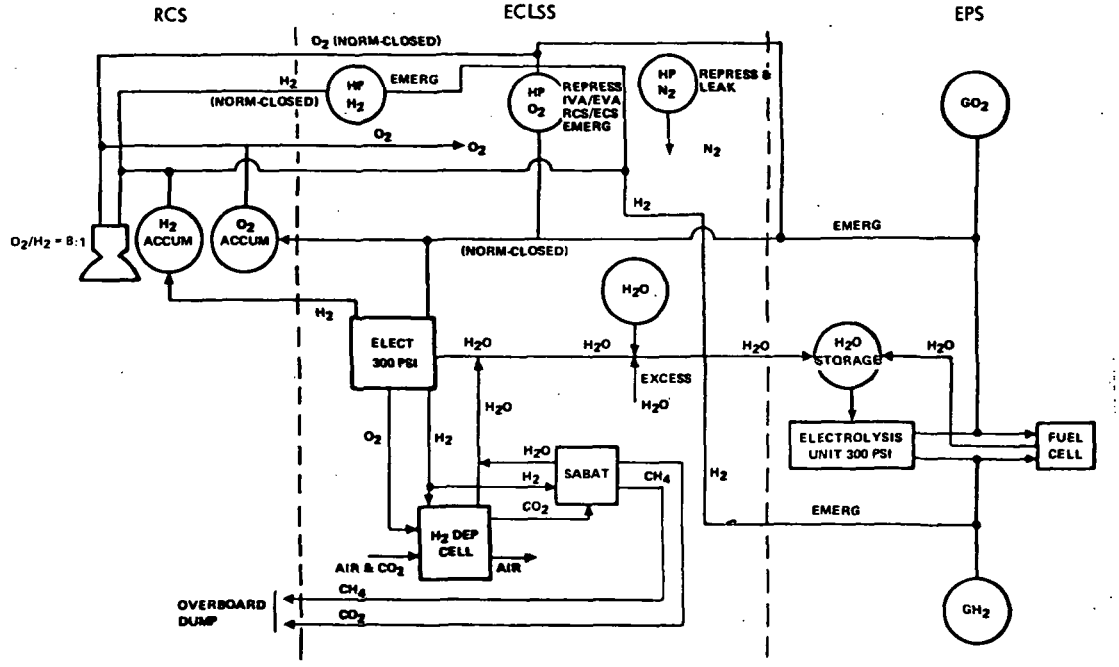


Figure 2-21. Integrated Subsystem Concept

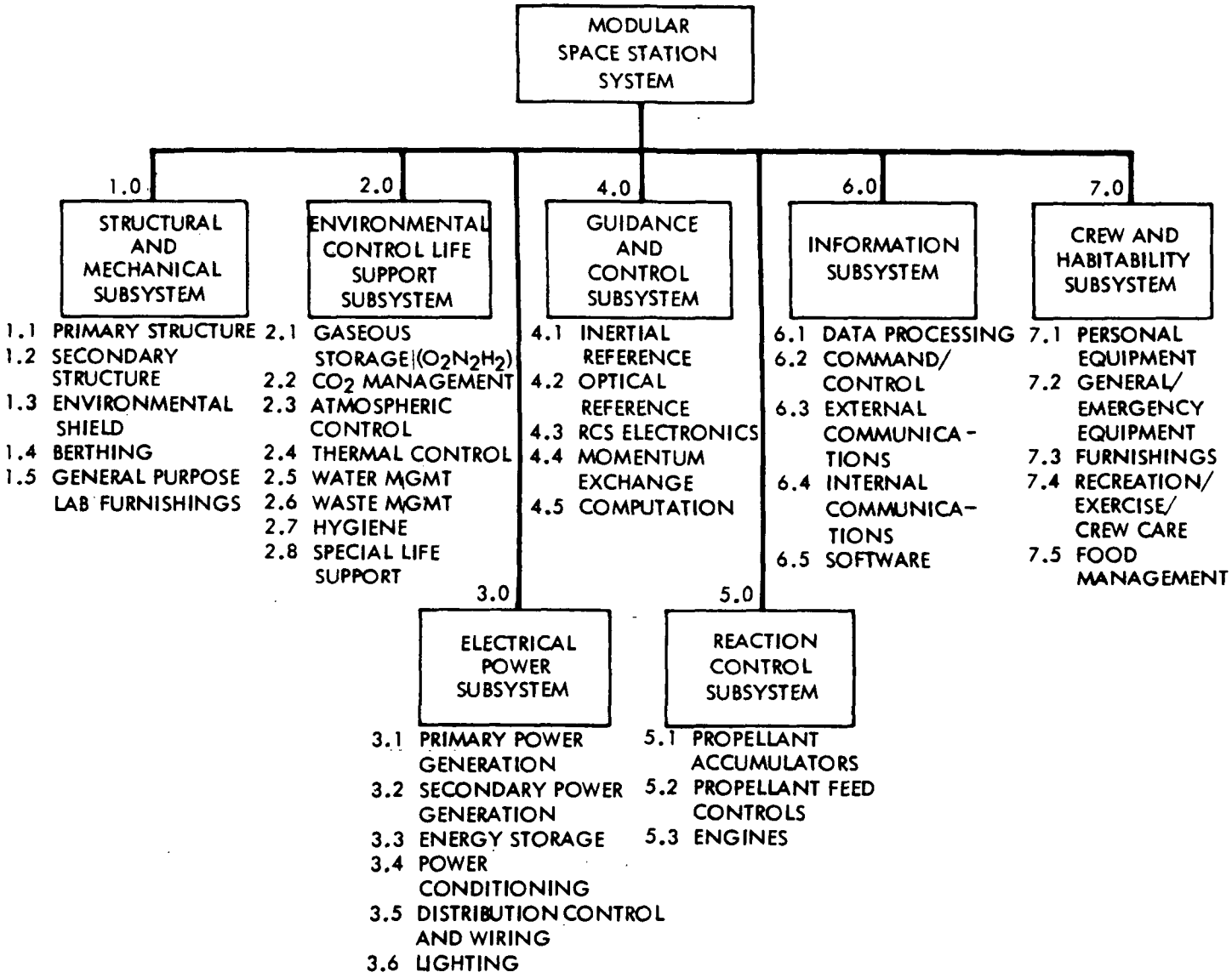


Figure 2-22. Modular Space Station Subsystems

Space Division
North American Rockwell

The Subsystems trade results and rationale for selected configurations are summarized as follows:

EPS: regenerative fuel cell energy storage selection
Cost reduction with shared development
Fuel cells provide secondary power generation function
Reduced weight, volume, complexity, thermal control
Improved operational flexibility
Selection sensitive to development cost and lifetimes

The EPS will utilize four regenerative fuel cell assemblies each consisting of one fuel cell, electrolysis unit, H_2 accumulator, O_2 accumulator, and one-half of an H_2O storage tank. The assembly can receive and supply in an emergency H_2, O_2, or H_2O to the ECLSS/RCS.

RCS: H_2O electrolysis H_2-O_2 RCS viable option
Safety-water resupply
Propellant transfer and conditioning improved
Shared development potential

The RCS stores H_2 and O_2 gases generated at 300 psia by the ECLSS. The oxidizer/fuel ratio has been changed from 3:1 to 8:1, which is the combination ratio of O_2 and H_2, to minimize venting.

ECLSS: Sabatier used for all closed O_2 recovery concepts
SSP technology
Minimum cost
Availability
CO_2 removal
H_2 depolarizer
Low power and heat rejection requirements
Shared development costs
Good growth capability
Low logistics costs

The ECLSS is a closed O_2 and H_2O concept consisting of an H_2 depolarizer for CO_2 removal, Sabatier for CO_2 reduction, electrolysis for O_2 recovery and for RCS H_2/O_2 generation, and vapor compression for H_2O reclamation. All resupply gases are by 3000-psia high-pressure storage. The integrated subsystem uses gaseous storage at 300 and 3000 psia. Because of the large number of tanks or accumulators involved, an integrated storage concept is used as previously shown.

As a result of the integrated subsystem selection, the cryogenic storage and solar-array battery system was deleted. The incorporation of the integrated subsystems required a reallocation of special module equipment (high-pressure tanks, fuel cells, etc.). During this reallocation analysis, it was concluded that the core module should be the first launched module because it contained a majority of the necessary functions for normal station operations. With the power module being launched first, functions had to be added such as RCS and G&C, which created additional scar weight. For subsequent studies, the core module was used as the first launched module.

2.5.2 MODULE REPLACEMENT

A key issue, module replacement impact assessment, was identified. This analysis was conducted and is summarized in the following paragraphs.

The optional functional allocations and equipment arrangements available to assess module replacement impact are depicted in Figure 2-23. Control of the station, life support for the crew, and galley functions with the subsystem equipment required for their operation is essential to mission continuation with a module removed for replacement.

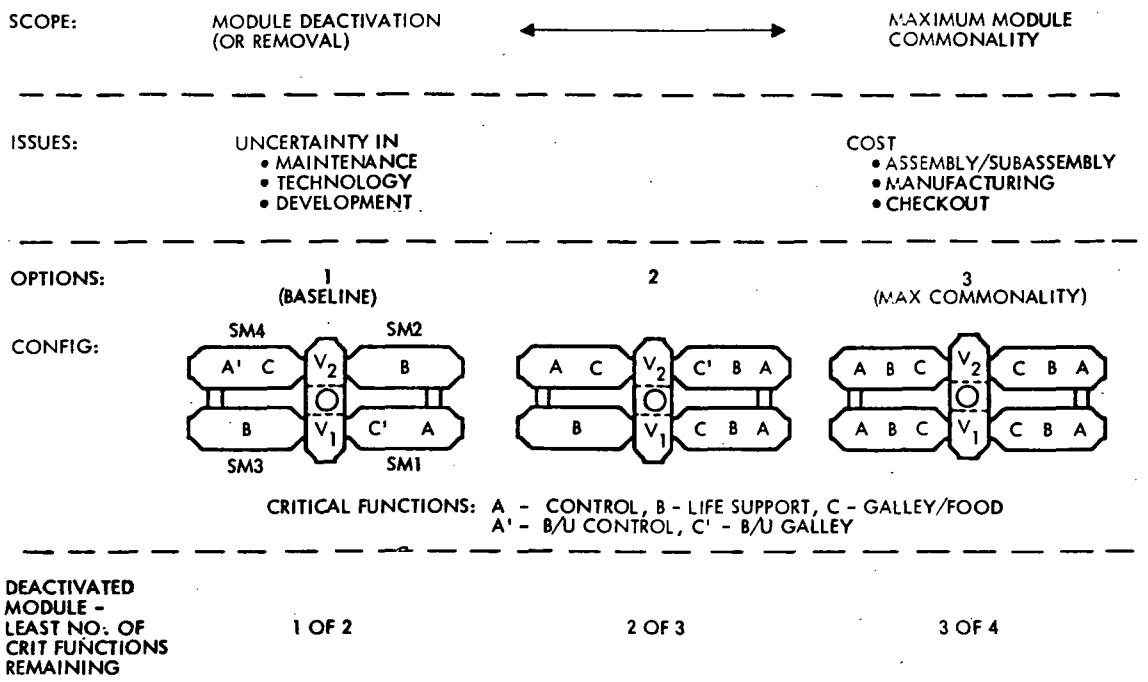


Figure 2-23. Module Replacement Impact on Facility/Hardware Allocations

Option 1 consists of two basic functional modules: two of type A - control center and staterooms, and type B - life support/galley-dining. With removal of any one module, the key function is still retained in the station without backup. Option 2 modules consist of control centers, staterooms, galley-dining areas, and life support functions in three modules; thus, two modules contain all of the functions listed. With removal of one module, the key functions are retained in two other modules. Option 3 modules have

maximum commonality with control centers, staterooms, life support, galley-dining, and GPL located in all four station modules. Since each function is provided in four modules, three of the four are retained after module removal.

Considerations and conclusions are as follows:

Option 1

Can station operate at reduced performance with one module deactivated

Loss of volume plus another module deactivated requires two separate accidents - too many to influence design requirements.

Space modules required for module replacement are costly - cargo kits are temporarily more practical and less costly.

Option 2

Increased (over Option 1) station operability with one module deactivated

No increase in capability over Option 1 for loss of one-half of the station volume

Weight and cost deltas are not significant

Option 3

Little increase (over Option 2) in station operability with one module deactivated

Significant increase (over Option 2) for loss of one-half of the station volume

Weight and cost deltas

No spare module required

Options 2 and 3, while increasing the level of commonality, offer no significant functional advantage over Option 1 that would justify their increased cost and complexity. The reference Option 1 level of commonaltiy between modules is considered adequate to offset uncertainties in technology, development, and maintenance. In addition, Option 1 level of commonality between modules allows mission continuation at a reduced level with a module deactivated or removed because of an accident.

The removal/deactivation approach to be considered for station operations as a result of this study is summarized as follows:

1. No routine plan for module replacement for subsystem maintenance

2. Nominal operation mode - all maintenance performed on-orbit

3. Provide capability for module replacement (consider as an unscheduled major event; result of accident, not failure)

4. Functions reallocated to permit mission continuation at reduced level during module replacement/deactivation

The initial station configuration desired for configuration 5 is illustrated in Figure 2-24:

The characteristics for this particular station configuration are as follows:

1. Station modules in single plane: 4, initial; 6, growth
2. Dual core initial, 3 for growth
3. RAM's in vertical plan near solar array
4. Cargo module in horizontal plane (2 ports)
5. Module spacing 5 feet (berth or dock)
6. High pressure O_2, H_2, N_2
7. Regenerative fuel cells
8. Launch sequence Core 1, Core 2, power, SM-1
9. Control centers in station modules

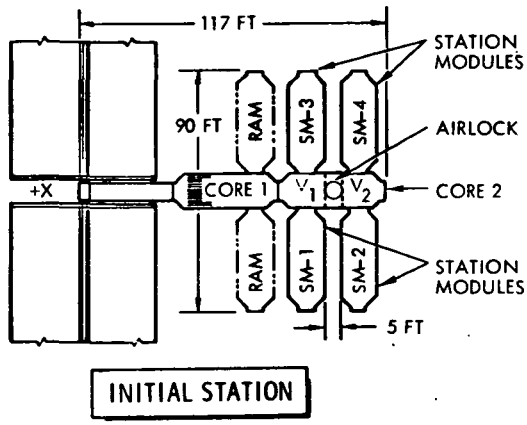


Figure 2-24. Study Configuration 5

2.6 STUDY CONFIGURATION 6

In configuration 5, the core module was selected for the first launch module and it contained the high-pressure gaseous storage tanks. From a safety viewpoint, the location of these high-pressure tanks was undesirable. For configuration 6, this activity was directed toward accomplishing two objectives:

1. Relocate the high-pressure tanks (emergency and repressure)

2. Investigate feasibility of installing control centers in core module

2.6.1 HIGH-PRESSURE TANKS RELOCATION

When the core module was selected for the first launched module, equipment no longer required for station buildup was removed from the power module. This module provided an ideal location for high-pressure tanks, being isolated from the habitability area and requiring minimum crew access. The power boom was selected as the location for the high-pressure tanks. Twenty high-pressure storage tanks were required and were located as depicted in Figure 2-25.

2.6.2 RELOCATED CONTROL CENTERS

Functional analysis indicated that the core modules were a logical location for the station control centers. It provided the capability of activating some systems earlier, centrally located, and eliminated some interim equipment required for initial station buildup.

A control center was located in each core module to provide subsystem control during buildup (without special buildup control equipment), as illustrated in Figures 2-26 and 2-27.

Station configuration 6 is illustrated in Figure 2-28. Its characteristics are as follows:

1. Station modules in single plane: 4, initial; 6, growth
2. Dual core initial, 3 growth
3. RAM's in vertical plane near solar array
4. Cargo modules in horizontal plane (2 ports)
5. Module spacing 5 feet (berth or dock)
6. High-pressure O_2, H_2, N_2
7. Regenerative fuel cells
8. Launch sequence Core 1, Core, power
9. Control centers in core modules

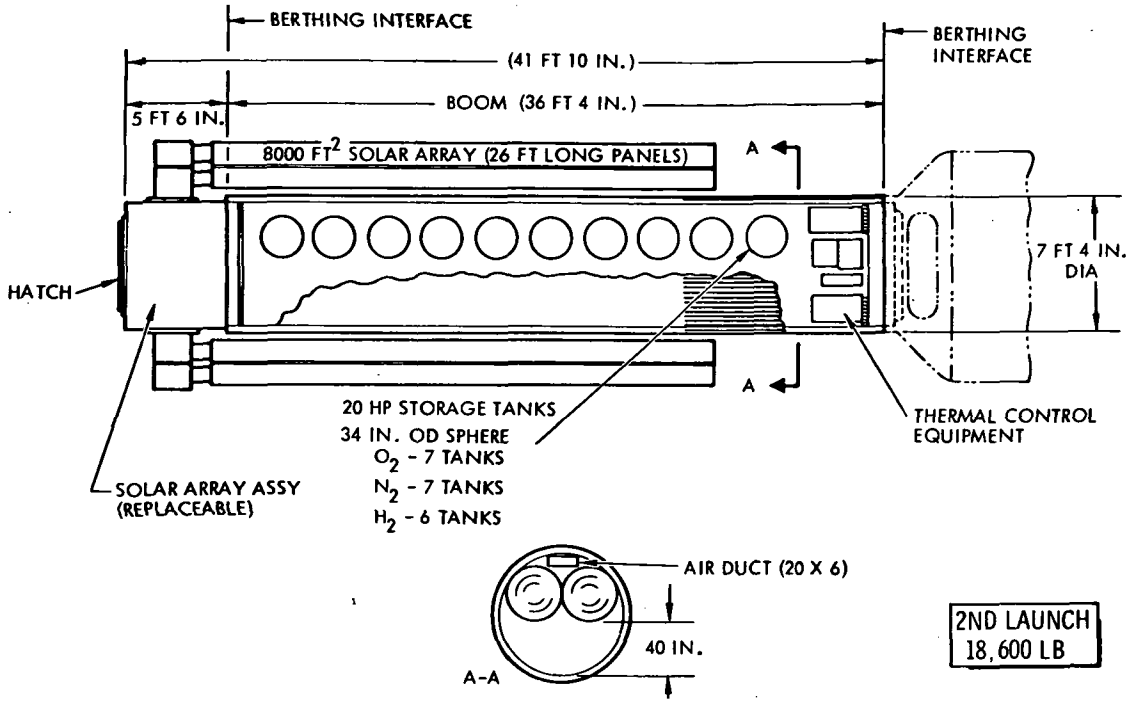


Figure 2-25. Power Boom--Initial Station (Study 6)

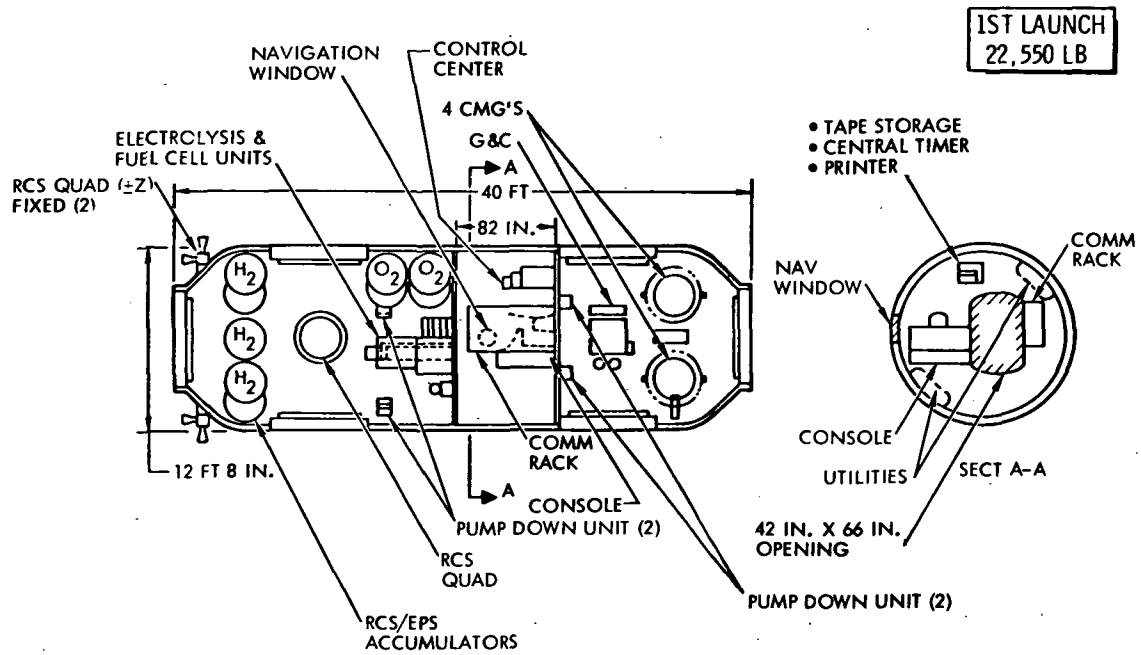


Figure 2-26. Core Module 1 (Study 6)

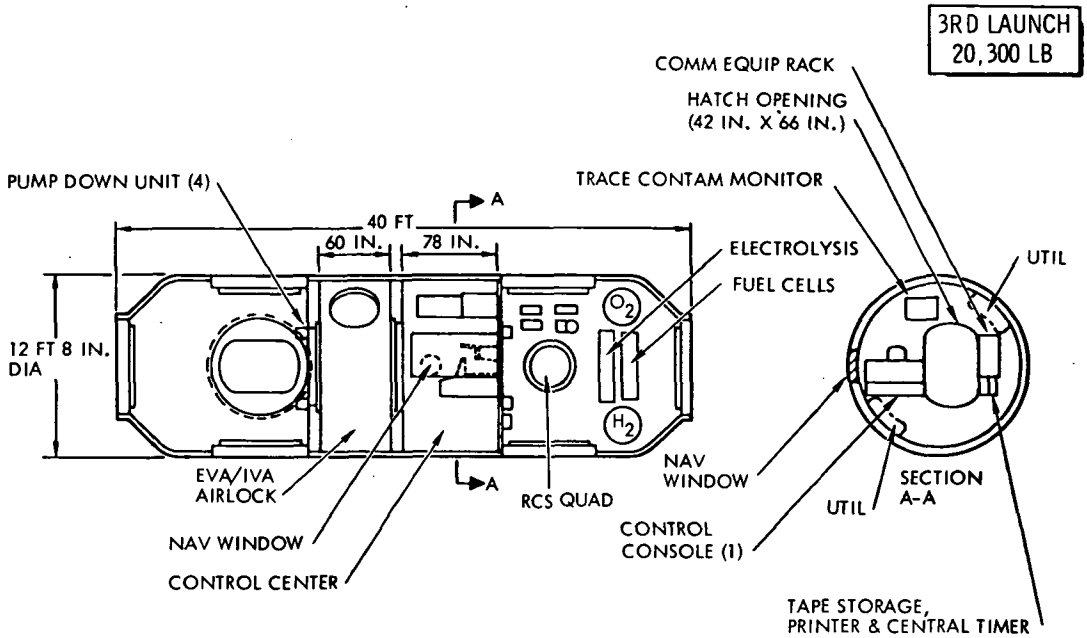


Figure 2-27. Core Module 2 (Study 6)

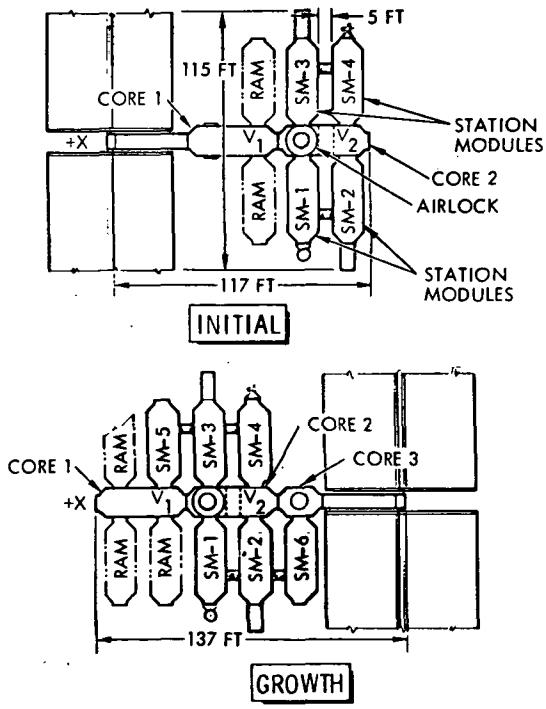


Figure 2-28. Study Configuration 6

2.7 STUDY CONFIGURATION 7

A review was conducted of the configurations studied and their sensitivities. The conclusion reached was that the barbell configuration inherently possessed characteristics that could not be corrected and thus produced the undesirable complexities and incompatibilities. Analyzing the effects of reverting to the cruciform configurations, it was determined that considerable reduction or resolution could be achieved. Selecting the cruciform concept would produce the effects noted:

1. Deletion of one core module from the initial station reduces repressurization gas volume

2. Reduced momentum exchange level reduces CMG size and number

3. Reduced impulse requirement reduces propellant usage and gas storage

4. Increased stiffness increases natural frequency

5. Nearly equalized minimum control moment gyro, minimum impulse, has minor effect on flight mode selection

For configuration 7, the decision was made to use the cruciform concept. Also, further analysis of the configuration 6 study showed that the core module exceeded the target weight. Therefore, the objectives for this particular study will be:

1. Evaluate and select a split-level crew quarters or single level

2. Reallocate equipment for a single core cruciform configuration

2.7.1 SPLIT-LEVEL CREW QUARTERS

The single-level and split-level internal arrangements were studied to determine the utilization of volume, desired groupings, and GPS facilities. The arrangement concepts used as a starting point are illustrated in Figure 2-29. Also, the crew/habitability functional arrangement preferences were considered and are presented in the following listing:

1. Active recreation area should be away from passive recreational area

2. Private areas (e.g., staterooms) should be away from high traffic/noise areas (e.g., aisles, dining, recreation)

3. Flexports should enter into public areas

4. Galley and dining should be adjacent facilities

5. Personal hygiene should be near staterooms

6. Control centers should be near staterooms

7. Dimensional criteria (ceiling height 82 inches, main deck and general mobility areas)

The allocation of functions per module between volume 1 and volume 2 for the two internal arrangements (single level and split level) are shown in Table 2-7. The circled number refers to the basic arrangement preferences from the listing above. The functions both above and below decks are listed for each of the four station modules.

The split-level concept was selected because of better utilization of volume and desired groupings. For the split-level staterooms, the internal arrangement for the crew and commander's area is depicted in Figure 2-30. It shows utility runs, bunk and desk locations, secondary bunk locations, and usable floor areas. The commander's stateroom is above deck and the crew staterooms are below deck.

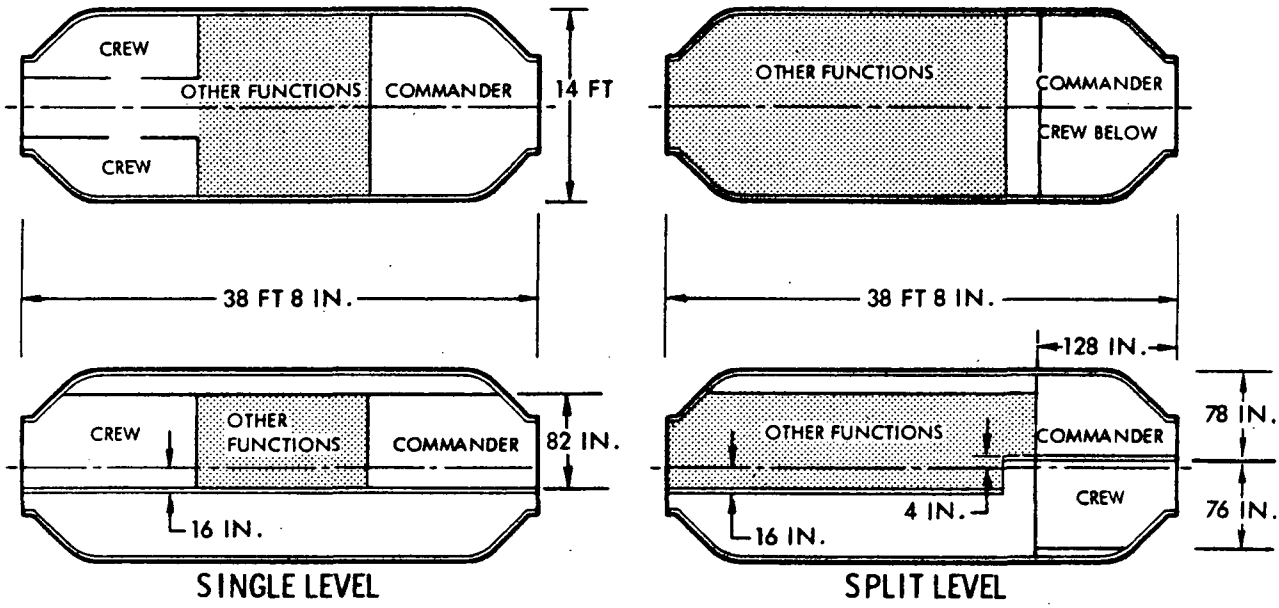


Figure 2-29. Arrangement Concepts

Table 2-7. Space Station Functional Allocation Comparison

	SINGLE LEVEL	SPLIT LEVEL	SINGLE LEVEL	SPLIT LEVEL
	SM-1 V_1		V_2 SM-2	
ABOVE DECK	CREW STATEROOM (3) ②ACTIVE RECREATION BACKUP GALLEY	EXECUTIVE STATEROOM ②ACTIVE RECREATION BACKUP GALLEY ⑤HYGIENE FACILITY	GPL-PHOTO LAB -DATA ANALYSIS LAB -FMDE -AIRLOCK ⑤HYGIENE FACILITY	GALLEY ②DINING/PASSIVE RECREATION GPL-PHOTO LAB
BELOW DECK	STORAGE	CREW STATEROOM (2) WASTE MANAGEMENT EQUIPMENT	AIR REVITALIZATION AIR EQUIPMENT WASTE MANAGEMENT EQUIPMENT	AIR REVITALIZATION EQUIPMENT FREEZER
	SM-3		SM-4	
ABOVE DECK	⑤HYGIENE FACILITY GPL-PHYSICS/MTL -PROCESSES LAB -MED CARE/BEHAV LAB -AIRLOCK	GPL-PHYSICS/MTL -PROCESSES LAB -AIRLOCK -FMOE -DATA ANALYSIS BACKUP MEDICAL CARE	CMDR STATEROOM/OFFICE CREW STATEROOM (2) { GALLEY ②DINING { PASSIVE RECREATION	CMDR STATEROOM/OFFICE ⑤HYGIENE FACILITY GPL-MED CARE/ BEHAV LAB
BELOW DECK	AIR REVITALIZATION EQUIPMENT WASTE MANAGEMENT EQUIPMENT	AIR REVITALIZATION EQUIPMENT STORAGE	STORAGE FREEZER	WASTE MANAGEMENT EQUIPMENT

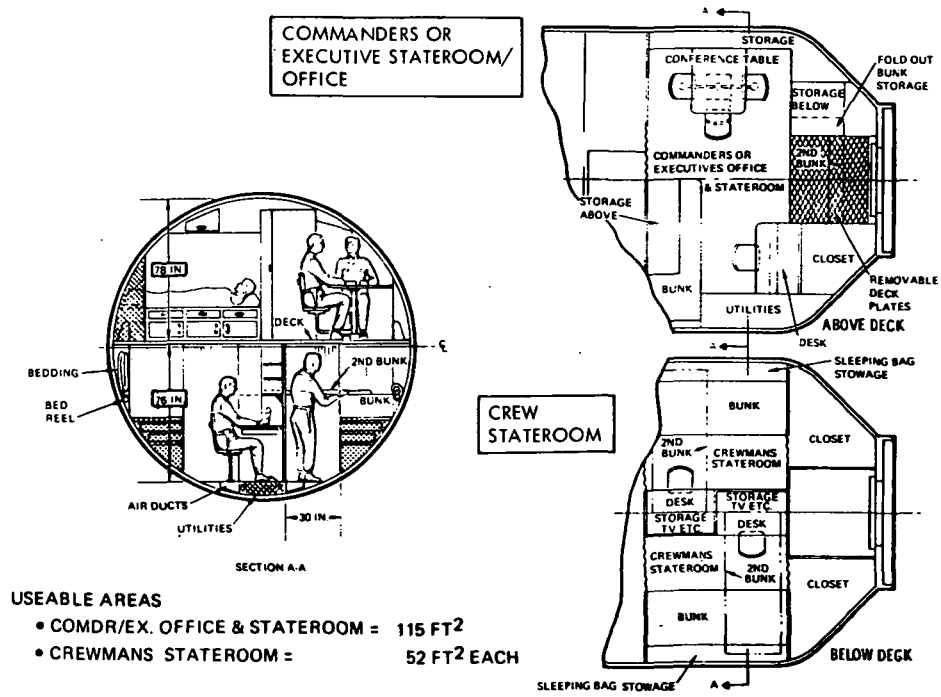


Figure 2-30. Split-Level Staterooms

2.7.2 EQUIPMENT RELOCATION

The reallocation of facilities for the initial station modules and description is presented in the following paragraphs.

Crew/Control Station Modules

The two crew/control modules, SM-1 and SM-4, have common functional allocations and equipment locations. Each module performs a similar function in each of the two pressure-isolatable volumes of the station. Where backup functions are provided, they are located in similar areas in the module of the opposite volume.

Both SM-1 and SM-4 contain a commander/executive type stateroom and two crew staterooms in a split-level arrangement. Control centers are located on the upper deck of each module outside the stateroom. The personal hygiene facilities are in similar locations; however, only SM-1 contains a shower. The waste management equipment is located below deck near the personal hygiene facility to simplify sewage transport and processing.

The area above deck in SM-1 contains the experiment data analysis equipment, including a data analysis control console, a photo-processing laboratory, and an isotonic exercise area. The exercise areas are also equipped to serve as a backup medical facility. The area above deck in SM-4 contains the primary medical and crew care facilities.

The crew/control modules, SM-1 and SM-4, are illustrated in Figures 2-31 and 2-32.

Laboratory/ECS Station Modules

The two laboratory/ECS modules, SM-2 and SM-3, are in different isolatable volumes of the station. Where backup functions are provided, they are located in similar areas in the module of the opposite volume.

The lower deck area of station modules 2 and 3 contains environmental control subsystem assemblies for air revitalization (CO_2 management and atmosphere control). Common installation arrangements provide easy access for maintenance and service. The remaining lower deck area is for storage of station and experiment supplies.

The above-deck area in SM-3 contains the primary galley/dining and recreation areas, as well as general-purpose laboratory facilities. The laboratory capability is designed to support both physics and biomedical experiments. The above-deck area in SM-2 contains primarily general-purpose laboratory installations; however, a small backup galley is installed at the inboard end of the module. GPL equipment and areas for mechanical, electrical, and optical maintenance are provided.

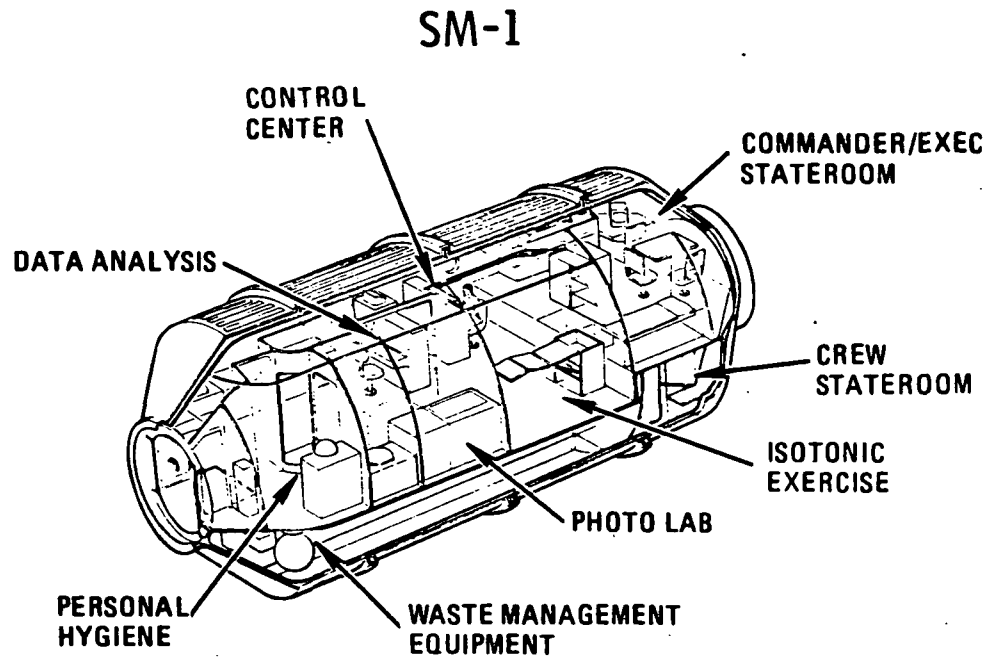


Figure 2-31. Station Module 1

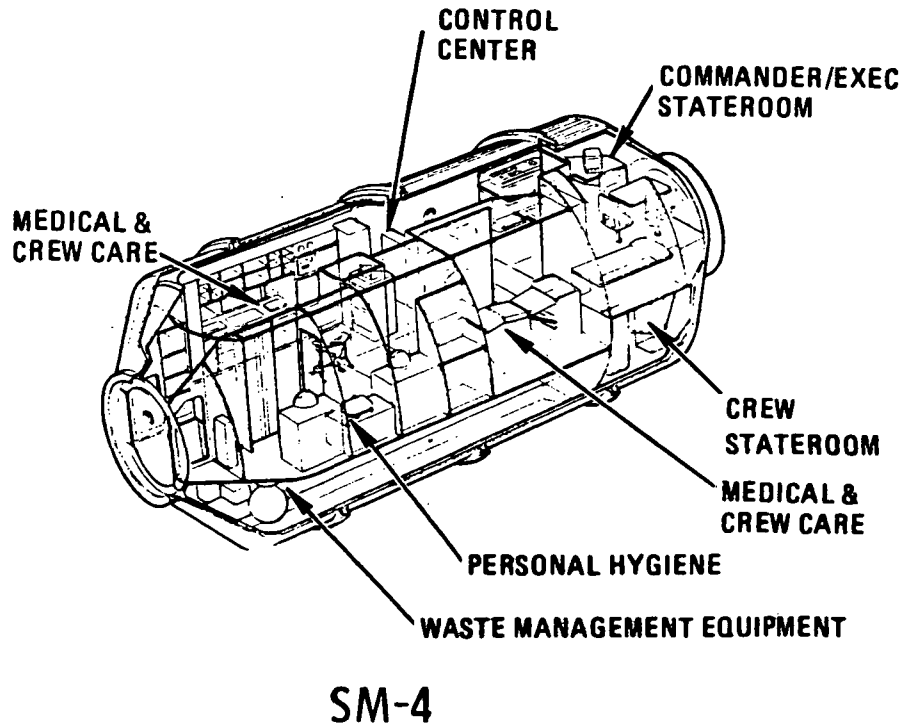


Figure 2-32. Station Module 4

A general-purpose airlock is attached to these laboratory modules. The one on SM-2 points to nadir on SM-3 to zenith. An experiment operations area and airlock loading access space are provided in each module at the airlock end.

The laboratory/ECS modules, SM-2 and SM-3, are illustrated in Figures 2-33 and 2-34.

Power Module

There were configuration changes between study configuration 6 and 7 for the power module. The thermal equipment and radiator were removed and installed on the station modules. Leakage makeup gas was relocated to the cargo module therefore reducing the number of tanks required in the boom.

The power module consists of two assemblies, a power boom and a solar array. The solar-array assembly consists of the arrays and an orientation drive and power transfer mechanism. Shirtsleeve maintenance of the mechanisms is provided. The solar-array assembly is replaceable and utilizes the standard berthing port.

The power boom is 88 inches outside diameter by 31 feet, 3 inches long (sized for growth). The 88-in diameter boom allows the solar-array panels to stow within the 15-foot diameter shuttle payload envelope. The boom is of monocoque construction utilizing 0.145-inch thick aluminum, which increases its stiffness and consequently increases the natural frequency of the total space station assembly. Four high-pressure gas storage bottles for makeup are placed in the boom. Shirtsleeve maintenance and replacement is provided even though the more module is normally operated unpressurized. The power boom configuration is illustrated in Figure 2-35.

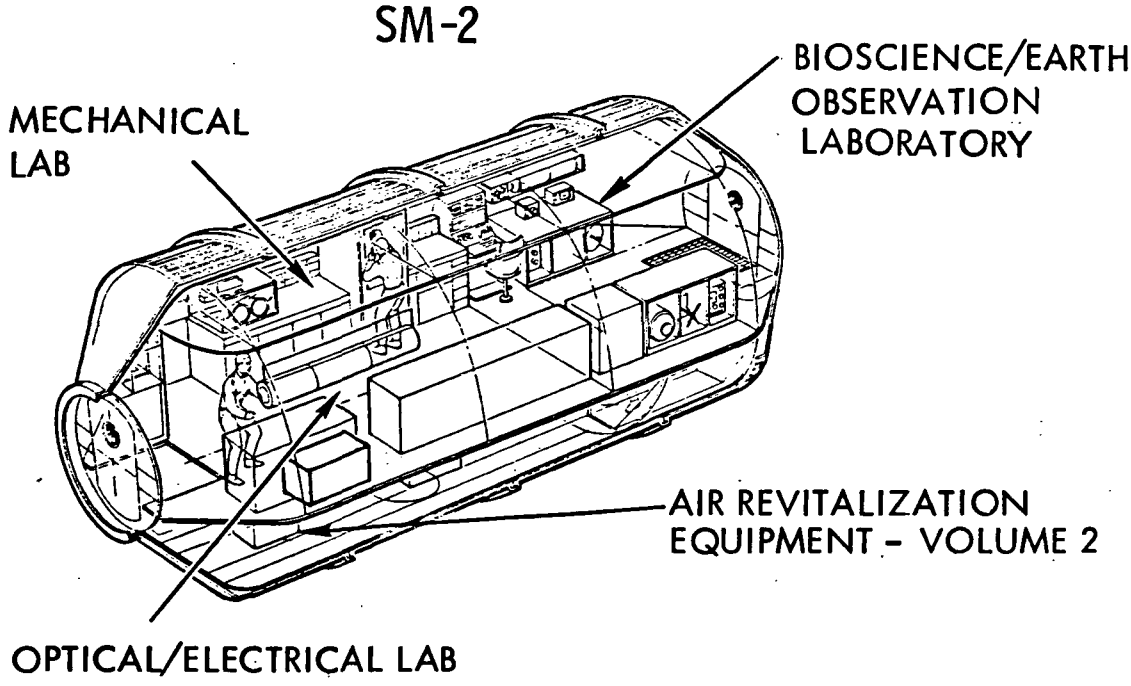


Figure 2-33. Station Module 2

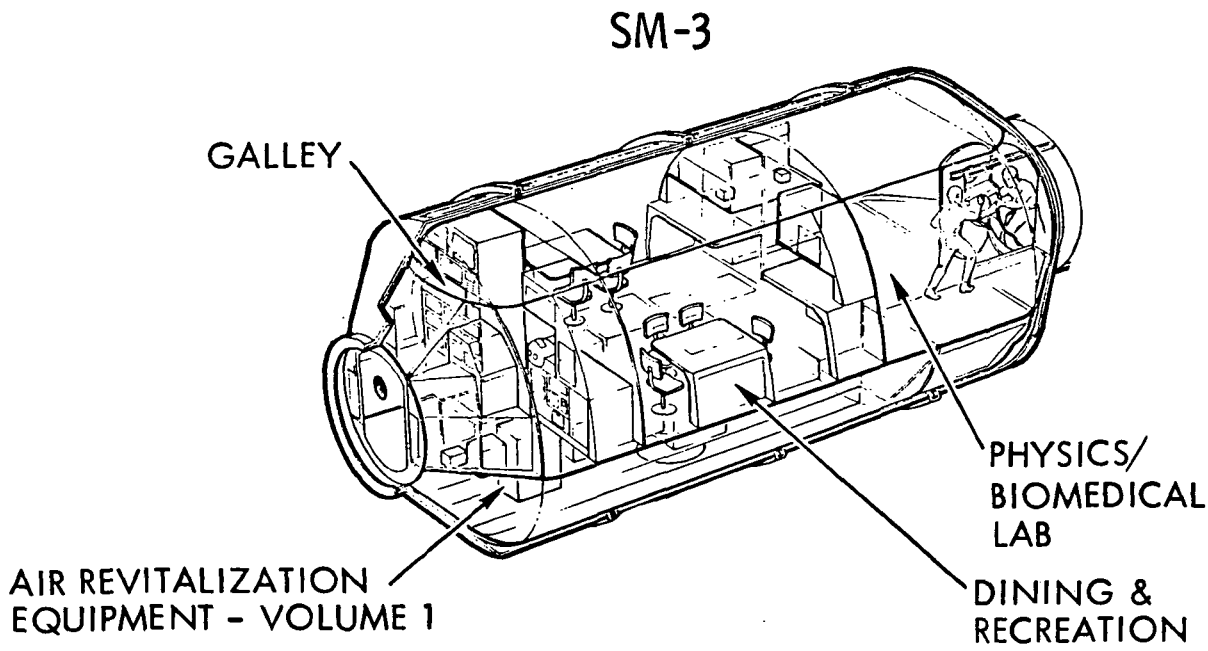


Figure 2-34. Station Module 3

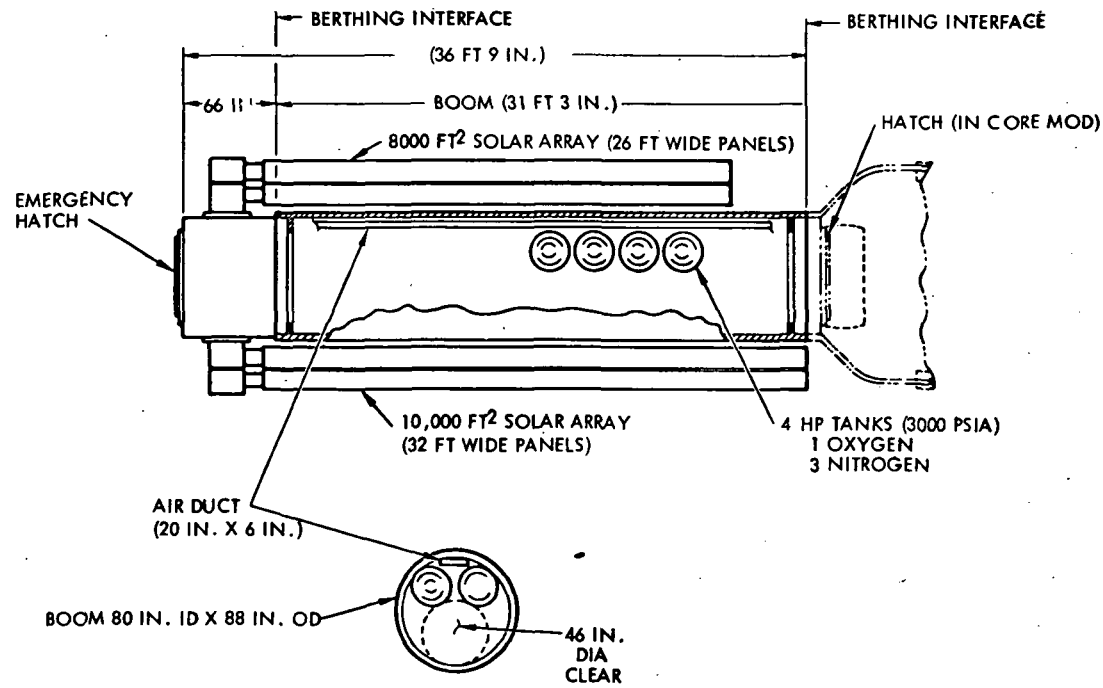


Figure 2-35. Power Boom Concept

Core Module

The core module is 40 feet long between berthing interfaces and is 12 feet, 8 inches outside diameter. The 15-foot diameter envelope intersects the edges of the side-berthing ports cluster. Lightweight skin (0.040-inch aluminum) and stringer construction is utilized. The eight side-berthing ports are spaced 20 feet apart, which allows a 5-foot clearance between the station modules.

The installed subsystems are distributed between the V_1 and V_2 volumes separated by the EVA/IVA airlock. The airlock provides an equivalent floor of approximately 5 feet by 7 feet. All of the hatches open outward from the airlock. The EVA hatch (40-inch diameter clear opening) is located at a 45-degree angle, which provides the maximum clearance between attached modules. The G&C optical reference and CMG's are located adjacent to the RAM berthing ports.

Certain buildup equipment is accommodated such as the antennas, thermal control radiators, RCS propellant, and initial power. All subsystem components are installed with on-orbit shirtsleeve maintenance accommodations including maintenance of the RCS engine assemblies. The utilities routing throughout the module from berthing port to berthing port and end to end of the module are redundant and separated for damage containment and safety.

The control centers were removed from the core modules and located in SM-1 and SM-4. The core module configuration is illustrated in Figure 2-36.

Initial Station

The selected configuration for the initial station is illustrated in Figure 2-37.

The cruciform was selected for preliminary design because of the major reductions in the influencing parameters discussed previously. The special modules required for the initial station are the 40-foot core and the 37-foot power module. Four station modules (denoted as SM-1 through SM-4) are common modules located on the Z ports. Selection of the cruciform configuration allowed the cargo and RAM modules to be located on the Y-axis ports. The station characteristics are as follows:

Station modules in two planes: 4, initial; 6, growth
Single core initial, 1-1/2 for growth
RAM's in horizontal plane
Cargo modules in horizontal plane
Module spacing 5 feet, (berth or dock)
High pressure O_2, H_2, N_2
Regenerative fuel cells
Launch sequence, core, power, SM-1
Control centers in station modules

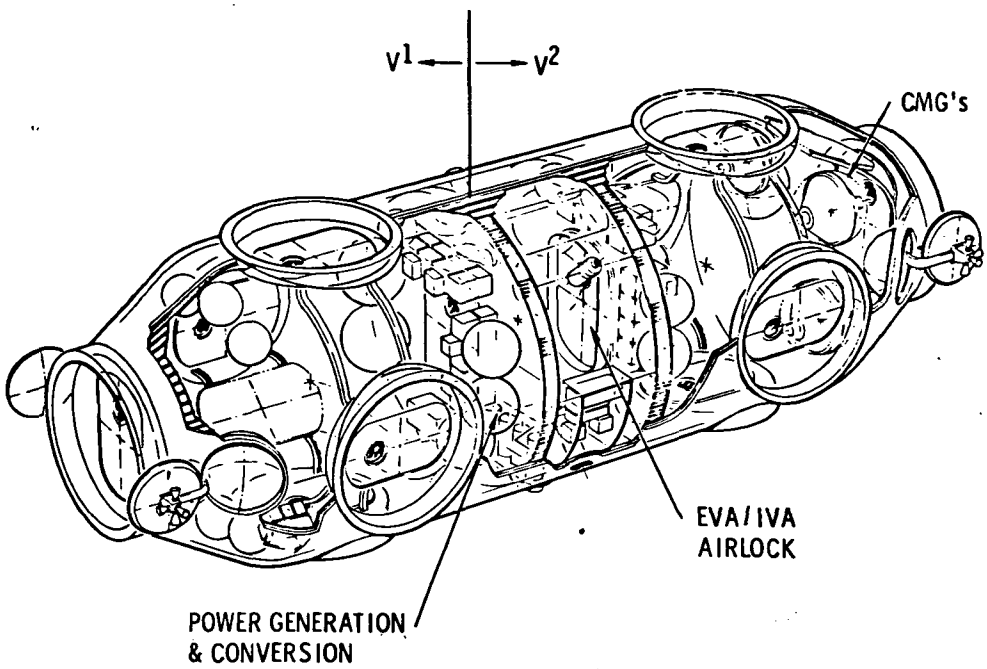


Figure 2-36. Core Module

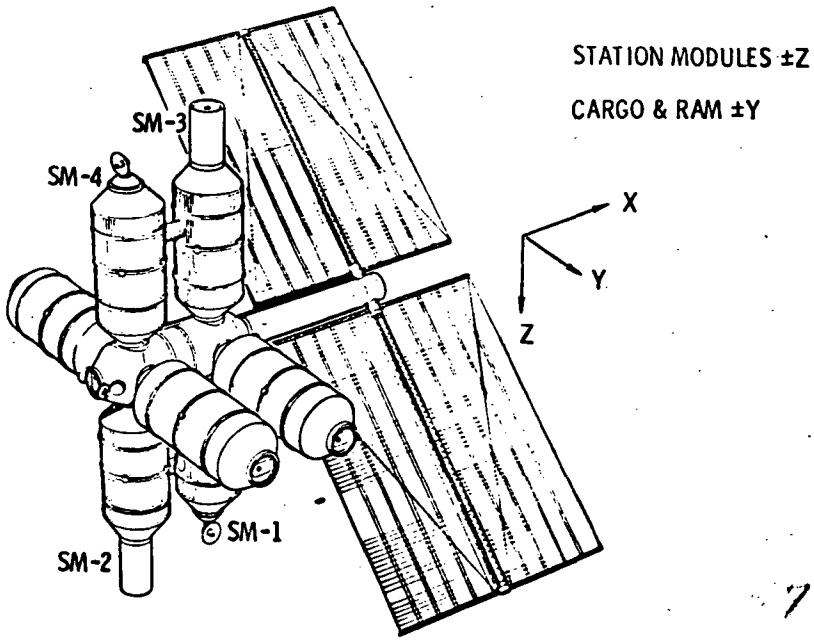


Figure 2-37. Selected Configuration - Initial Station

2.8 STUDY CONFIGURATION 8

The configuration study was directed toward incorporation of the final equipment sizing and minor arrangement changes resulting from preliminary design integration.

The station modules, SM-1 through SM-4, as previously discussed and illustrated in study configuration 7 remained basically the same in internal and external arrangements in the final preliminary design configuration. These modules are discussed in detail in Section 1 of this report. The design changes between study configuration 7 and 8 are in the power boom and core module. Previously, the power boom was sized for the growth configuration. It was resized for the initial station, and for 7000 square-foot array panels. For the growth station configuration, the 7000 square-foot array is replaced with a 10,000 square-foot array and an extended ODAPT unit to compensate for the initial station boom length. Repressurization gas for one-half the station volume was relocated to the normally unpressurized power boom. Thus, six additional tanks were added to the power boom.

The design changes that occurred to the core module were: (1) RCS engines were relocated from the Y axis to the Z axis, (2) the four side ports are provided with thermal covers, and (3) thermal control of the vertical ports is provided during buildup with special insulation panels. Selection of the gravity gradient mode for flight operations during station buildup alleviate complexity problems associated with antenna locations.

The initial station configuration with its characteristics remains the same as in study configuration 7. A list of the configuration issues previously identified is presented in Table 2-8 with the selected alternative.

Table 2-8. Configuration Drivers and Selected Alternatives

Configuration Driver	Selected Alternative
System sizing	Optimize initial station at 6-man level
Cargo operations	Up/stay mode
Dual shirtsleeve egress	Common modules
Module diameter	14 feet
Subsystem assemblies	Distributed
Y-plane modules	Cargo
Pressure volumes	Two independent
RAM accommodations (initial station)	Two attached (earth and zenith oriented)
RAM sizing	Not applicable to this study
Crew quarters	Split between modules
ECLSS assemble sizing	Six-man units
Floor orientation	Longitudinal
Internal arrangements	Selected facilities below deck
Berthing ports per module	Dual ends, all common modules
Experiment airlock location	External, movable, dual locations
RCS engine fuel location	On space station
High gain antenna	Separate packages
Solar array location	Power boom single end
Initial buildup sequence	Core module/power module
Core modules	Single initial and half growth
Manipulation	Shuttle only
EVA/IVA airlocks	EVA/IVA and IVA
Berthing port commonality	Delay for subsequent studies
Flex port operation	Emergency egress only
Module spacing	5 feet

APPENDIX A. SUPPORTING TRADES

1. STRUCTURAL CONCEPTS

A description of structural trades performed during the Phase A analyses to provide useful data on which to base a selection of the best MSS structural configuration is documented in SD 70-546-1, Shuttle Launched Modular Space Station, Configuration Definition. Five basic types of aluminum structural shell constructions were considered in the trade: monocoque, waffle, skin-stringer with rings, skin-stringer without rings, and honeycomb sandwich. In addition, consideration was given to a sandwich construction that utilizes Saturn II-type spray foam insulation for the core. The foam is sprayed onto a 0.040-inch thick aluminum pressure shell that also serves as one facing of the sandwich. The other facing is a 0.015-inch thickness of fiberglass laminates bonded to the foam outer surface. The fiberglass laminates also serve as the secondary micrometeoroid bumper. Because of its favorable combination of strength, ductility, and weldability properties, 2219-T87 aluminum alloy was selected for all the candidate constructions.

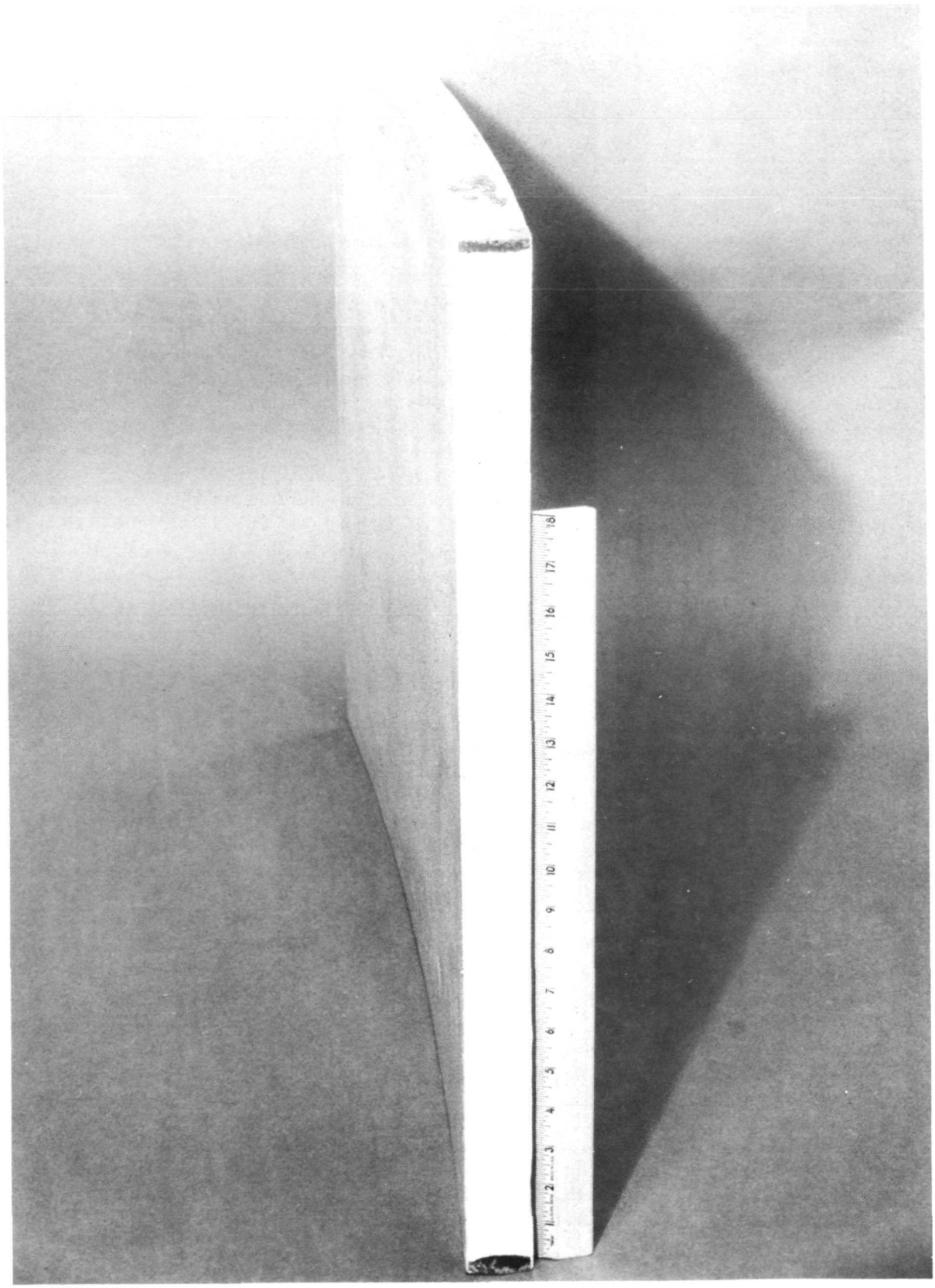
1.1 SPRAY FOAM SANDWICH

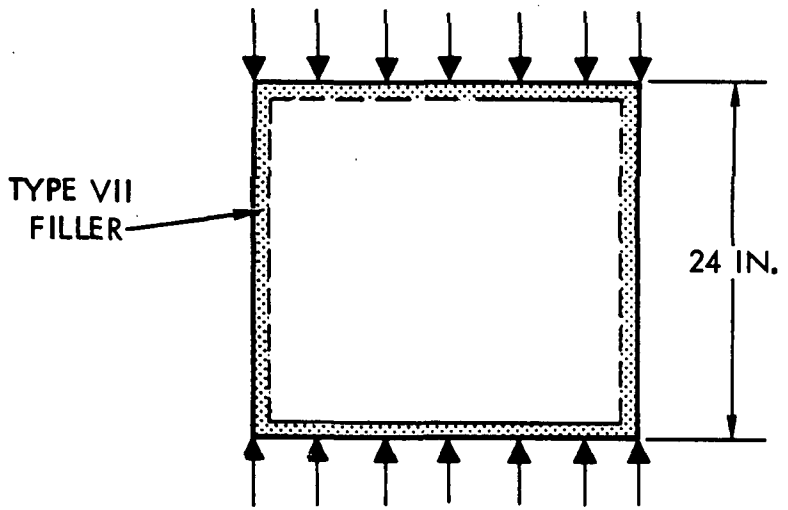
The results of the trade study showed the spray foam sandwich construction to be more efficient from a weight standpoint than the other five candidates. Subsequent manufacturing cost studies have shown the foam sandwich to be second only to monocoque in economy of construction. Because of this weight and cost competitiveness, a program was initiated to verify the fabrication practicality and strength of the spray foam sandwich construction. To accomplish these tasks, four 24- by 24-inch spray foam sandwich panels contoured to a radius of 86 inches were fabricated and subjected to axial compression testing. A picture of a test panel is shown on Figure A1-1. A summary of test results is given on Figure A1-2. All of the buckling loads for the test panels are more than double the maximum longitudinal compressive load (193 lb/in.) experienced by station modules during their missions. A complete description of the test specimens, test procedure, and test results is presented in NR Laboratory and Test Report, 10000-4126.[1]

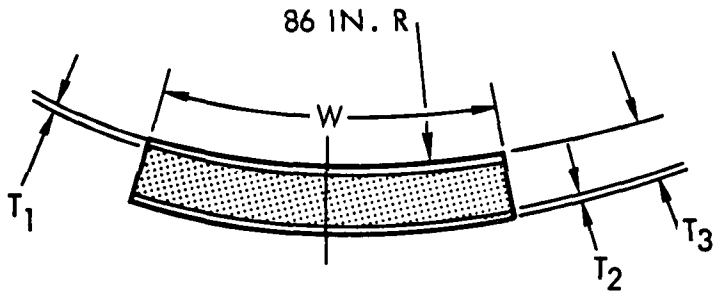
1.2 MONOCOQUE CONSTRUCTION

A further investigation of the monocoque type modular construction was made. The major advantage of the monocoque shell is low cost at the expense of increased weight. By utilizing 5052-H34 aluminum alloy a skin thickness of 0.145 is required. This is a thicker shell than would be required if

[1] "Edgewise Compressive Testing of Fiberglass/Polyurethane Spray Foam/Aluminum Sandwich Construction for Space Station Sidewall Design," NR LR 10000-4126, May 1971.







FOAM DENSITY 2.0 LB/FT^3

T_1 2024-T62 BARE ALUMINUM SHEET

T_2 2 LAYERS WET FIBERGLASS LAY UP

PANEL	T_1 (IN.)	T_2 (IN.)	T_3 (IN.)	W (IN.)	ELASTIC BUCKLING LOAD (LB)	RUNNING BUCKLING LOAD (LB/IN.)
1*	0.050	0.020	1.5	23.94	15,000	630
2	0.062	0.020	1.5	24.0	19,650	815
3	0.050	0.020	1.0	24.0	16,500	690
4	0.062	0.020	1.0	23.69	17,200	730

*BUCKLE WAS LOCATED AT EDGE, DID NOT HAVE MAO-106-060 TYPE VII FILLER ALONG UNLOADED EDGE

- ALL BUCKLES WERE ELASTIC - NO YIELD
- BUCKLING STRESS LEVELS 11,000 - 14,000 PSI
- ESTIMATED LOWER LIMIT ALLOWABLE BUCKLING LOAD FOR 0.040 SKIN≈440 LB/IN.

Figure A.1-2. Foam Sandwich Compression Tests

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2219-T87 aluminum alloy were utilized. However, this increased thickness with the addition of an 0.030 aluminum meteoroid bumper provides a 0.175 thickness of aluminum which will provide the required radiation protection as defined in the design curves of NASA TM X-53865.[2] A radiation analysis utilizing this thickness is documented in Appendix B of this volume. The 5052-H34 material is used for the station modules because of its superior welding qualities. Since crewmen do not frequently inhabit the core module for extended periods of time, its structural shell is a skin and stringer-type construction to emphasize weight efficiency. It is not felt that use of spray foam sandwich for a single module warrants its development.

Figure A1-3 illustrates the variation in theoretical station module weight with length for the monocoque and other typical types of construction. It can be seen on Figure A1-3 that the monocoque construction results in a weight increase of about 2500 pounds over the minimum structure concepts. However, there are several advantages that monocoque construction has over structures designed for minimum weight. These advantages are listed as follows.

1. Cost - Manufacturing cost estimates have indicated the monocoque shell to be about 60 percent of the cost of the nearest competitor based on a 10-module total manufacturing cost estimate of material, labor, and tooling.

2. Stiffness - Increased station stiffness resulting from the thicker monocoque shell increases the station natural frequencies. This is desirable since modal analyses have shown the minimum station frequency to be less than the 1.0 Hz minimum recommended for guidance and navigation purposes.

3. Ease of Handling - Ground handling restrictions should be less severe for the monocoque shell compared to the lighter construction because of the inherent damage resistance of the 0.145-inch thick skin.

[2]NASA TM X-53865, "Natural Environment Criteria for the NASA Space Station Program" 2nd Edition, August 20, 1970.

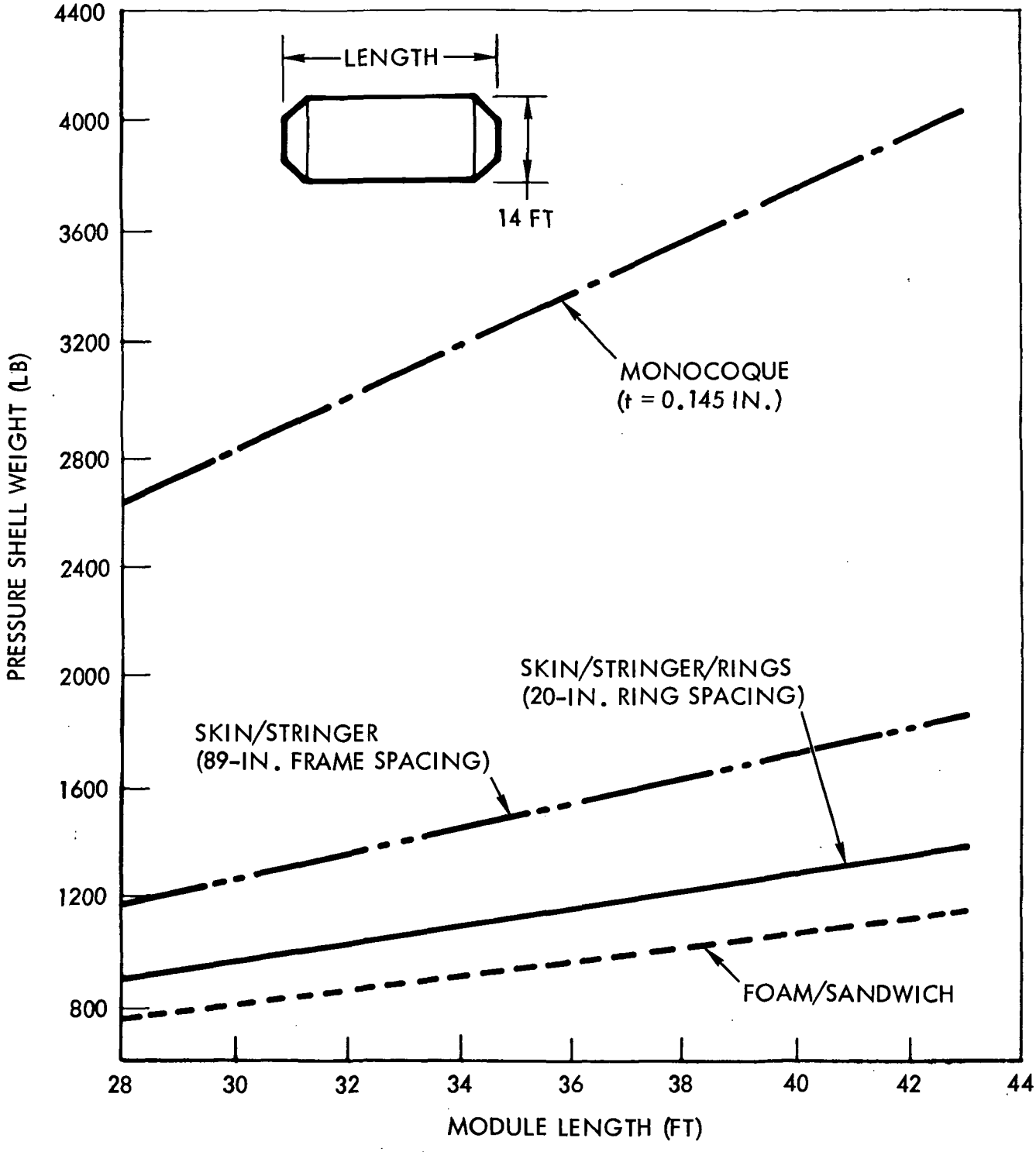


Figure A.1-3. Pressure Shell Weight Vs Module Length

2. MANUFACTURING TRADES

Manufacturing engineering has performed manufacturing trade studies in the structural area of the modular space station. These studies include elements of manufacturability, complexity of manufacturing, and relative costs based on gross estimates of direct labor hours. The areas studied were: (1) structural shell, (2) materials, (3) longitudinal floor configurations, and (4) fabrication configurations for the external radiator panels. Each of these studies are discussed separately in the following paragraphs. The manufacturing trade tree is shown on Figure A2-1.

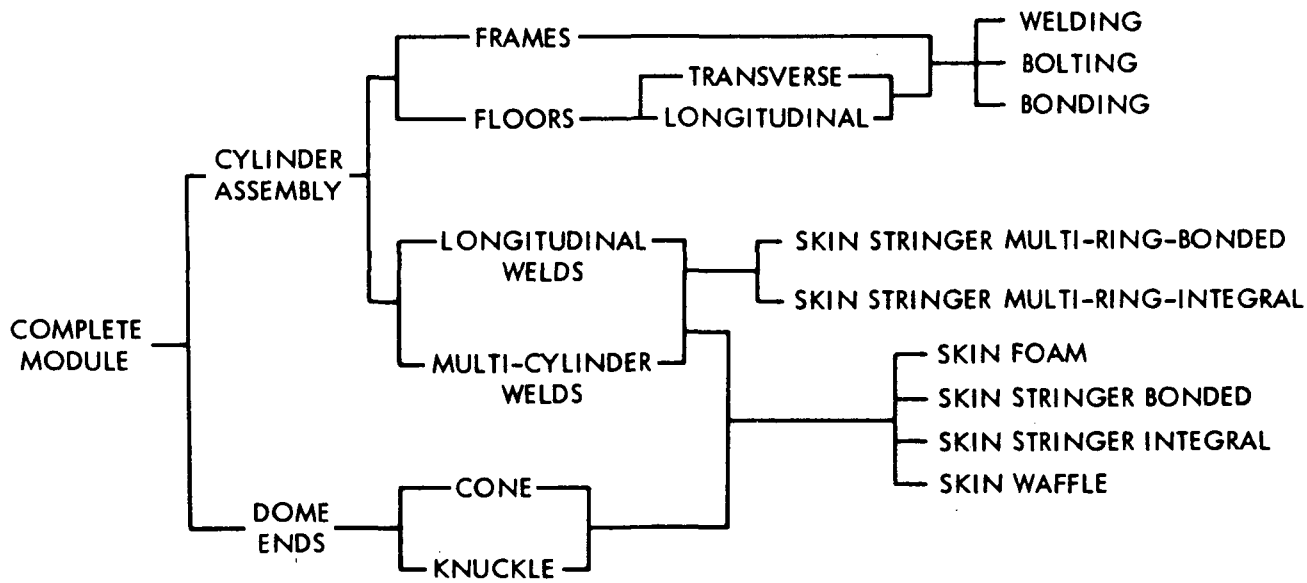


Figure A2-1. Manufacturing Trade Tree

2.1 STRUCTURAL SHELL

The structural shell construction trades for the common module were based on the following assumptions established by engineering and manufacturing:

1. Tension loads result in lighter weight and fewer parts than compression loads.

2. Shortest load path results in the lightest weight and the fewest number of parts.

3. Inner surface of the pressure wall to be as clear of structure as possible.

4. Radiators will only be in the cylindrical portion of the environmental shield.

5. Four-inch radius reduction of pressure wall to allow for structure and environmental shield.

6. Structure with least number of parts is most economical.

7. Integrally machined assemblies are less expensive than parts buildup.

8. Bonded assemblies require greater/more stringent in-process controls.

9. Thinnest and lightest structure, not necessarily the least costly.

Four types of shell structure were analyzed for the sidewall and end bulkhead areas: integrally machined skin stringer, bonded skin stringer, integrally machined skin waffle, and polyurethane spray foam sandwich. Manufacturing analysis results on these configurations are shown as pros and cons on Figure A2-2. Cost differences were found to be insignificant. The spray foam sandwich was found to be the lightest type of construction. The recommended method of fabrication of a skin/foam pressure shell is shown on Figure A2-3. A welded aluminum pressure shell is foam-sprayed with low-density foam developed for the S-II program. The foam is machined to a constant thickness, and two layers of a wet layup of fiberglass are applied. The fiberglass acts as a secondary meteoroid bumper, as well as providing the second face of the sandwich.

Manufacturing assembly techniques were studied for the complete module. Two buildup methods were considered for the cylindrical portion of the module: multiple cylinder assemblies circumferentially welded and full length panels joined together with longitudinal welds. Longitudinal welding was selected because the least number of weld joints and fewest parts resulted in the least overall cost.

Three methods of attaching the frames and transverse floors into the shell structure were studied: welding, bolting, and bonding. Since longitudinal welding was selected for the cylindrical shell, the attachment of frames and floors by bolting or bonding is approximately the same; therefore, the bolting/bonding decision is the designer's option.

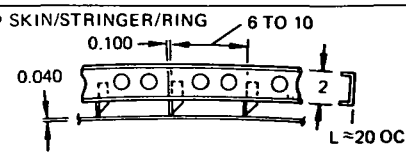
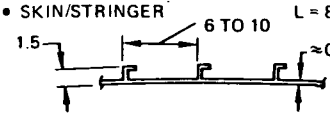
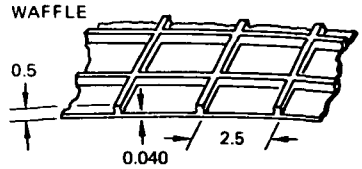
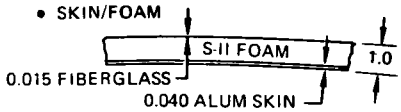
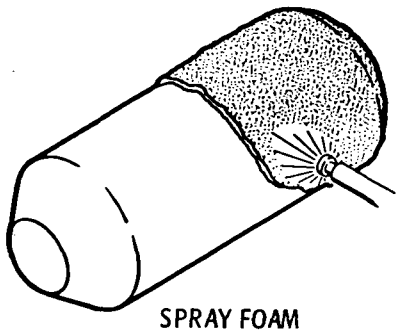
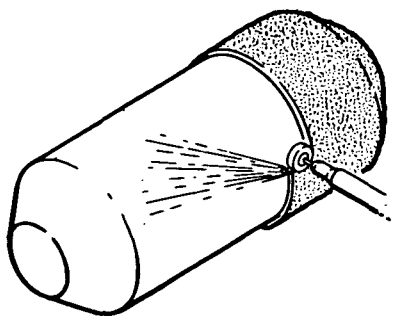
TYPES OF CONSTRUCTION	PRO'S	CON'S
• SKIN/STRINGER/RING 	• VAST EXPERIENCE • SIMPLE SHIELD ATTACH	• MANY PARTS
• SKIN/STRINGER 	• EASY MACHINING • MINIMUM PARTS • LOW COST • SIMPLE SHIELD ATTACH	• MATERIAL WASTE
• WAFFLE 	• MINIMUM PARTS	• DIFFICULT FORMING MACHINING CHEM MILLING SHIELD ATTACH HIGHEST COST
• SKIN/FOAM 	• SIMPLE/FAST FAB • LOW COST • MINIMUM WEIGHT • LARGEST GROWTH POTENTIAL	• SPECIAL SHIELD ATTACH • REQUIRES DEV TESTS FOAM DEGRADATION OUTGASSING • REQUIRES ADDITIONAL IN-PROCESS CONTROL

Figure A.2-2. Shell Structures

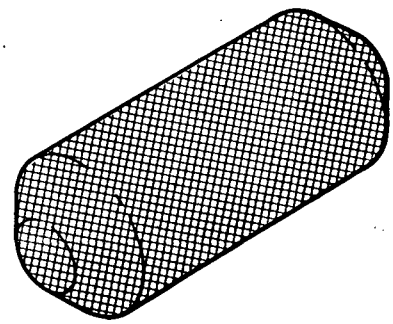


SPRAY FOAM

- ASSEMBLY OF SKIN & SUPPORTING FOAM/LAYUP
  - LOW DENSITY MATERIAL (~2 LB/FT3)
  - NORMALLY UTILIZED FOR INSULATION
  - PROPOSED FOR SKIN REINFORCEMENT ONLY (NONLOAD CARRYING)
- FOAM/LAYUP APPLICATION
  - RELATIVELY SIMPLE/FAST/LOW COST
  - DEVELOPED FOR S-II
  - FIBERGLASS ACTS AS SECONDARY METEOROID BUMPER
- TO BE USED ONLY FOR LOW LOAD APPLICATIONS
  - REQUIRES STRUCTURE ALLOWABLES
  - DEVELOPMENT PROGRAM



CUT FOAM



LAYUP FIBERGLASS

Figure A.2-3. Skin Foam Construction

Cone and cone/knuckle construction configurations were studied for end dome bulkheads. The cone configuration for the four types of skin construction, shown on Figure A2-2, was determined to be the easiest to fabricate; however, the cone requires an additional kick frame for the transition of load from the cone to the cylinder. The waffle bulkhead concept presents some difficulties in forming. Two fabrication methods were studied: (1) preform a thick aluminum plate gore segment to the required contour, machine the waffle grid using a 5-axis numerically controlled machine, Chem-Mill to complete the final dimensions; and (2) pre-machine and Chem-Mill the waffle grid in a flat plate gore segment, form the contour using special filler materials, saddle blocks, etc., to support the fragile upstanding legs. In view of forming and machining complexities, waffle bulkheads require a major development program and would be too costly. The complexities of cone/knuckle bulkhead contours and cone bulkheads with required kick rings are about equal. Therefore, the final selection must be made based on design rather than manufacturing considerations.

Two methods of fabricating the berthing port were studied: (1) a single one-piece aluminum forging, and (2) a two-piece aluminum weldment consisting of a wrought plate welded to a ring forging. The single forging concept was found to be too complex because of its overall size (88-inch diameter) and large cross sectional length (21 inches). A single forging of this size would require an extensive manufacturing development program. The two-piece weldment was determined to be well within the present state of the art and, therefore, recommended as the design concept.

The same elements of the manufacturing trades for the common module apply to the core module and power module as the structural shell, bulkheads, and berthing rings are basically common in shape and require the same manufacturing approach. For the lightweight structural concepts, manufacturing recommends the skin/stringer or skin foam fabricated pressure shell with the cone or cone/knuckle end dome bulkheads and the two-piece weldment berthing ports as being the least cost concept.

A simplier but heavier shell structure, the monocoque, was investigated. A 0.145-inch thick sidewall skin was required, which made it possible to fabricate a constant thickness pressure shell without stringers and a minimum of frames. This greatly simplified the structure by eliminating many intricate machining and forming operations. The heavier structure is also advantageous by providing additional mass which is utilized for radiation and micrometeoroid protection. Manufacturing cost estimates have indicated the monocoque shell to be about 60 percent of the cost of the nearest competitors shown on Figure A2-2.

The manufacturing assembly sequences for the final module configurations are shown in Section 1 of this volume.

2.2 MATERIALS

The materials selected for the trade study are only for the primary structure pressure shell. The four factors considered in the trade were: (1) weldability, (2) machinability, (3) general manufacturability, and (4) cost per pound. Aluminum was selected as the primary material and the alloy series studied were 2021, 2219, 5052, and 6061. The results of the study indicate the 5052 series to be the least overall cost from a manufacturing standpoint, especially for the monocoque structure. This structure is the lowest cost per pounds and considered the most weldable of all series studied; however, it is very difficult to machine. The 2219 aluminum on the other hand is easier to machine, but higher in cost and requires more process controls in the weld processes; therefore, 2219 aluminum was recommended for all aluminum parts requiring machining. The 5052 and 2219 aluminum materials were selected due to their compatibility with each other, especially in welding. The 5052 aluminum was specified for the nonmachined parts and 2219 for all machined parts.

2.3 LONGITUDINAL FLOOR CONFIGURATIONS

Two fabrication and installation concepts were studied for the floor assembly: (1) preassemble the complete floor and install it with special equipment through one end of the module shell before the end dome bulkhead is installed, and (2) fabricate smaller subassemblies and install them through the berthing port openings after the shell structure is complete and pressure-tested. The preassembled floor concept provides easier access for systems installation out on the floor, and is ideal for high production rates; however, it is more costly as it requires a removable bulkhead and several additional parts including a highly reliable sealing system. The advantages in the manufacturing cycle of having access to the full diameter of the module as opposed to working through the 5-foot berthing port openings for the limited number of assemblies involved was not sufficient to justify the added fabrication costs and the potential problems of interface leakage. Another method of installing a preassembled floor would be to install the floor in the shell assembly with one bulkhead unwelded. This method would be very complex because of the handling and clearances needed for trimming, cleaning, backup weld fixtures, and radiographic inspection of the bulkhead to cylinder closeout weld.

Manufacturing's recommended assembly sequence is to install the floor in modular segments after the primary structure is completed and pressure tested. These modular segments are sized for standard material sizes, ease of handling and assembly, minimum special tooling, and installation through the berthing port.

The selected concept configuration for the fabrication and installation of the longitudinal floor is shown on Figure A2-4.

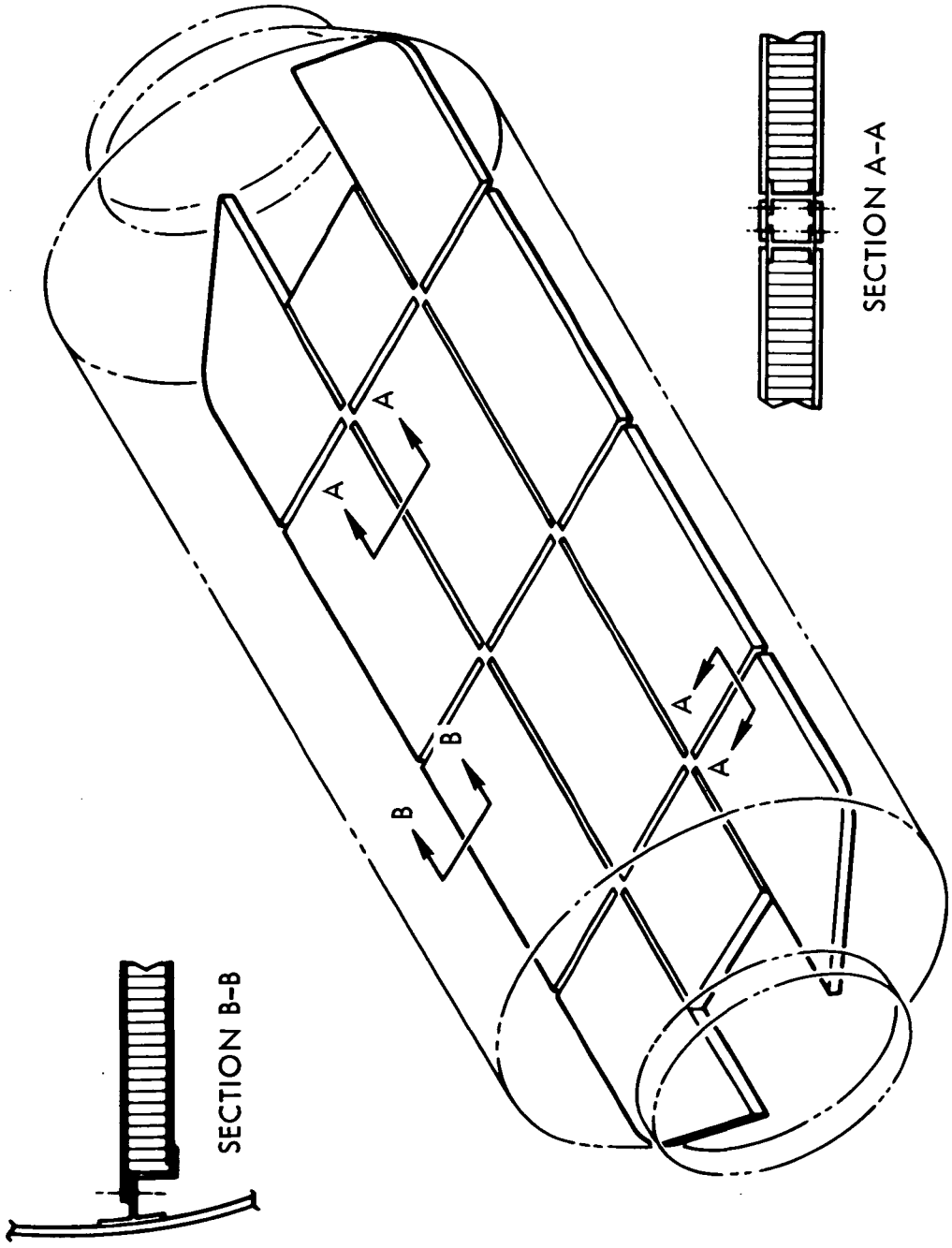


Figure A.2-4. Longitudinal Floor Fabrication

2.4 MANUFACTURING CONFIGURATION TRADES FOR THE RADIATOR CONCEPT

Four radiator configuration concepts were selected by manufacturing engineering for study: (1) special closed extrusions on a common sheet, (2) special open extrusions on a common sheet, (3) standard tubing extrusions on a common sheet, and (4) diffusion-bonded homogeneous tubed sheet.

These four configuration concepts are shown on Figure A2-5. The fabrication techniques studied for the first three concepts were welding, brazing, and bonding. These processes are conventional manufacturing techniques; however, in this application where panel size is relatively large, they have several disadvantages such as low-joint reliability caused by the requirement of forming after welding, additional weight from joining requirements, and warpage problems due to locked-in stresses induced during the heating cycle for these processes. From a manufacturing point of view, the diffusion-bonded homogeneous tube sheet is the least complex to fabricate and lowest cost of all the proposed concepts. This configuration is a current and well-proven fabrication technique presently being utilized throughout the industry for heat exchangers and refrigerators. The configuration has maximum heat transfer characteristics, high reliability, and can be made with the least weight.

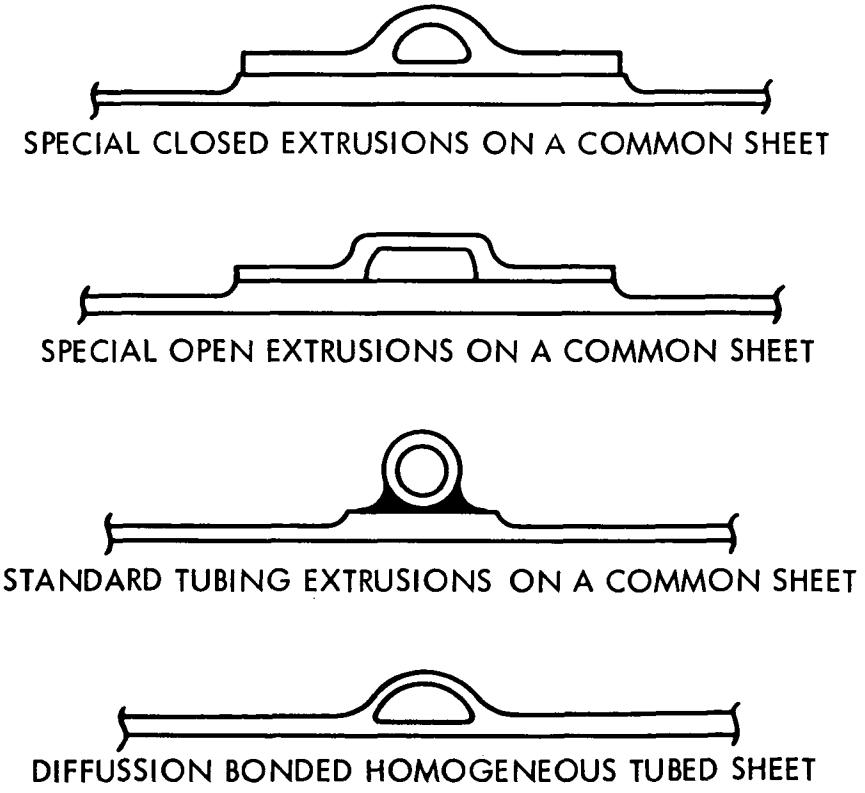


Figure A.2-5. Radiator Tube Concepts

3. FUNCTIONAL ALLOCATION

To establish requirements for the modular space station (MSS) facility functional allocations, data available from the 33 foot station Phase B study; modular space station Phase A; and the modular space station Phase B, reference configuration, were utilized in the initial portion of the MSS Phase B study. From these data, crew and General Purpose Laboratory (GPL) facilities were identified and then developed into sizing and location criteria. Commonality criteria, including incompatible sets and favorable sets were evaluated to establish a preferred facility merging. From these data, facilities were allocated to individual modules and module location, with respect to one another, were established in the MSS cluster. This approach to establishing functional allocations is shown on Figure A3-1.

3.1 CANDIDATE FACILITIES

In considering all of the data available from related studies and in consideration of other similar scientific experiment programs, a list of facility requirements was established. This list was based on all of the crew needs relative to station operations and maintenance; experiment operations and maintenance; personal hygiene; diet considerations; food stowage, preservation and preparation; dining; sleeping and relaxation; recreation; exercise; medical care; privacy and solitude; housekeeping; clothing and linens; comfort; discipline; physical conditioning; stay-time qualification; emergency operations; safety; and psychological well-being.

The preliminary MSS facility requirements list is shown in Table A3-1. This list is based on the needs of the crew, for all activity and operations, only and has not considered commonality of facilities; sizes or locations.

3.2 SIZING AND LOCATION CRITERIA

Habitability criteria previously developed for the 33 foot space station in the Phase B study was initially used as a baseline in considering facility sizing. Evaluations to determine the applicability of these data for the MSS were conducted. From the facility requirements list determined in the previous section (3.1), equipments for each of these facilities were listed, along with their function, utilizing spacecraft systems data, experiment (FPE) data, and all of the crew requirements. Sizing for these equipments were then assigned to each, based on the individual function of each. Mobility/access area associated with each item of equipment must next be considered to establish the first cut at gross area for each facility. Again, utilization of the 33 foot space station, Phase B data, was the prime consideration and was evaluated against MSS reference configuration modules size and potential interior arrangement adaptability. The station modules utilized the 14 foot diameter throughout. Also, this functional allocation study did not influence the module length to any degree, as the length varied only

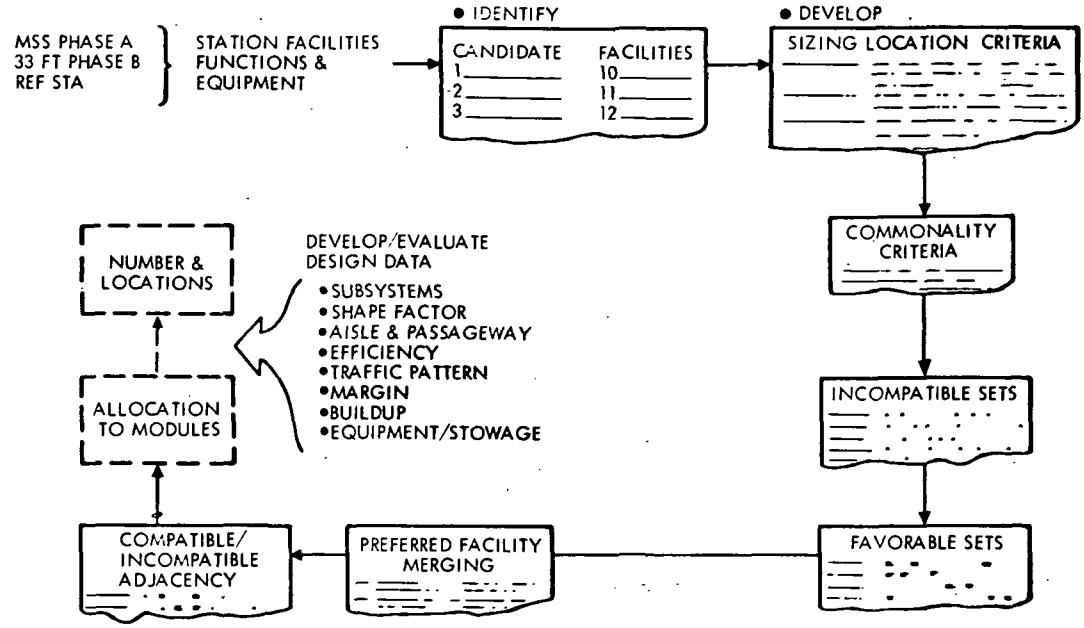


Figure A.3-1. Functional Allocation Logic Flow

Table A3-1. Preliminary MSS Facility Requirements

Facility	Quantity Initial Station	Quantity Growth Station	Facility	Quantity Initial Station	Quantity Growth Station
A. STATION OPERATIONS			B. EXPERIMENT SUPPORT OPERATIONS		
1. Private staterooms	6	12	1. Experiment control center	(1*)	1
2. Office	2	2	2. Backup expt. control center	(1*)	1
3. Personal hygiene 1	1	2	3. Experiment airlock	(1*)	1
4. Personal hygiene 2	1	2	4. Physics lab	(1*)	1
5. Primary control center	1	1	5. Materials processing lab	(1*)	1
6. Backup control center	1	1	6. Photo lab	(1*)	1
7. Primary galley	1	1	7. Data analysis lab	(1*)	1
8. Backup galley	1	1	8. Fluid-mech. lab	(1*)	1
9. Dining	1	1	9. Optics lab	(1*)	1
10. Active recreation	1	1	10. Electronics lab	(1*)	1
11. Passive recreation	1	1	11. Aerospace medical/behavioral lab	(1*)	1
12. EVA airlock	1	1	(* When required)		
13. Backup EVA airlock	1	1			
14. IVA airlock	1	1			
15. Backup IVA airlock	1	1			
16. Fluid-mech. shop	1	1			
17. Optics shop	1	1			
18. Electronics shop	1	1			
19. Primary crew health & med treatment	1	1			
20. Backup crew health & med treatment	1	1			
21. Exercise	1	1			
22. Crew med & behavioral qual.	(1*)	1			
23. Cargo handling	1	1			
24. Cargo storage	1	1			
25. Housekeeping	1	1			

Ground Rules and Definitions

1. Each facility will be defined in terms of independent, self-sustaining operation.
2. Each facility includes wall-to-wall floor space, major equipments (if any), storage for minor equipments and consumables as required, access floor space/volume and subsystems.
3. Storage shall consist of a nominal weeks supply or as necessary for efficiency of crew activities or where special design considerations exist.

slightly, and ended up approximately 38 feet, which was utilized during this study. As a result of this evaluation access/mobility area associated with each function and functional area was established.

The final data to be established for this phase of the study was location criteria. In consideration of this, such features as convenience, safety, noise/traffic, two separate pressure volumes, spacecraft operational efficiency and experiments operational efficiency were some of the major considerations evaluated utilizing the candidate facilities previously identified. As a result, location criteria was identified for each of the facilities.

Table A3-2 presents a summary of all of the candidate facilities, functions of each, equipment notes for each, access/mobility area of each, and location criteria for each.

3.3 COMMONALITY CRITERIA

Compatibility and commonality factors can be grouped into three categories: facility arrangements, design requirements, and operational constraints.

In establishing facility arrangements, there are four specific factors that were considered: functional commonality, equipment commonality, space savings, and internal traffic efficiency.

In design requirements, there are three factors that were considered: maximum sizing requirements, pressure volume considerations, and separate and same module considerations.

Operational constraints presents three factors to consider: program scheduling, timeline sensitivity, and operational interferences.

3.3.1 Compatibilities

Table A3-3 lists the noncommon 25-station and 11-experiment support facilities with the designated facility reference number shown across the top. The three compatibility/commonality factors described above were used to identify those factors between sets of facilities that exhibited the specific characteristics listed. It is noted that the open square symbol is used where there is no obvious reason not to allow merging between the numbered facilities shown. A study of the table indicates which facilities appear to be most compatible for merging.

The rationale for favoring facility sharing is listed below:

1. Equipment - Facilities can or should be grouped when equipment is similar in function or characteristics.

2. Space Saving - Merging of the facilities permits a significant saving in floor space with no loss of efficiency or habitability.

Table 3-2. Facility Requirements Initial Station--Station Operations

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Private Stateroom	Sleep Private Rec. Study/work Personal equip/effects Backup/emergency	Sleeping restraints/bunks Television, radio - 2-way Book shelves, desk, seat/restraints Storage units	23.75	50	. Should be located conveniently to personal hygiene areas . Should be located apart from noise and contaminant producing work areas . One-half of all staterooms should be located in separate pressure volumes
Office	Work Conference Comm & Control	Conference table 3 seat restraints Display console Book shelves/cases (2) Radio, 2-way	22.75	50	
Personal Hygiene No.1	Waste Mgmt. Grooming	Dry toilet Urinal Shower Sink	23.6	45	. Should be located adjacent to staterooms . Should be located apart from galley and dining areas . Should be readily accessible to medical facilities and work stations
Personal Hygiene No.2	Waste Mgmt. Grooming	Dry toilet Urinal Sink	25.4	35	. Same as personal hygiene No. 1

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Primary Control Center	Flight Mgmt. Operations Mgmt. Communications Display & Control Planning & Sched. Exper. Support Inventory Mgmt. Manipulator Control	Command Console Terminal Unit Processors Camera (TV) T.V. Monitor	55.8	75(100)	. No identified driving criteria
Backup Control Center	Flight Mgmt. Operations Mgmt. Communications Display & Control	Command Console Processors	42.6	60(60)	. Must be located in alternate pressure volume from that occupied by the primary control center
Primary Galley	Food Storage Food Preparation Waste Mgmt. Cleanup	Freezer, Refrigerator Oven (Resistance) Oven (Microwave) Reconstitution Unit Compactor Sink/Washer	19.4	63(63)	. Should be located adjacent to dining area . Should be located apart from personal hygiene area
Backup Galley	Food Storage Food Preparation Waste Mgmt. Cleanup	Freezer/Refrigerator Oven (Microwave) Reconstitution Unit Compactor	11.4	30(30)	. Should be located in alternate pressure volume from that occupied by the primary galley

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area (1) G Ft^2	Location Criteria
Backup Galley (Cont)					. Should be located apart from personal hygiene area
Dining	Food Serving Eating/Drinking	Tables Seats/Restraints (6)	8	50(100)	. Should be located adjacent to primary galley . Should be conveniently accessible from crew quarters and work stations
Backup Dining					. Should be located adjacent to backup galley
Recreation - Passive	Movies Television Music Snacks/Drinks	Projector Audio-Video Unit Seat/Restraints (6)	48.4	75(100)	. Should be located apart from noise producing work area
Recreation - Active	Games	Table/Surfaces (2) Seat/Restraints (6)	53.5	100(150)	. No identified driving criteria
EVA Airlock	EVA Station Support EVA Experiment Support	Control/Display Unit	25	30(30)	. No identified driving criteria
Backup EVA Airlock	Rescue Emergency Egress/ Ingress	Control/Display Unit	25	30(30)	. No identified driving criteria

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
IVA Airlock	IVA Station Repair	Control/Display Unit	25	30(30)	. Must be located between isolatable pressure volumes
Backup IVA Airlock	Emergency Return	Control/Display Unit	25	30(30)	. Must be located between isolatable pressure volumes
Fluid-Mech Shop	Component/Assy: Test Repair Calibrate Disassemble Assemble	Work Bench/Surface & Test Console	31.25	50(50)	. Should be located conveniently to electronics shop
Optics Shop	Component/Assy: Test Repair Calibrate Disassemble Assemble	Work Bench/Surface Test & C/O Console	26.25	45(45)	. Should be located conveniently to electronics shop
Electronics Shop	Component/Assy: Test Repair Calibrate Disassemble Assemble	Work Bench/Surface Test Console	31.25	50(50)	. Should be conveniently located to both the optics shop and fluid mech shop
Primary Crew Health & Medical Treatment	Dental Treatment Pharmaceutical preparation & dispensing	Instruments Examination Table Refrigerator Freezer Sterilizer	10.1	65(75)	. Should have ready access to personal hygiene facility

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Primary Crew Health & Medical Treatment (Cont)	Routine Physical Exam Primary Emerg. Treatment Treatment of Illness Medical Records & Data Collection & Storage	Mass Meas. Unit Neg. Presi. Unit Desk/Table Seat/Restraint (2) Sink/Washer Biomedical Equipment Lab Analysis Equipment			. Should be located apart from noise and contaminant producing work areas
Backup Crew Health & Medical Treatment	First Aid Short Term Emergency Treatment Backup Pharmaceuticals	Medicine/Instrument Locker		Per Storage Design	. Should be located in alternate pressure volume from that occupied by the primary crew health and treatment facility
Exercise	Muscular Conditioning Physiological Stress Combat zero-gravity Deconditioning	Bicycle Ergometer Bungee Units	80.7	85(85)	. Should be located near primary crew health & medical treatment . Should be located mear aerospace medical/ behavioral lab
Crew Medical & Behavioral Qualifications	Evaluation of: Cardiovascular Musculo-Skeletal Pulmonary Digestive	Bio-console Mass Meas. Unit Neg. Press Unit Lab Anal. Equipment Behavioral Console	71.3	100(100)	. Should be located near exercise area

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft ^{2}	Gross Area(1) G Ft^2	Location Criteria
Cargo Handling	Cargo Transport Cargo Unpackaging Cargo Repackaging Inventory Control Waste Handling	Cargo transporter Table(s) Surface(s) (2) Inventory Mgmt. Console	85	125(125)	. Should be located conveniently to cargo module docking ports
Cargo Storage	Store Return Equipment Store Return Specimens/Data Store Return Waste Store Up Cargo	Cargo transporter		Per storage design	. Should be located in a transportable module
Laundry	Cleaning of clothing and linens Drying of clothing and linens Waste management	Clothes washer Clothes dryer	5.4	30(30)	. Should be located conveniently to crew operations
Housekeeping	Station cleanup periodic Station cleanup non-routine Waste collection Waste disposal	Vacuum cleaner Compactor		Per storage design	. Facility may be divided among several modules . Should be conveniently located to galley, work shops, labs, personal hygiene and crew medical & health facilities

(1) Gross areas presented in this column do not include areas associated with storate volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Exper. Control Center	Remote flight management Experiment oper. management Communications Displays & control Planning & Sched. Inventory mgmt. Data management	Command console Terminal units Processors	56.6	75(100)	. Should be located conveniently to primary control center
Backup Exper. Control Cntr.	Remote flight management Exper. oper. mgmt. Communications Display & control	Command console Processors	57.6	60(60)	. Should be located conveniently to backup primary control center . Should be located in alternate pressure volume from that occupied by the experiment control center
Physics Lab	Investigate external phenomena Perform lab experiments	Work/assembly Bench Photometer Coronograph Microbalance (16) Panel pallet	28.8	60(60)	. Must be located in experiment airlock facility
Materials Processing Lab	Perform lab experiments Cast metals	Test stand & work bench/ surface heating unit (2) Control unit		60(60)	. Must be located in experiment airlock facility

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Materials Processing Lab (continued)	Thin film deposition Grow crystals Form Metal Alloys	Processing unit (6)			. Should be located conveniently to data analysis lab
Photo Lab	Process film Process emulsion Protect film Load film	Work bench/surface Emulsion processor Photo developer	8.5	40(40)	. Should be located conveniently to photo generating experiments (astronomy, earth survey) . Should ensure environmental protection (radiation) for stored film
Data Analysis Lab	Analyse film Retrieve hard copy Reproduce data Data callup and display Evaluate data Record data	Table/surface Seat/restraints (2) Straight edge Plotter	21	50(50)	. Should be located conveniently to photo lab . Should be located conveniently to experiment control center
Fluid-Mech Lab	Component/Assy: Developmental testing Qualification testing	Test stand & work bench/surface	31.25	50(50)	. Should be located conveniently to electronic lab

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Fluid-Mech Lab (continued)	Evaluation of equipment Evaluation of testing techniques				
Optics Lab	Component/Assy: Developmental testing Qualification testing Evaluation of equipment Evaluation of testing techniques	Test stand & work bench/ surface	26.25	45(45)	. Should be located conveniently to the electronics lab
Electronics Lab	Component/Assy: Developmental testing Qualification testing Evaluation of equipment Evaluation of testing techniques	Test stand & work bench/ surface	31.25	50(50)	. Should be located conveniently to the fluid mechanical lab . Should be located conveniently to the optics lab

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Aerospace Medical/Behavioral Lab	Investigate: Cardiovascular function Pulmonar functions and energy metabolism Endocrinology Hematology and immunology Neurophysiology Nutrition & Musculskeletal function Microgiology Behavioral effects	Freezer Cont. temp refrigerator Freeze dry unit Oven Sterilizer General instr. Bench & storage Interview desk Behav. meas. console Biomed. meas. console Lab analysis console Bicycle ergometer	65.7	150(150)	. Should be co-located primary crew care and exercise facilities
Experiment Airlock	Provide: A vacuum environment for experiments A means of projecting experiments into the immediate vicinity of the spacecraft	Airlock Tripan boom (inside airlock) Telescopic boom (inside airlock)	15	65(65)	. No particular driver affecting location . Except that extended sensors should be able to view earth and celestial phenomena

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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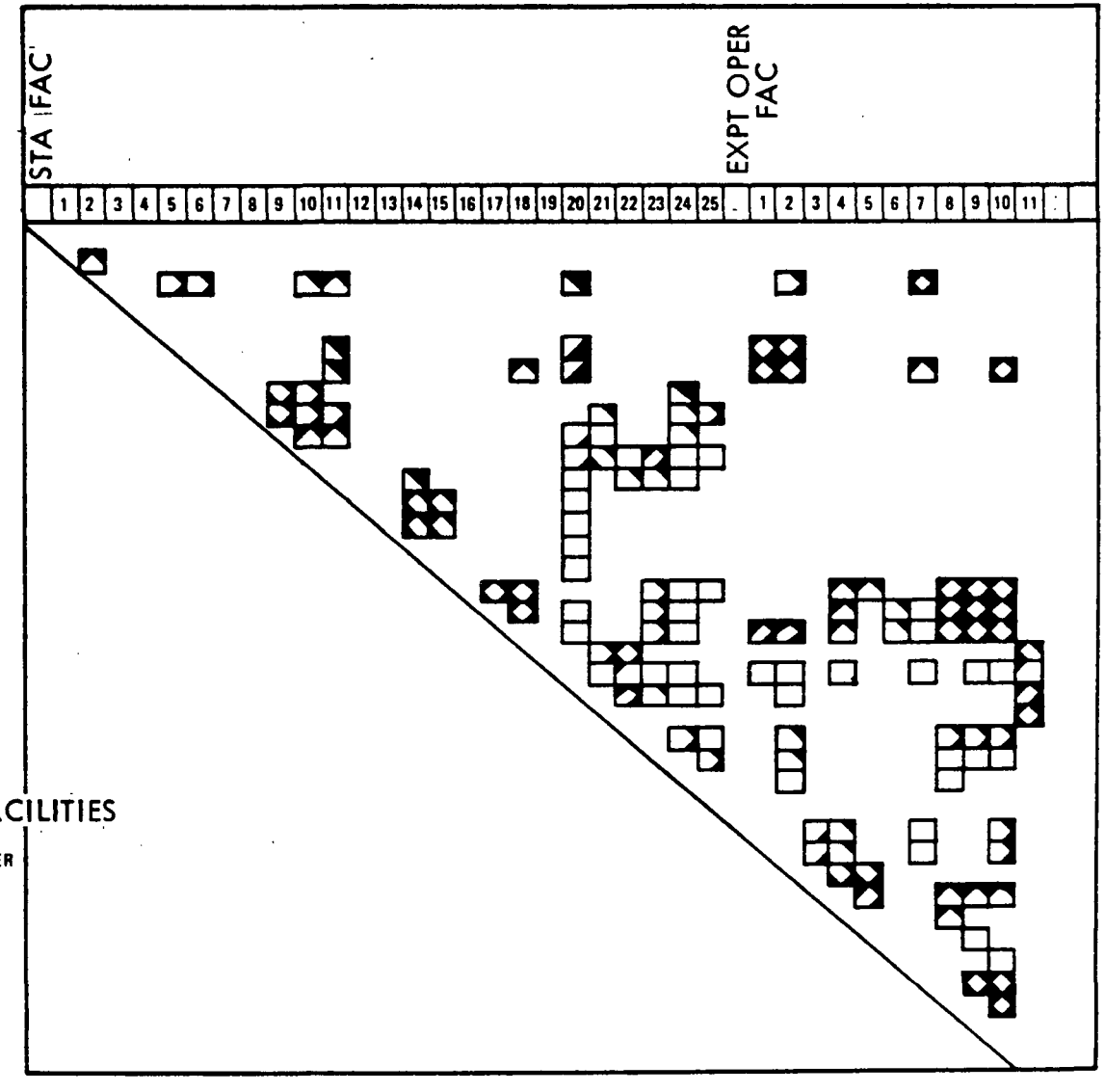
Table 3-2. Facility Requirements Initial Station--Station Operations (Cont)

Facility	Function	Equipment Notes	Access Area A Ft^2	Gross Area(1) G Ft^2	Location Criteria
Experiment Airlock (continued)	Provide: A means of extending sensors for observing earth/celestial phenomena				

(1) Gross areas presented in this column do not include areas associated with storage volume requirements.

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Table A3-3. Evaluation of Sets



STATION FACILITIES

1. PRIVATE STATE ROOMS
2. OFFICE
3. PERSONAL HYGIENE NO. 1
4. PERSONAL HYGIENE NO. 2
5. PRIMARY CONTROL CENTER
6. BACKUP CONTROL CENTER
7. PRIMARY GALLEY
8. BACKUP GALLEY
9. DINING
10. ACTIVE RECREATION
11. PASSIVE RECREATION
12. EVA AIRLOCK
13. BACKUP EVA AIRLOCK
14. IVA AIRLOCK
15. BACKUP IVA AIRLOCK
16. FLUID-MECH SHOP
17. OPTICS SHOP
18. ELECTRONICS SHOP
19. PRIMARY CREW HEALTH & MED TREAT
20. BACKUP CREW HEALTH & MED TREAT
21. EXERCISE
22. CREW MED & BEHAVIORAL QUAL
23. CARGO HANDLING
24. CARGO STORAGE
25. HOUSEKEEPING

EXPERIMENT SUPPORT FACILITIES

1. EXPERIMENT CONTROL CENTER
2. BACKUP EXPERIMENT CONTROL CENTER
3. EXPERIMENT AIRLOCK
4. PHYSICS LAB
5. MATERIALS PROCESSING LAB
6. PHOTO LAB
7. DATA ANALYSIS LAB
8. FLUID-MECH LAB
9. OPTICS LAB
10. ELECTRONICS LAB
11. AEROSPACE MED/BEHAV LAB

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3. Efficiency - Primarily evaluated as to traffic pattern with subjective evaluation of efficiency of resultant merged internal arrangements.

4. Like Functions - Evaluation of factors such as commonality of functions so that functional improvement results.

5. Other - No obvious reason not to merge facilities.

3.3.2 Incompatibilities

Table A3-4 is a matrix of noncommonality factors and also lists the noncommon 25-station and 11-experiment support facilities with the designated facility reference number shown across the top. The rationale for precluding facility sharing (reference matrix of noncommonality) as shown in Table A3-4 is listed below:

A. Timeline - Events occur in one facility which cause interference with scheduled or random events in the other facility.

B. Program Schedule - One or both of the facilities are subject to program on-orbit scheduling thus precluding merging of the facilities.

C. Number of Facilities Incompatible - Merging of the facilities would require a penalizing increase in the size of one or both of the facilities.

D. Size - Merging of the facilities would require a penalizing increase in the size of one or both of the facilities.

E. Operations - Functions performed would be incompatible in terms of disturbance, noise, contamination, etc.

3.4 PREFERRED FACILITY MERGING

Merged facility sizing requirements are presented in Table A3-5, which is a continuation of the sizing requirements. This table shows 17 merged facilities designated by letter in the far left column. In the function number column, the numbers are the same as the previous facility listing for station facilities.

Minimum floor area requirements are shown for the initial and growth stations. The maximum volumes listed for storage and allocated equipment occupies space on, above, or within the designated floor space. The floor area requirements represent minimums for design. As the actual facility is located and arranged in modules, and as more definitive equipment is developed, additional space is provided to the maximum extent possible. In addition, as the preliminary design phase of the study program progressed, changes in merging concept, equipment space allocation and total floor area

Table A3-4. Matrix of Non-Commonality Factors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	1	2	3	4	5	6	7	8	9	10	11
STATION OPERATIONS																																				
Private staterooms	X		C	C	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	C	E	E	E	E	E	E	E	E	E	E	E
Office		X	E	E			E	E	A			E	E	E	E	E	E	E	E		E	E	E	E	E	E		E	E	E		E	E	E	E
Personal hygiene 1			X	A																																A
Personal hygiene 2				X	E																															E
Primary control cen					X	F	E	E	E			E	E	E	E	E	E	E	E		E	E	E	E	E			B	E	E	E	E	E	E	E	E
Backup control cen						X	E	E	E			E	E	E	E	E	E		E		E	E	E	E	E			B	E	E	E		E	E		E
Primary galley							X	F			E	E	E	E	E	E	E	E	E	E	A	E	E		E	E	E	B	E	E	E	E	E	E	E	E
Backup galley								X				E	E	E	E	E	E	E	E	E		E	E			E	E	B	E	E	E	E	E	E	E	E
Dining									X			D	D	D	D	E	E	E	E			E	E		E	E	E	B	E	E	E	E	E	E	E	E
Active recreation										X	E	D	D	D	D	E	E	E	E							E	E	B	A	A	A	A	A	A	A	A
Passive recreation											X	D	D		D	E	E	E	E		E					E	E	B	A	A	A	A	A	A	A	A
EVA airlock												X	E			E	E	E	E		D	B	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Backup EVA airlock													X			E	E	E	E		D	B	E	E	E	E	E		E	E	E	E	E	E	E
IVA airlock														X	F	D	D	D	A		D	B	D	D	E	D	D	E	D	D	D	D	D	D	D	D
Backup IVA airlock															X	D	D	D	A		D	B	D	D	E	D	D	E	D	D	D	D	D	D	D	D
Fluid-mech shop																X			E	E	E	E				E	E	B			E	E				E
Optics shop																	X		E		E	E			E	E	E	B		E						E
Electronics shop																		X	E		E	E			E			B		E						E
Primary crew health & med treatment																			X	F			E	E	E	E	E	E	E	E	E	E	E	E	E	
Backup crew health & med treatment																				X					D			E		E	D		E			
Exercise																										E		B	E	E	E	E	E	E	E	
Crew med & behavior-al qual																						X	E	E	E	E	E	E	E	E	E	E	E	E	E	
Cargo handling																							X			E		E	E	E	E	E				E
Cargo storage																								X		E		E	E	E	E	E				E
Housekeeping																									X	E		E	E	E	E	E		E	E	E
EXPERIMENT SUPPORT OPERATIONS																																				
Experiment cont cen																										X	F			E	E		E	E		E
Backup expt cont cen																											X			E	E		E	E		E
Experiment airlock																												X			E	E	E	E	E	E
Physics lab																													X		E	E				E
Materials proc lab																														X	E	E		E	E	E
Photo lab																															X	E	E		E	E
Data analysis lab																																X	E	E		E
Fluid-mech lab																																	X			E
Optics lab																																		X		E
Electronics lab																																			X	E
Aero med/behav lab																																				X

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Table A3-5. Merged Facility Sizing Requirements

FACILITY	FUNCTION NO.	PREFERRED FACILITY MERGING	INITIAL		GROWTH	
			FLOOR AREA (SQ FT)	MAXIMUM STORAGE VOLUME & ALLOCATED EQUIP. (CU FT)	FLOOR AREA (SQ FT)	MAXIMUM STORAGE VOLUME & ALLOCATED EQUIP. (CU FT)
A	1	INITIAL STA PRIVATE STATEROOMS - 4 AT 50 FT^2, 2 AT 70 FT^2				
		GROWTH STA PRIVATE STATEROOMS - 10 AT 50 FT^2, 2 AT 70 SQ FT	340	300	640	600
B	2	EXPERIMENT COORD OFFICE	90	51	90	51
	E7	DATA ANALYSIS LAB				
C	2	COMANDERS OFFICE	100	58	100	58
	6	BACKUP STA CONTROL				
	E2	BACKUP EXP CONTROL				
D	3	PERSONAL HYGIENE TYPE 1 (WITH SHOWER)	45	30	90	60
E	4	PERSONAL HYGIENE TYPE 2 (W/O SHOWER)	35	30	70	60
F	5	PRIMARY STATION CONTROL	100	50	150	50
	E1	PRIMARY EXP CONTROL				
G	7	PRIMARY GALLEY	90	197	90	370
H	9	DINING	100	15	175	15
	11	PASSIVE RECREATION				
J	10	ACTIVE RECREATION	125	37	175	49
	8	BACKUP GALLEY				
	25	HOUSEKEEPING				
K	12	EVA AIRLOCK	35	5	35	5
	15	BACKUP IVA AIRLOCK				

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Table A3-5. Merged Facility Sizing Requirements (Cont)

FACILITY	FUNCTION NO.	PREFERRED FACILITY MERGING	INITIAL		GROWTH	
			FLOOR AREA (SQ FT)	MAXIMUM STORAGE VOLUME & ALLOCATED EQUIP. (CU FT)	FLOOR AREA (SQ FT)	MAXIMUM STORAGE VOLUME & ALLOCATED EQUIP. (CU FT)
L	14	IVA AIRLOCK	30	3	30	3
	13	BACKUP EVA AIRLOCK				
M	16	FLUID MECH SHOP	280	570	280	659
	17	OPTICS SHOP				
	18	ELECTRONICS SHOP				
	E8	FLUID MECH LAB				
	E9	OPTICS LAB				
	E10	ELECTRONICS LAB				
	23	CARGO HANDLING				
N	19	PRIMARY CREW CARE	155 MIN 300 MAX	190	300	215
	21	EXERCISE				
	22	CREW MED/BEHAV QUAL				
	E11	AEROSPACE MED/BEHAV LAB				
P	20	BACKUP CREW CARE	5	2	5	2
Q	E3	EXPERIMENT AIRLOCK	180	435	180	435
	E4	PHYSICS LAB				
	E5	MATERIAL PROCESSING LAB				
R	E6	PHOTO LAB	40	185	80	185
S	24	CARGO STORAGE		TBD		

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were integrated. A facility list with floor areas and storage volumes for the initial station are presented in Table A3-6. Where two volume sizes appear in the storage column, the first represents the volume required in the immediate area, the second is the total volume required for the facility on the space station. Convenient access to the personal hygiene areas is required, and privacy is a prime consideration with capabilities to accommodate male and female crew members (not necessarily at the same time).

Crew quarters area requirements, arrangements, and shape factors were significant drivers on the interior arrangement and total sizing of modules. The general arrangement of staterooms is based on the philosophy of providing an earthlike facility in which the resident senses common down/up side directions even though zero-g conditions prevail.

The minimum stateroom area size is approximately 50 square feet. The shape factor of this total floor area is constrained by either minimum length or minimum width. The minimum length of a typical stateroom is limited to the minimum acceptable bunk length which is 78 inches. The minimum width of a stateroom is established by bunk width (at least 30 inches) plus aisle access width (at least 24 inches) and minimum desk top width of 18 inches. This provides a minimum stateroom width of 6 feet. If the desk is arranged at the end of the bunk where it does not affect stateroom width, the minimum width of the room should not be less than 5 feet.

3.5 ALLOCATION TO MODULES

Internal configuration elements, e.g., the location of rooms/compartments, access openings, etc., have significant relationships with each other, and with various external configuration elements, e.g., relative location of flexport, etc. The merging and adjacency of facilities are based on the criteria shown in Table A3-7, for facilities that must be located in: (1) separate pressure volumes, (2) separate modules, (3) the same module.

Staterooms, control centers, hygiene facilities, and galleys must be located in at least two pressure volumes, to permit station operations to continue with double occupancy in staterooms when a loss of one pressure volume occurs.

Maintenance shops and laboratories should be in separate modules from the staterooms, galley and dining, and medical care areas, to remove maintenance activity discussion and noises. The airlock laboratory is also to be allocated to separate modules from the stateroom areas, primarily due to airlock noise disturbances to the staterooms. The combination of offices and staterooms as well as galley and dining facilities in the same module results in general efficiency, space savings, and combines facilities where similar or related functions are performed.

Flexport usage also impacts overall configuration and allocation of facilities to modules. If, in fact, flexports are used only for emergency egress, then their location is merely a function of ease and efficiency of crew escape. However, for day to day use, other issues such

Table A3-6. Facility List

Functional Area	No. Reqd. V2	No. Reqd. V1	Min Ft^2/ Facility	Storage Ft^3/Fac	Shape Factor
General stateroom	2	2	50	30	1-1, 8.5-6, height shall allow crew members to maneuver erect between stateroom facilities
Cmdrs stateroom/off Backup control	0	1	90	55	
Exec stateroom	1	0	90		
Personal hygiene with shower	0	1	54	30	
without shower	1	0	38		
Primary cont ctr 2	1	0	50	50	
Primary cont ctr 1	0	1	50		
Primary galley	0	1	85		
Backup galley	1	0	15		Min length-to-width 3-5 Min width-to-length 1-3
Dining/recreation	0	1	160		Min length-to-width 3-5 Min width-to-length 1-3
Prime crew care/ exercise	1	0	190	140-190	
Backup med care/ exercise	0	1	51	2	
EVA/IVA airlock			35	0	144-in dia x 60-in length
GPL (physics)	0	1	34		
GPL (biomed/biolog)	0	1	34		
GPL (mech, elect, optical maint)	1	0	232	490	
GPL (photo lab)	0	1	33		
GPL (data analysis)	0	1	95		
Expt ops (zenith A/L)	0	1	100		
Expt ops (nadir A/L)	1	0	168		
Expt airlocks	1	1			80-in dia x 150-in length One earth oriented One zenith oriented

Table A3-7. Preferred Facility Location Criteria

Separate Pressure Volumes	
V_1	V_2
3 staterooms (initial)	3 staterooms (initial)
3 staterooms (growth)	3 staterooms (growth)
Commanders office(backup control)	Control center
Personal hygiene type 1 (initial)	Personal hygiene type 1 (initial)
Personal hygiene type 2 (growth)	Personal hygiene type 2 (growth)
Galley	Recreation backup galley
Separate Modules	
All staterooms	Maintenance shops & labs
All staterooms	Airlock lab
Galley and dining	Maintenance shop & labs
Galley and dining	Airlock lab
Medical care	Maintenance shops & labs
Same Module	
Commanders office	Commanders stateroom
Executive office	Executive stateroom
Galley	Dining

as flexport terminus and travel distance for egress must be considered. Accordingly, flexports should enter into public areas, not private areas such as staterooms, personal hygiene, etc. Areas such as dining and recreation are preferred over work areas for flexport terminus. In addition, to simplify and decrease evacuation time, the flexports should be located centrally in the modules rather than at the ends of the modules.

Table A3-8 presents the station modules final functional allocation including each facility area requirements location per module, above or below deck and in what pressure volume each is located. By utilizing the criteria shown in Table A3-7 and the rationale described above, each pressure volume contains three staterooms, a personal hygiene area, control center, medical care facility, galley, and an experiment airlock with the remaining functional facilities equally divided. This provides necessary facility availability in either pressure volume should one or the other become nonhabitable in the event of pressure loss.

Table A3-9 presents the final functional allocation of the special modules including the core module and power module. The core module includes the IVA/EVA airlock which becomes the center of the MSS by dividing the two pressure volumes. In addition, segments of major subsystems are included in the core. The power module basically contains the electrical power system gas storage tanks, ECLSS gas tanks for repressurization, and the solar arrays. Ample clearance for pass through or maintenance is provided in the power module.

3.6 ALLOCATION TO MODULES

In allocating the configured modules to the MSS cluster, some of the criteria utilized during the evolution of the functional allocations were again used, along with other specific considerations. One of the main considerations for both functional allocation to modules and allocation of modules, is the pressure volume rule. Figure A3-2 shows the final functional allocation to modules as well as the allocation of the modules to the initial station cluster. Again, the modules are allocated to the cluster to provide the key facilities, staterooms, control centers, galleys, personal hygiene, and medical care/exercise areas in each of the two pressure volumes. Other specific criteria for allocation of modules are listed as follows:

1. Window Locations - The modules incorporating windows shall be located in the cluster to permit maximum use of the windows for the intended purpose. Modules with windows located adjacent to the control centers, shall be located for maximum use of the windows during shuttle approach and docking with the MSS. The module, with dining/recreation window, shall be located for maximum viewing of earth and celestial bodies.

2. Traffic Patterns - In allocating modules to the cluster total traffic and traffic patterns must be considered. Consideration of arrangement to provide highest traffic as close to the core module as possible should be a prime goal.

Table A3-8. Station Module Final Functional Allocation

Pressure Volume 1 (V-1)				Pressure Volume 2 (V-2)			
STATION MODULE 1 (SM-1)				STATION MODULE 2 (SM-2)			
Functional Facility	Location/Quantity		Area (ft^2)	Functional Facility	Location/Quantity		Area (ft^2)
	Above Deck	Below Deck			Above Deck	Below Deck	
Commander's stateroom	1		90	GPL (mech,elec,optical)	1		232
Crew stateroom		2	50	Experiment operations (NADIR)	1		168
Personal hygiene 1	1		54	Air revitalization		1	-
Data analysis lab	1		95	Experiment storage		1	-
Control center 1	1		50	Backup galley	1		15
Photo processing	1		33	Experiment airlock	1		-
Backup medical/exer	1		51				
Thermal control		1	-				
Water management		1	-				
EPS electrolysis		1	-				
PGA & support		2	-				
STATION MODULE 3 (SM-3)				STATION MODULE 4 (SM-4)			
Functional Facility	Location/Quantity		Area (ft^2)	Functional Facility	Location/Quantity		Area (ft^2)
	Above Deck	Below Deck			Above Deck	Below Deck	
Primary galley	1		85	Executive stateroom	1		90
Dining	1		160	Crew stateroom		2	50
Recreation				Personal hygiene 2	1		38
GPL (physics)	1		34	Control center 2	1		50
GPL (medical/biological)	1		34	Primary medical/exer	1		190
				Thermal control		1	-
Experiment operations (zenith)	1		100	Water management		1	-
				EPS electrolysis		1	-
Experiment airlock	1		-	PGA & support		2	-
Air revitalization		1	-				
Experiment storage		1	-				

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TABLE A3-9. SPECIAL MODULES - FINAL
FUNCTIONAL ALLOCATION

Core Module			Power Module	
Functional Facility	Area (ft^2)	Qty	Functional Facility	Qty
EVA/IVA airlock	35	1	EPS gas storage	1
Guidance & control	-	1	Repressurization gas	1
Reaction control	-	1	Solar arrays	1
Information	-	1		

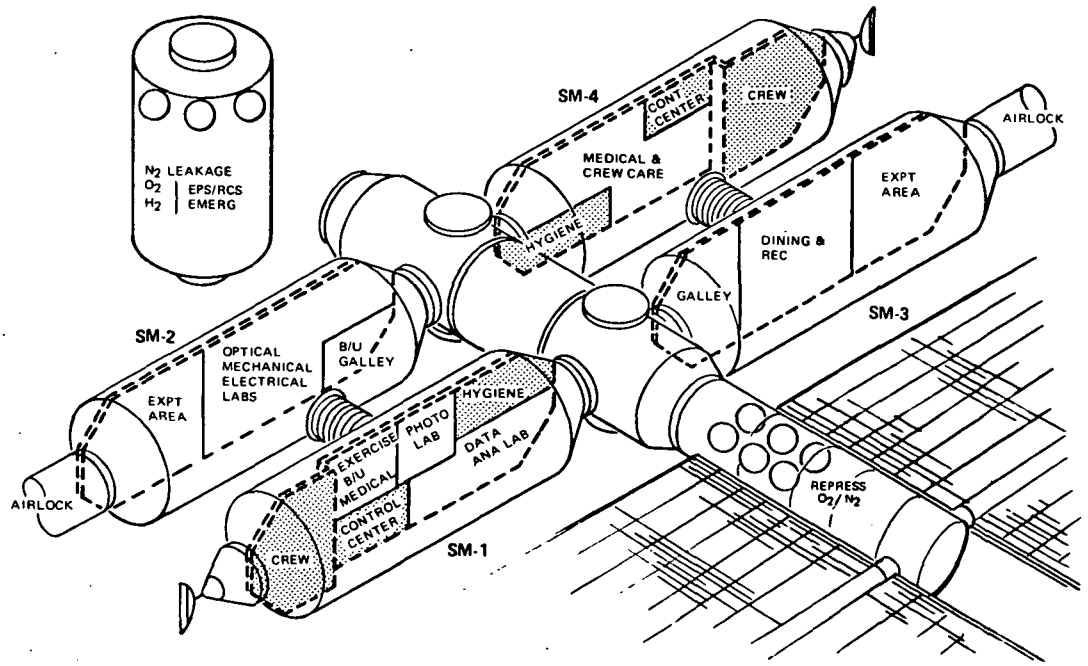


Figure A.3-2. Final Functional Allocation

3. Location of SM-1 - The location of SM-1 and the control center within SM-1 shall be such that maximum use can be provided during MSS buildup operations.

4. Location of SM-2 - SM-2, which contains the nadir experiment airlock, shall be located so that the nadir airlock is as far as possible from the solar arrays of the power module.

Figure A3-2 reflects the results of consideration of the above criteria in establishing the allocation of modules to the MSS cluster.

4. BERTHING AND DOCKING

The selection of the concept for the delivery and controlled mating of space station modules has an impact on the space station design requirements. The two basic mating alternatives considered were berthing using the shuttle manipulator and direct docking. In the berthing concept, the shuttle manipulator performs all mating operations between the space station, space station modules and the space shuttle. In the direct docking concept, the space shuttle is used directly to perform the mating operations. A study was conducted to determine the differences in the requirements for berthing and docking and to assess the impact of deferring the berthing versus docking selection. The results of the study and the baseline concept with the associated rationale are presented in this section. Also, the penalties associated with deferring the berthing/docking decision are presented.

4.1 MODULE DELIVERY AND RETURN ALTERNATIVES

The alternative procedures considered for the delivery and return of the space station modules are identified in Figure A4-1. Two basic alternatives were considered: direct docking using the space shuttle, and berthing using the shuttle manipulator. Within the direct docking concept, two alternatives were considered. First, the space shuttle performs all maneuvers necessary to mate modules and the shuttle manipulator is not required. Second, the shuttle docks directly to the space station core module at the shuttle passenger port and then uses the shuttle manipulator to mate modules to the space station core module.

Two alternatives were also considered for the berthing of modules. In the direct berthing concept, the module is first positioned on the shuttle crew compartment port using the shuttle manipulator. The manipulator then berths the module (with the shuttle) to the appropriate berthing port. The second berthing alternative uses the manipulator to berth the space station core module to the shuttle passenger port. The shuttle manipulator then performs the module mating/removal operations.

4.2 OPERATIONAL CONSIDERATIONS

The alternative modes for delivery and return of space station modules were investigated to establish the operational sequences, identify critical mission continuation operations, identify potential crew hazardous situations, identify potential vehicle hazardous situations, and select a preferred operational mode. The operational sequences used during the trade study are summarized in Tables A4-1 through A4-4. For each sequence, the operations considered critical for mission continuation and operations considered potentially hazardous to the vehicle were identified. During the analyses, potentially hazardous crew situations were identified; however, the hazardous crew situations were removed by changing the operational procedures. Therefore, no residual crew-hazardous situations are identified.

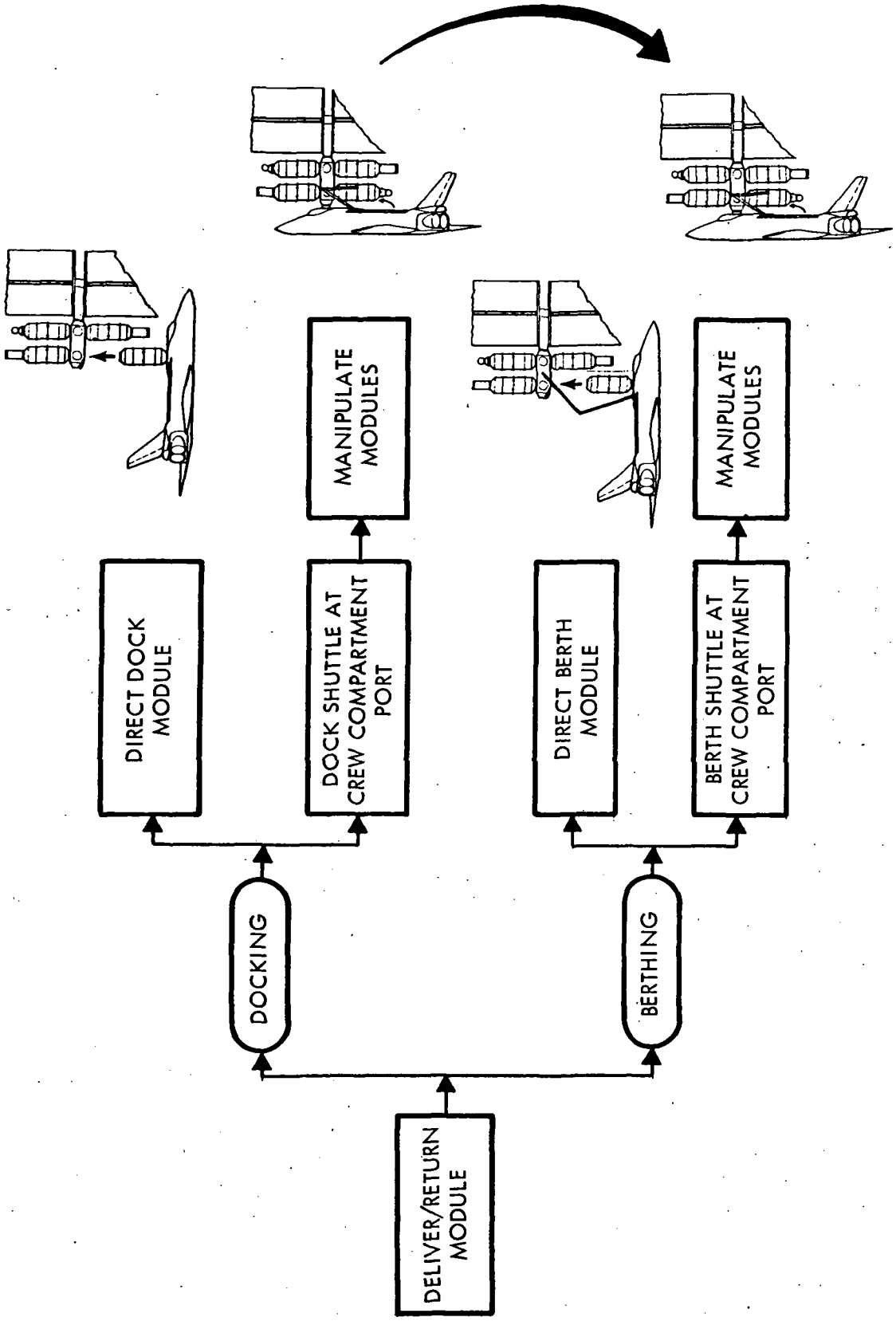


Figure A.4-1. Module Delivery/Return Alternatives

Table A4-1. Direct Docking of Cargo Module

SHUTTLE	STATION
. VERIFY TRANSFER TO TPI	
✓. ATTACH MANIPULATOR TO ADAPTER	
. REMOVE ADAPTER FROM CARGO BAY	
✓. BERTH ADAPTER TO PASSENGER PORT	
. DETACH MANIPULATOR FROM ADAPTER	
. STOW MANIPULATOR	
. TPI	
. RENDEZVOUS	. INHIBIT SOLAR ARRAY
. CREW TRANSFER TO SHUTTLE COCKPIT	. MONITOR RENDEZVOUS
✓. ATTACH MANIPULATOR TO "UP" CREW-CARGO MODULE	
. REMOVE "UP" CREW-CARGO MODULE FROM CARGO BAY	
✓. BERTH "UP" CREW-CARGO MODULE TO ADAPTER	
. STATION KEEP & ALIGN SHUTTLE FOR DOCKING	
I . INITIATE FINAL CLOSING	
✓. DOCKING CONTACT	. INHIBIT RCS . VERIFY "UP" CREW-CARGO MODULE ENVIRONMENT . EQUALIZE PRESSURE BETWEEN STATION & "UP" CREW-CARGO MODULE . OPEN HATCHES BETWEEN STATION & "UP" CARGO MODULE . CONNECT STATION/CARGO MODULE INTERFACE . VERIFY STATION/CARGO MODULE INTERFACE . TRANSFER "UP" CREW FROM SHUTTLE, THRU ADAPTER/MODULE TO STATION

✓ CRITICAL MISSION CONTINUATION OPERATIONS
II POTENTIAL CREW HAZARDOUS SITUATIONS
I POTENTIAL VEHICLE HAZARDOUS SITUATIONS

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Table A4-1. Direct Docking of Cargo Module (Cont)

SHUTTLE	STATION
. UNDOCK SHUTTLE	. ACTIVATE RCS
✓. TRANSLATE & REPOSITION FOR "DOWN" CREW-CARGO MODULE	
. STATION KEEP & ALIGN SHUTTLE FOR DOCKING	
‖ . INITIATE FINAL CLOSING	
✓. DOCKING CONTACT	. INHIBIT RCS . TRANSFER "DOWN" CREW FROM STATION THRU MODULE/ADAPTER TO SHUTTLE COCKPIT . DISCONNECT STATION/"DOWN" CREW-CARGO MODULE INTERFACES . CLOSE HATCHES BETWEEN STATION AND "DOWN" CREW-CARGO MODULE . ACTIVATE RCS . UNINHIBIT SOLAR ARRAY
. UNDOCK SHUTTLE	
. STATION KEEP/STANDOFF	
✓. ATTACH MANIPULATOR TO "DOWN" CREW-CARGO MODULE	
. UNBERTH "DOWN" CREW-CARGO MODULE FROM ADAPTER	
✓. STOW "DOWN" CREW-CARGO MODULE IN CARGO BAY	
✓. ATTACH MANIPULATOR TO ADAPTER	
. UNBERTH ADAPTER FROM PASSENGER PORT	
✓. STOW ADAPTER, MANIPULATOR IN CARGO BAY	
. TRANSFER CREW FROM SHUTTLE COCKPIT TO "DOWN" CREW-CARGO MODULE	
. DEORBIT	
. ENTRY	
. LAND AT PRESELECTED LANDING SITE	

‖ POTENTIAL CREW HAZARDOUS SITUATIONS
‖ POTENTIAL VEHICLE HAZARDOUS SITUATIONS
✓ CRITICAL MISSION CONTINUATION OPERATIONS

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Table A4-2. Docking of Shuttle at Crew Compartment - Manipulation of Cargo Module

SHUTTLE	STATION
. TPI	
. RENDEZVOUS	. INHIBIT SOLAR ARRAY
. STATION KEEP & ALIGN SHUTTLE FOR DOCKING	. MONITOR RENDEZVOUS
I . INITIATE FINAL CLOSING	
✓ . DOCKING CONTACT	. INHIBIT RCS
	. EQUALIZE PRESSURE BETWEEN STATION & SHUTTLE
	. OPEN HATCHES BETWEEN STATION/ADAPTER & SHUTTLE
	. CONNECT STATION/SHUTTLE INTERFACE
	. VERIFY STATION/SHUTTLE INTERFACE
	. TRANSFER "UP" CREW FROM SHUTTLE, THRU ADAPTER TO STATION
✓ . ATTACH MANIPULATOR TO "UP" CREW-CARGO MODULE	
. REMOVE "UP" CREW-CARGO MODULE FROM CARGO BAY	
✓ . BERTH "UP" CREW-CARGO MODULE TO STATION	
. DETACH MANIPULATOR FROM "UP" CREW-CARGO MODULE	
. STOW MANIPULATOR	. VERIFY "UP" CREW-CARGO MODULE ENVIRONMENT
	. EQUALIZE PRESSURE BETWEEN STATION & "UP" CREW-CARGO MODULE
	. OPEN HATCHES BETWEEN STATION AND "UP" CARGO MODULE
	. CONNECT STATION/CARGO MODULE INTERFACE
	. VERIFY STATION/CARGO MODULE INTERFACE

II POTENTIAL CREW HAZARDOUS SITUATIONS
I POTENTIAL VEHICLE HAZARDOUS SITUATIONS
✓ CRITICAL MISSION CONTINUATION OPERATIONS

Table A4-2. Docking of Shuttle at Crew Compartment
Manipulation of Cargo Module (Cont)

SHUTTLE	STATION
	. DISCONNECT STATION/"DOWN" CREW-CARGO MODULE INTERFACES . CLOSE HATCHES BETWEEN STATION AND "DOWN" CREW-CARGO MODULE
✓. ATTACH MANIPULATOR TO "DOWN" CREW-CARGO MODULE . UNBERTH "DOWN" CREW-CARGO MODULE ✓. STOW "DOWN" CREW-CARGO MODULE IN CARGO BAY . DETACH MANIPULATOR FROM "DOWN" CREW-CARGO MODULE . ESTABLISH DEORBIT PARAMETERS . TRANSFER "DOWN" CREW TO SHUTTLE THROUGH "UP" CREW-CARGO MODULE ADAPTER . CLOSE HATCHES BETWEEN SHUTTLE AND STATION . UNBERTH SHUTTLE . STOW MANIPULATOR . STATION KEEP . DEORBIT . ENTRY . LAND AT PRESELECTED LANDING SITE	. VERIFY DEORBIT PARAMETERS . ACTIVATE RCS . UNINHIBIT SOLAR ARRAY . MONITOR DEORBIT . MONITOR SHUTTLE TO ENTRY INTERFACE (400,000 FT)
POTENTIAL CREW HAZARDOUS SITUATIONS POTENTIAL VEHICLE HAZARDOUS SITUATIONS CRITICAL MISSION CONTINUATION OPERATIONS	

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Table A4-3. Direct Berthing of Cargo Module

SHUTTLE	STATION
. VERIFY TRANSFER TO TPI	
✓. ATTACH MANIPULATOR TO ADAPTER	
. REMOVE ADAPTER FROM CARGO BAY	
✓. BERTH ADAPTER TO PASSENGER PORT	
. STOW MANIPULATOR	
. TPI	
. RENDEZVOUS	. INHIBIT SOLAR ARRAY
. TRANSFER CREW FROM "UP" CREW-CARGO MODULE TO SHUTTLE COCKPIT	
✓. ATTACH MANIPULATOR TO "UP" CREW-CARGO MODULE	
. REMOVE "UP" CREW-CARGO MODULE FROM CARGO BAY	
✓. BERTH "UP" CREW-CARGO MODULE TO ADAPTER	
. STATION KEEP & ALIGN SHUTTLE FOR BERTHING	
|. ATTACH MANIPULATOR TO STATION	. INHIBIT RCS
|. BERTH STATION TO SHUTTLE	
. DETACH AND STOW MANIPULATOR	. VERIFY "UP" CREW-CARGO MODULE ENVIRONMENT . EQUALIZE PRESSURE BETWEEN STATION & "UP" CREW-CARGO MODULE . OPEN HATCHES BETWEEN STATION & "UP" CREW-CARGO MODULE . CONNECT STATION/"UP" CREW-CARGO MODULE INTERFACE . VERIFY STATION/"UP" CREW-CARGO MODULE INTERFACE . TRANSFER "UP" CREW FROM SHUTTLE, THRU ADAPTER/MODULE TO STATION

|| POTENTIAL CREW HAZARDOUS SITUATIONS
| POTENTIAL VEHICLE HAZARDOUS SITUATIONS
✓ CRITICAL MISSION CONTINUATION OPERATIONS

Table A4-3. Direct Berthing of Cargo Module (Cont)

SHUTTLE	STATION
	. DISCONNECT STATION/"DOWN" CREW-CARGO MODULE INTERFACES . CLOSE HATCHES BETWEEN STATION AND "DOWN" CREW-CARGO MODULE
✓. ATTACH MANIPULATOR TO "DOWN" CREW-CARGO MODULE . UNBERTH "DOWN" CREW-CARGO MODULE ✓. STOW "DOWN" CREW-CARGO MODULE IN CARGO BAY . DETACH MANIPULATOR FROM "DOWN" CREW-CARGO MODULE ✓. ATTACH MANIPULATOR TO STATION . ESTABLISH DEORBIT PARAMETERS . TRANSFER "DOWN" CREW TO SHUTTLE THROUGH "UP" CREW-CARGO MODULE/ADAPTER . CLOSE HATCHES BETWEEN SHUTTLE AND STATION . UNBERTH SHUTTLE . DETACH MANIPULATOR FROM STATION . STOW MANIPULATOR . STATION KEEP . DEORBIT . ENTRY . LAND AT PRESELECTED LANDING SITE	. VERIFY DEORBIT PARAMETERS . ACTIVATE RCS . UNINHIBIT SOLAR ARRAY . MONITOR DEORBIT . MONITOR SHUTTLE TO ENTRY INTERFACE (400,000 FT)
II POTENTIAL CREW HAZARDOUS SITUATIONS I POTENTIAL VEHICLE HAZARDOUS SITUATIONS ✓CRITICAL MISSION CONTINUATION OPERATIONS	

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Table A4-4. Berthing of Shuttle to Crew Compartment - Manipulation of Cargo Module

SHUTTLE	STATION
. RENDEZVOUS	. MONITOR RENDEZVOUS . INHIBIT SOLAR ARRAY
. STATION KEEP	
‖ . ATTACH MANIPULATOR TO STATION	. INHIBIT STATION RCS
‖ . BERTH SHUTTLE	
. EQUALIZE PRESSURE BETWEEN STATION & SHUTTLE	
. OPEN HATCHES	
. TRANSFER "UP" CREW THROUGH PASSENGER PORT	
. DETACH MANIPULATOR FROM STATION	
✓ . ATTACH MANIPULATOR TO "UP" CREW-CARGO MODULE	
. REMOVE "UP" CREW-CARGO MODULE FROM CARGO BAY	
✓ . BERTH "UP" CREW-CARGO MODULE	
. DETACH MANIPULATOR FROM "UP" CREW-CARGO MODULE	
. STOW MANIPULATOR	
	. VERIFY "UP" CREW-CARGO MODULE ENVIRONMENT . EQUALIZE PRESSURE BETWEEN STATION AND "UP" CREW-CARGO MODULE . OPEN HATCHES BETWEEN STATION AND "UP" CREW-CARGO MODULE . CONNECT STATION/CARGO MODULE INTERFACE . VERIFY STATION/CARGO MODULE INTERFACE

‖ POTENTIAL CREW HAZARDOUS SITUATIONS
‖ POTENTIAL VEHICLE HAZARDOUS SITUATIONS
✓ CRITICAL MISSION CONTINUATION OPERATIONS

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Table A4-4. Berthing of Shuttle to Crew Compartment - Manipulation of Cargo Module (Cont)

SHUTTLE	STATION
	. DISCONNECT STATION/"DOWN" CREW-CARGO MODULE INTERFACES . CLOSE HATCHES BETWEEN STATION AND "DOWN" CREW-CARGO MODULE
✓. ATTACH MANIPULATOR TO "DOWN" CREW-CARGO MODULE . UNBERTH "DOWN" CREW-CARGO MODULE | . STOW "DOWN" CREW-CARGO MODULE IN CARGO BAY . DETACH MANIPULATOR FROM "DOWN" CREW-CARGO MODULE ✓. ATTACH MANIPULATOR TO STATION . ESTABLISH DEORBIT PARAMETERS . TRANSFER "DOWN" CREW TO SHUTTLE THROUGH PASSENGER PORT . CLOSE HATCHES BETWEEN SHUTTLE AND STATION . UNBERTH SHUTTLE . DETACH MANIPULATOR FROM STATION . STOW MANIPULATOR . STATION KEEP . DEORBIT . ENTRY . LAND AT PRESELECTED LANDING SITE	. VERIFY DEORBIT PARAMETERS . ACTIVATE RCS . UNINHIBIT SOLAR ARRAY . MONITOR DEORBIT . MONITOR SHUTTLE TO ENTRY INTERFACE (400,000 FT)

!! POTENTIAL CREW HAZARDOUS SITUATIONS
\| POTENTIAL VEHICLE HAZARDOUS SITUATIONS
✓ CRITICAL MISSION CONTINUATION OPERATIONS

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A comparison of the four alternatives was made considering the number of critical operations, the number of residual potential vehicle hazardous situations, and the number of manipulator operations required. The comparison of the critical operations is shown in Table A4-5. For the four alternatives considered, five critical operations were identified. No one concept contained all critical operations, but two of the alternatives contained four of the critical operations. For the direct dock and the direct berthing concepts, eight critical operations were identified. The concept, which involves direct docking of the shuttle and manipulating the modes, resulted in the least number of critical operations.

A summary of the number of potential vehicle hazardous situations is presented in Table A4-6. Five potentially hazardous situations were common to the four operational alternatives considered. Of the four alternatives, direct docking of the shuttle and manipulating the module presents the least number of potentially hazardous situations.

An overall operational comparison of the four modes is presented in Table A4-7. In addition to summarizing the number of critical operations and the number of potentially hazardous situations, the number of manipulator operations are identified. The manipulator operations considered were attachment and detachment of the manipulator arm to a module and manipulator translation maneuvers considering the manipulator only and the manipulator with a module attached. As can be seen from the table, the concept which involves direct docking of the shuttle at the passenger port and manipulating the module results in the least number of critical operations, potentially hazardous operations, manipulator attach/detach operations, and manipulator translation operations. Because of the reduced operational complexity, the alternatives using direct docking of the shuttle and manipulation of the modules is the preferred alternative from an operational point of view. Before the final selection can be made, however, additional considerations require investigation.

4.3 MODULE SPACING CONSIDERATIONS

Any differences in the module spacing requirements for the different operational modes considered will have an impact on the core module design in terms of the required spacing between berthing and docking ports. The module spacing is dictated primarily by considerations of the errors associated with berthing or docking. The error sources considered for the two basic alternatives are identified in Figure A4-2. For the berthing mode, the position (translation), angular alignment, module manufacturing tolerances, manipulator stability deadband, and errors in orientation of adjacent modules (docked module alignment) must be considered. For the docking alternative, station attitude stability, shuttle attitude stability, shuttle position accuracy, module manufacturing tolerances, and docked module alignment must be considered. The magnitude of the alignment errors considered representative for the berthing concepts are summarized in Figure A4-3. The impact of these errors is shown in Figure A4-4 as a function of module length. As can be seen from the figure, a minimum module space of approximately 20 inches is required for module lengths of 40 feet. Applying a 50-percent margin, the required displacement must be 30 inches, which is much too close for 15-foot diameter modules.

Table A4-5. Critical Operations Comparison

Critical Operation	Operational Mode			
	Direct Dock Crew/Cargo Module	Direct Berth Crew/Cargo Module	Dock Shuttle at Crew Compartment Port	Berth Shuttle at Crew Compartment Port
Attach manipulator to adapter/module	4	3	2	2
Berth adapter/module	2	2	1	1
Dock shuttle	2	-	1	-
Attach manipulator to station	-	2	-	2
Berth shuttle	-	1	-	1

Table A4-6. Potential Vehicle Hazardous Situation Comparison

Potentially Hazardous Situation	Operational Mode			
	Direct Dock Crew/Cargo Module	Direct Berth Crew/Cargo Module	Dock Shuttle at Crew Compartment Port	Berth Shuttle at Crew Compartment Port
Direct dock crew/cargo module	1			
Direct dock shuttle at crew compartment port	1		1	
Attach manipulator to station		1		1
Berth at crew compartment port				1
Berth at crew/cargo module port		1		

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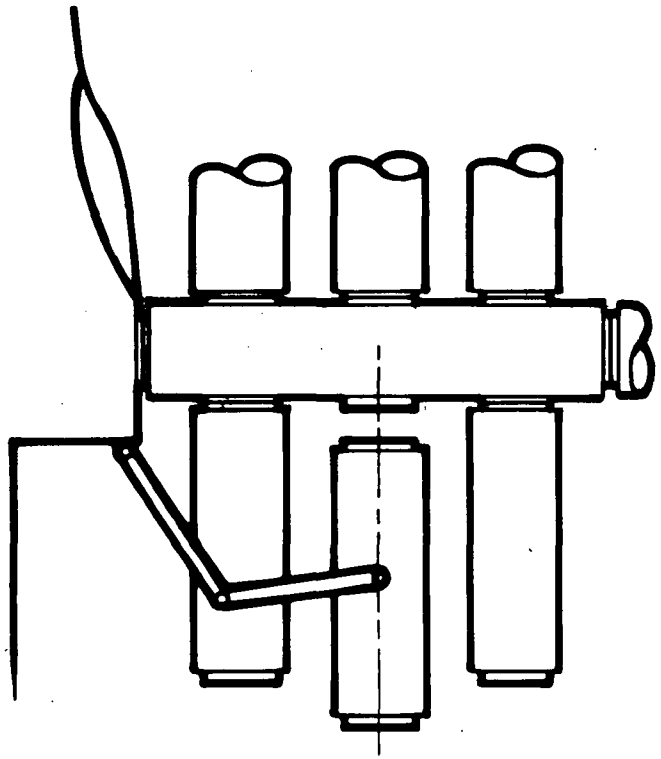
Table A4-7. Operational Comparison

Operational Mode	Potentially Hazardous Operations	Critical Operations	Manipulator Operations		
			Attach/ Detach	Translate	
				Manual Only	Manual + Module *
Direct dock crew cargo module	2	8	4	5	4
Direct berth crew/cargo module	2	8	5	8	5
Dock shuttle at crew compartment port	1	4	2	4	2
Berth shuttle at crew compartment port	2	6	4	6	4

*Adapter, crew/cargo module or shuttle/station

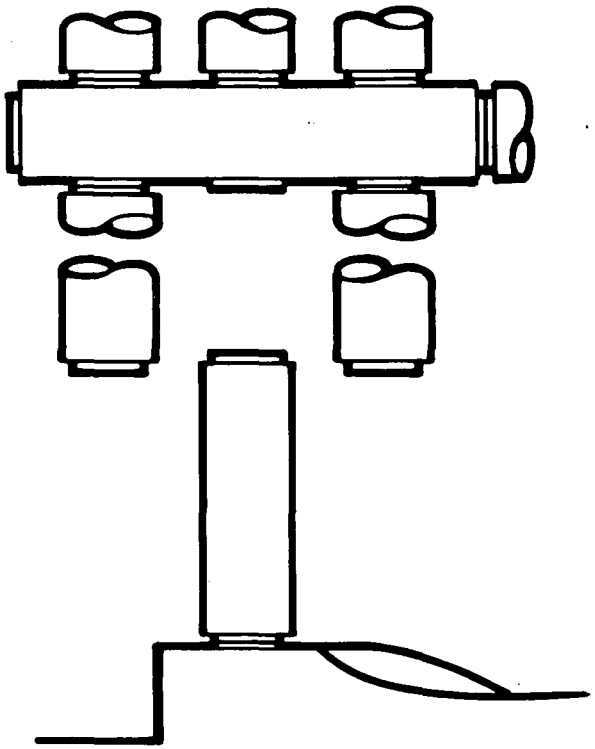
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BERTHING



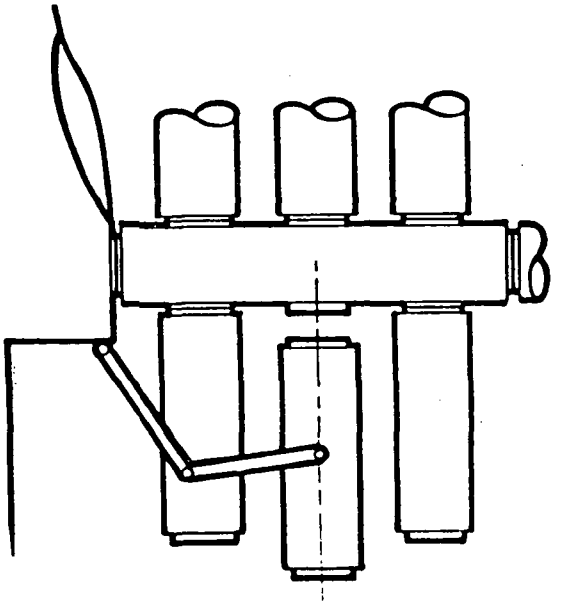
- POSITION
- ANGULAR ALIGNMENT
- MODULE MANUFACTURING
- STABILITY DEADBAND
- DOCKED MODULE ALIGNMENT

DOCKING



- STATION ATTITUDE STABILITY
- SHUTTLE ATTITUDE STABILITY
- SHUTTLE POSITION ACCURACY
- MODULE MANUFACTURING
- DOCKED MODULE ALIGNMENT

Figure A.4-2. Alignment Error Sources



ALIGNMENT ERROR SOURCE	ALIGNMENT ERROR
POSITION	6 IN.
ANGULAR ALIGNMENT	1 DEG
MODULE MANUFACTURING	1 IN.
STABILITY DEADBAND	2.5 IN.
DOCKED MODULE ALIGNMENT	0.067 DEG

Figure A.4-3. Berthing Alignment Errors

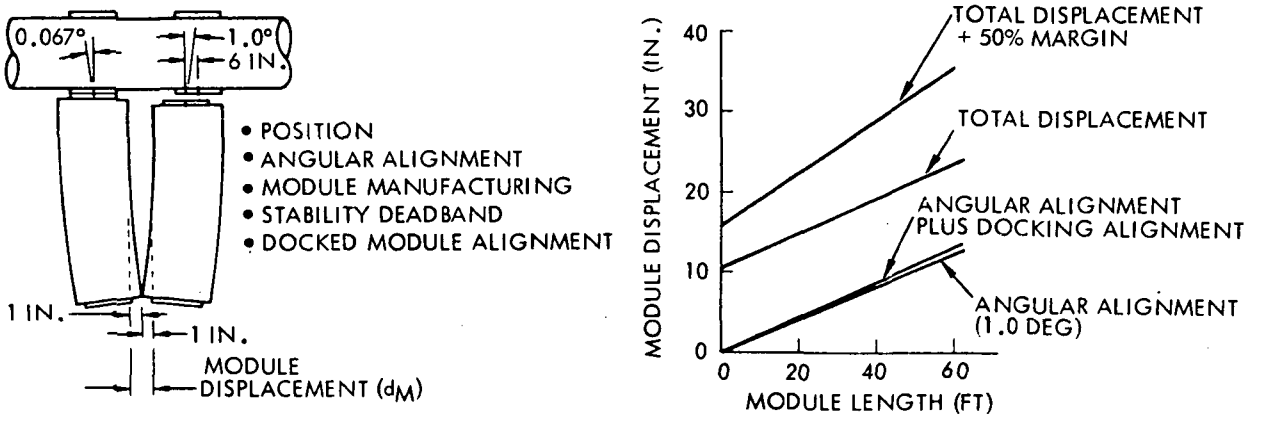


Figure A.4-4. Berthed Module Displacement Requirements

The magnitude of the alignment errors for the direct docking mode are summarized in Figure A4-5. An examination of the error sources has shown that the module manufacturing tolerances and the docked module alignment errors are insignificant relative to the station attitude stability, shuttle attitude stability, and shuttle position accuracy error sources. In considering these three error sources, the required module separation for a 40-foot length module is approximately five feet. As a result of the increased errors, the direct docking mode requires approximately twice the module separation required by the berthing mode.

4.4 DESIGN CONSIDERATIONS

The selection of the berthing/docking mode has an impact on the design of the core module, station modules, and cargo modules. The magnitude of the impact is illustrated in Figure A4-6. The berthing mode imposes the minimum impact on all modules in that the core module length can be minimized and the interface between the core module and all other modules can be minimized. Also, the berthing adapter length can be minimized because the adapter length is not dependent upon the length of adjacent station modules.

The docking mode imposes a requirement for an increased core module length of approximately three feet, resulting in an increase in core module weight of 384 pounds. Also, the docking ports must provide the capability for impact attenuation resulting in a 550-pound docking port interface on one core module docking port, one station module docking port, and the adapter docking port. Also, the docking adapter must have an increased length of approximately nine feet to permit berthing of adjacent modules with different module lengths. The resultant increased adapter weight is approximately 538 pounds. As a result, the increased structural requirements for the docking mode requires an increased weight in all modules: 724 pounds in the core module; 340 pounds in the station modules, RAM's, and cargo modules; and 878 pounds in the adapter.

4.5 MODE SELECTION

The principal considerations which impact the berthing/docking selection are listed in Table A4-8. If the direct docking mode is adopted, the resultant module spacing will accommodate either the berthing or the docking mode. Direct docking has the advantage of being independent of manipulator reach. The core module must be approximately three feet longer to accommodate direct docking and the common modules must all have active docking ports with attenuation. In addition, the shuttle adapter must be sized (length) to compensate for various module lengths when direct docking is employed.

Based on the mode selection considerations previously identified, the manipulator berthing mode will be retained as the baseline mode, but the space station design will be compatible with direct docking. This results in a five-foot nominal clearance between modules with a resultant core module weight penalty of approximately 384 pounds. This decision allows final selection of the berthing versus docking mode to be deferred until Phase C design studies when increased knowledge of manipulator operations should be available.

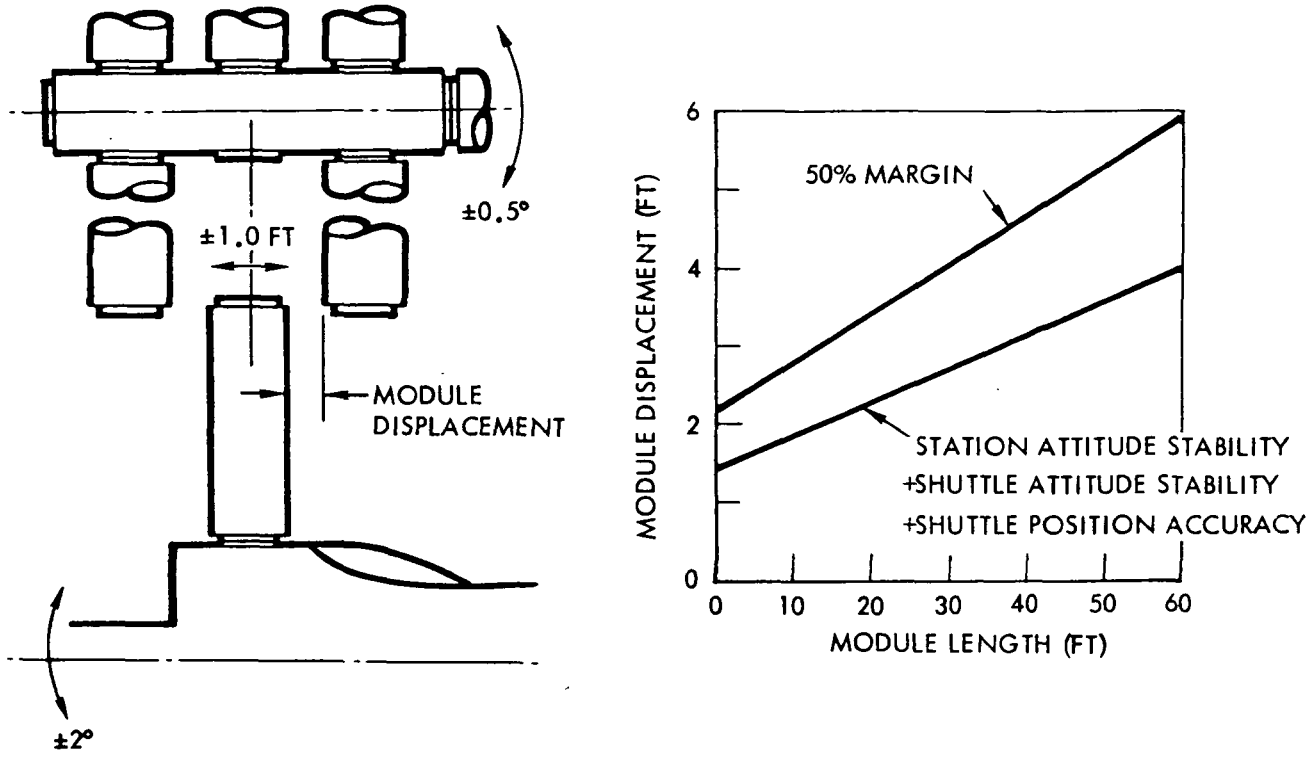


Figure A.4-5. Docked Module Displacement Requirements

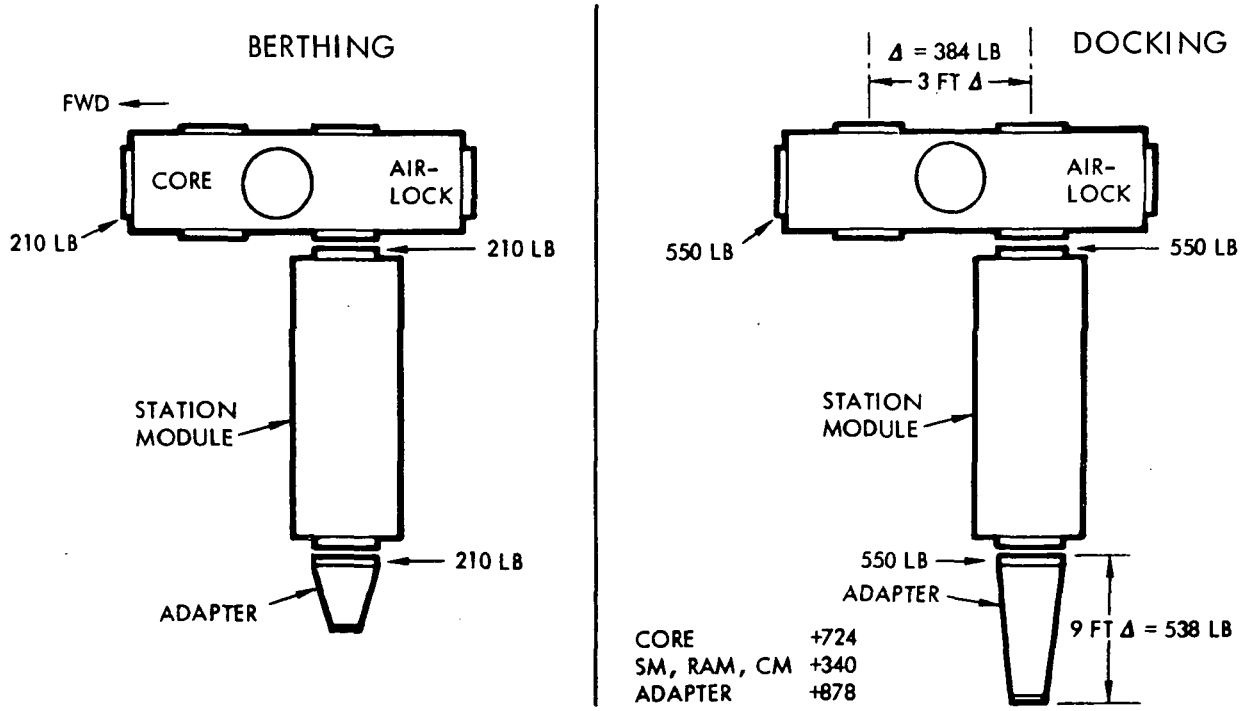


Figure A.4-6. Structural Weight Comparison

Table A4-8. Mode Selection Considerations Summary

CONSIDERATIONS	IMPACT OF MODE SELECTION	
	BERTHING	DOCKING
CHANGE IN MODE	NOT POSSIBLE	WILL ACCOMMODATE EITHER
MANIPULATOR DESIGN	REACH DEPENDENT	INDEPENDENT
CORE MODULE PENALTY	NONE	3-FOOT LENGTH
COMMON MODULE PENALTY	NONE	ACTIVE PORT W/ATTENUATION
SHUTTLE ADAPTER	SIZED TO SHUTTLE RQMTS	SIZED TO MODULE LENGTH DELTAS

MODE SELECTION RECOMMENDATION

RECOMMENDATIONS

1 RETAIN BERTHING MODE

2 MAKE SYSTEM/CONFIGURATION COMPATIBLE WITH DIRECT DOCKING

- MODULE SPACING 5 FT
- SCAR WEIGHT = 384 LB

RATIONALE

☐ ALLOWS DEFERRABLE OPTION (PHASE C+)

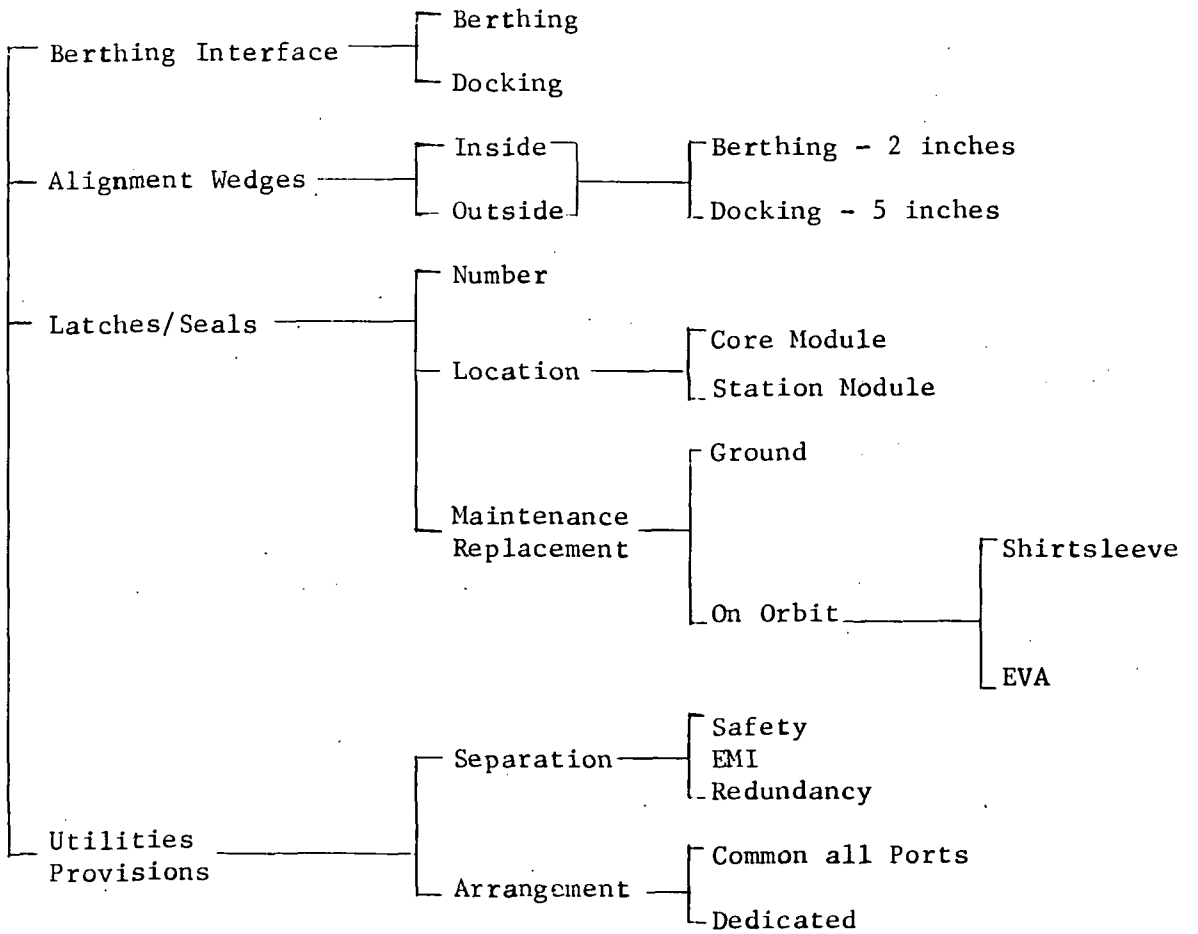
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5. BERTHING INTERFACE

The modular space station is a semipermanent cluster of modules which are transported to and from orbits by a space shuttle. The shuttle utilizes a manipulator to assemble the station. The berthing/docking interface provides the following important functions for the station buildup sequence:

1. Controlled mating of modules
2. Structural attachment of modules
3. Sealed volume before berthing and sealed interface after berthing
4. Utilities interface connections for electrical power, data transfer, environmental control, water, and gases
5. Crew and cargo transfer

The berthing trade tree of key berthing interface elements is shown below:



5.1 BERTHING/DOCKING

Two methods of assembling the space station were investigated: berthing and docking. In berthing, a manipulator is employed to bring the elements together slowly, thus requiring a minimum of attenuation. Docking is making direct contact or flying the elements together. The initial impact velocity and alignment parameters for berthing and docking are listed below:

Parameter	Berthing	Docking
Centerline miss distance (inches)	2.0	5.0
Miss angle (degrees)	1.0	4.0
Longitudinal velocity (feet per second)	0.05	0.50
Lateral velocity (feet per second)	0.05	0.30
Angular velocity (degrees per second)	0.10	0.50

Interface load is a function of closing velocity between modules. The variation of load with closing velocity is estimated using the axial stiffness characteristics of the structural shells. The capability of the modules to withstand loads without buckling failure of the structural shell is shown in Figure A5-1 for both pressurized and unpressurized conditions. These allowables are estimated based on a misaligned operation that introduces the load over a localized region of the interface. From Figure A5-1 it is seen that the velocities that will induce loadings equal to the structural capability are 0.095 fps and 0.235 fps for an unpressurized and pressurized common module, respectively, and 0.18 fps and 0.355 fps for the core module. All of these velocity capabilities are well above the 0.05 fps initial berthing impact condition and, therefore, an active attenuation system is not required for berthing. Although a berthing concept is incorporated into the modular space station preliminary design, adequate space has been provided at each berthing port to accept an adapter and active attenuation system that will absorb the higher energy levels associated with direct docking velocities.

5.2 ALIGNMENT WEDGES

The active berthing port has alignment wedges and guides and the passive port has guides only. The alignment wedges act as fingers spaced and tapered so that an identical approaching ring's alignment guide will mesh with it. The intermeshing tapered wedges and guides provide radial and angular indexing capability. The wedges and guides also provide final alignment and shear capability.

The trade study evaluated wedge lead, wedges inside or outside the pressure shell, and pressure shell diameter in the berthing port area and their influence on core module pressure shell diameter. The wedge lead must accommodate the centerline miss distance for the initial impact alignment conditions. The miss distance for berthing is 2 inches and for docking is 5 inches. Figures A5-2 and A5-3

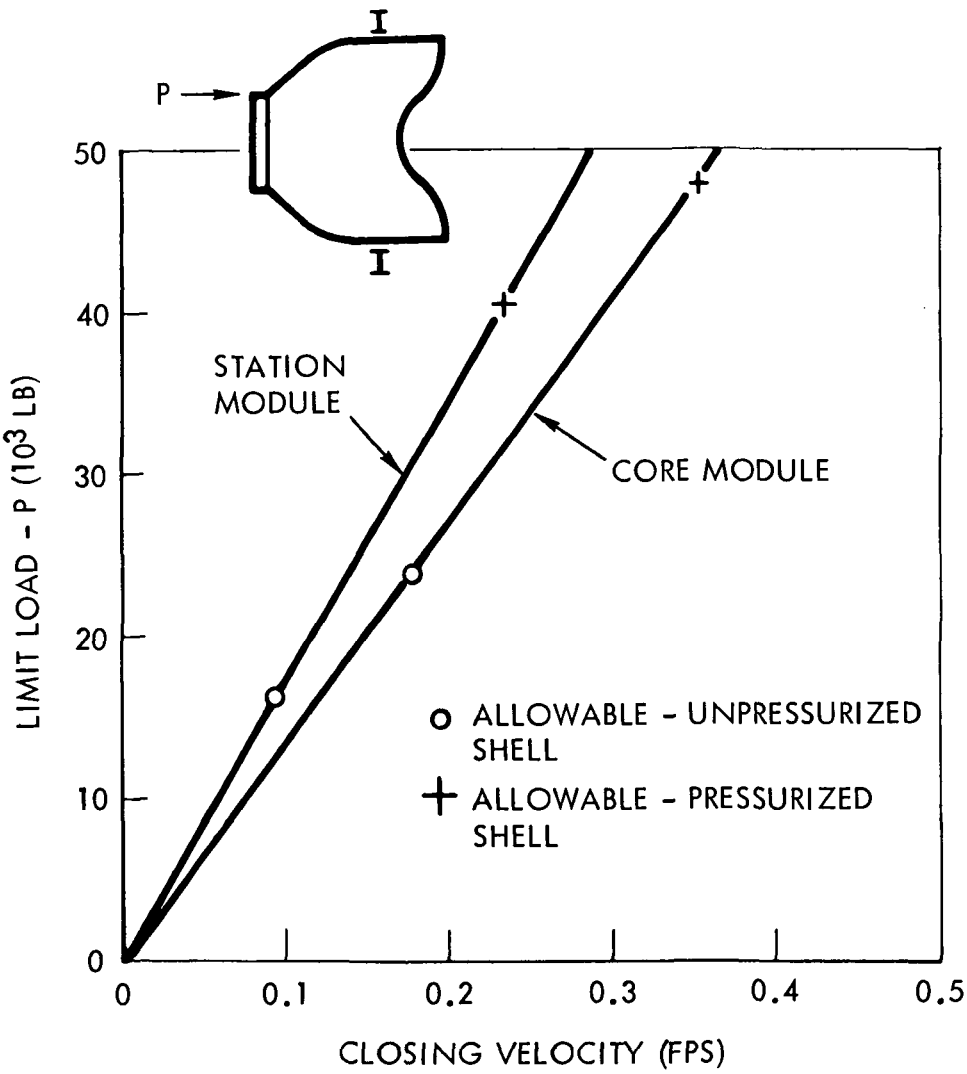


Figure A.5-1. Load Vs Closing Velocity

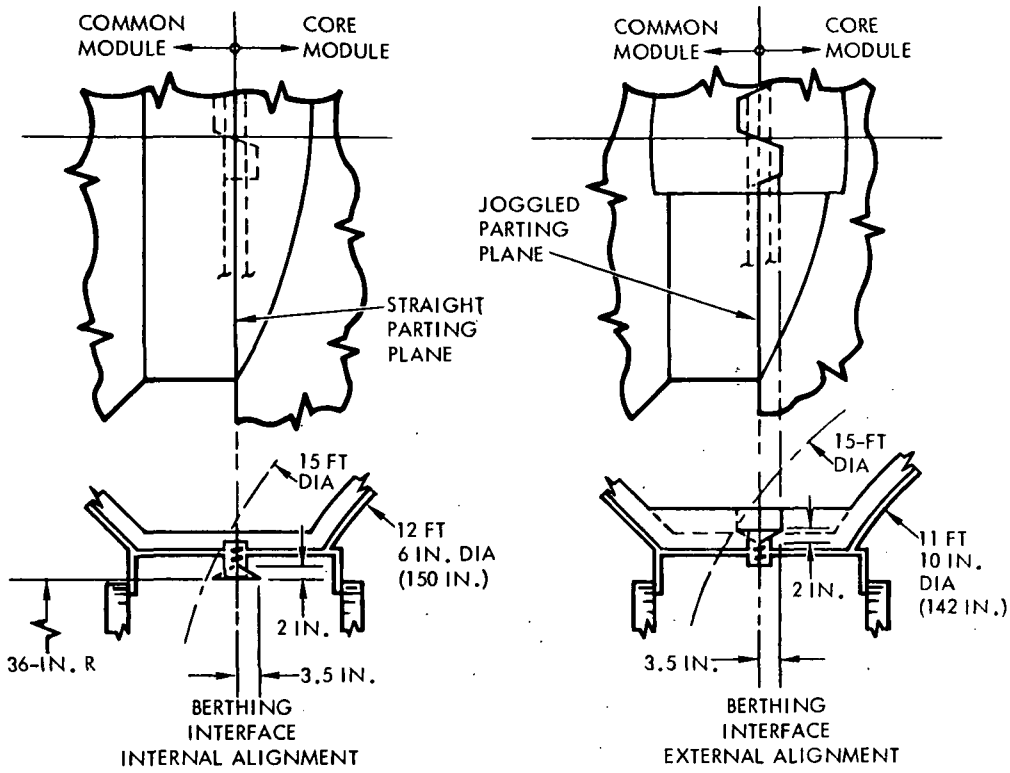


Figure A.5-2. Alignment Wedges ±2-Inch Centerline Misalignment

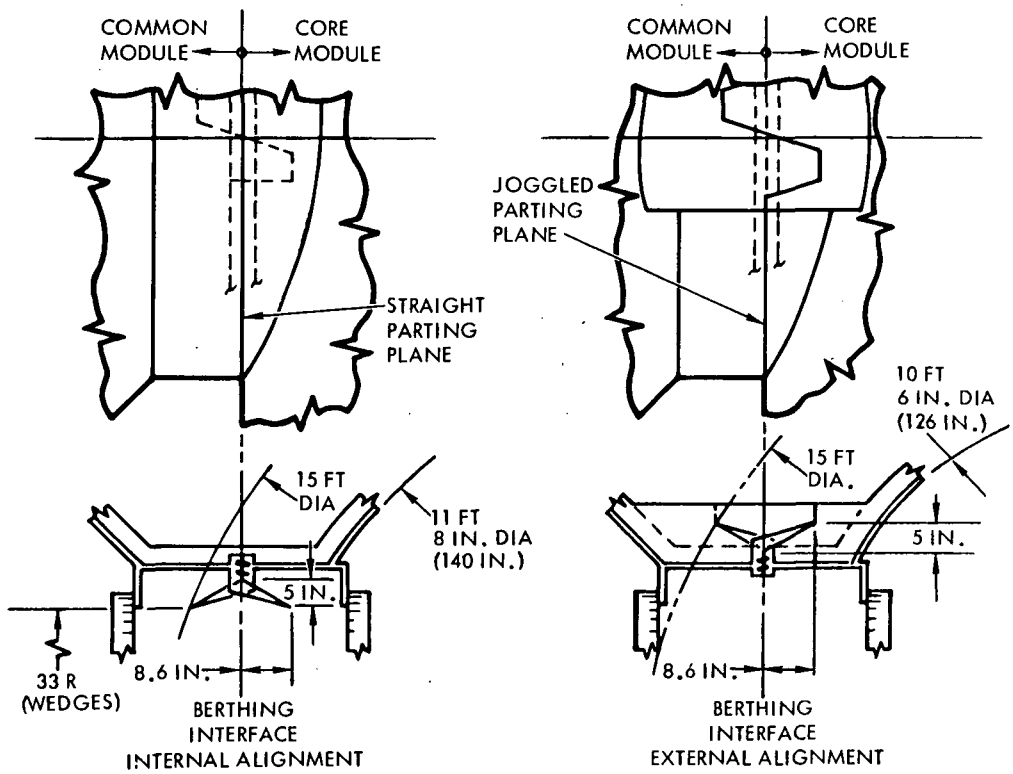


Figure A.5-3. Alignment Wedges ±5-Inch Centerline Misalignment

show the effects of internal and external wedges on the core module pressure shell diameter for a pressure shell diameter of 80 inches in the berthing port vestibule area. As shown in Figures A5-2 and A5-3, the alignment wedge or flat berthing interface ring is constrained by the 15-foot maximum diameter of the shuttle cargo bay. The berthing port vestibule length then determines the maximum diameter of the core module pressure shell.

Table A5-1 shows the study results. The MSS preliminary design incorporates a 5-inch lead internal wedge alignment guide to accommodate direct docking capability and provide the maximum core module shell diameter for a 5-inch wedge. The effects of the vestibule diameter is discussed in the Utilities Provisions section of the trade study.

Table A5-1. Core Module Inside Diameter

Port Configuration		Core Module Inside Diameter (inches)	
Vestibule Diameter (inches)	Wedge Lead (inches)	Wedges Inside	Wedges Outside
80	5	144	126
90	5	138	122
80	2	150	142
90	2	146	136

5.3 LATCHES AND SEALS

The latches provide for the capture and attachment of the modules into an integrated space station. The seals provide a sealed interface after berthing to effort a shirtsleeve environment for crewman or cargo transport and to meet the station leakage requirements. The number of latches is determined by the ultimate internal pressure condition and the diameter of the interface vestibule area. For an 80-inch diameter vestibule, 12 latches are required and for a 90-inch diameter vestibule, 16 latches are required. Dual seals at the interface provide redundancy. The latches and seals are located on the active port of the station modules. The core module utilizes passive ports and, therefore, does not have latches or seals. This is because the station modules are exposed to the space environment for only a short period of time before berthing. The seals are the only component of the berthing system that are not accessible in a shirtsleeve environment and if degraded, may be replaced on earth after the return of a station module.

5.4 UTILITY PROVISIONS

The number and size of utilities that must be connected between modules actually sizes the pressure shell in the berthing port vestibule area. Since connection of the umbilicals is made in a shirtsleeve environment, the utilities must fit in the area between the structural pressure shell and the hatch opening. Previous studies indicated that an 80-inch diameter pressure shell and 64- by 70-inch oval hatch do not accommodate the required utilities. This study is to define the berthing port utilities interface.

The berthing interface criteria used for this study are as follows:

1. Hazardous fluid and gas lines will be double walled and vented, and will be barried or physically separated from power wires and each other. Gaseous oxygen is considered hazardous in the interface areas.

2. GH_2 and GO_2 will be barried or separated by a minimum of 45 degrees.

3. Redundant connectors will be separated a minimum of 45 degrees as a goal.

4. Redundant fluid and gas lines will be separated a minimum of 45 degrees.

5. EMC and EMI standards will be met.

6. Cargo and RAM core module berthing ports will be standard.

7. All core module X-axis berthing ports will be standard as a goal.

8. Station module berthing ports will be standard as a goal.

9. Each core module berthing port will be capable of mating with any module.

10. Each core module berthing port will be capable of supporting any module with basic utilities (air, power, cooling, and communications).

Table A5-2 shows the ducting and plumbing utilities required at the interface of each module. Table A5-3 shows the electrical signal and power requirements at the berthing interface. The 690 square inches for electrical signal and power are required at the interface bulkhead only because the bulkhead contains the large interface connections and umbilicals. The cross-sectional area for the electrical/signal wires at the port interface is only 354 square inches. Wire bundles only, no connections, pass between the berthing port bulkheads and across the interface.

Table A5-2. Ducting and Plumbing Utilities

Item No.	Interface	MODULE						Line or Duct Size Inside Dim.
		Core	Power	Crew 1 & 2	Control 1 & 2	RAM 1 & 2	Cargo	
1	Freon Supply	2		2	2			1
	Freon Return	2		2	2			1
2	H_2 Supply Line Gas	2	2	1	1	TBD	2	3/8
	N_2 Supply Line Gas	2	2	1	1	TBD	2	3/8
	O_2 Supply Line Gas	2	2	1	1	TBD	2	3/8
3	Cabin Coolant Loop Supply	2	2	2	2	2	2	1
	Cabin Coolant Loop Return	2	2	2	2	2	2	1
4P	Potable Water Supply	1		1	1	1	1*	1/2
4W	Waste Water Return	2	1	1	1	1		1/2
5	Air Process Ducts for CO_2 & Contamination Removal & Humidity Control	1	1	1	1	1	1	9
	Air Process Duct Return	1	1	1	1	1	1	9
6	H_2 Supply Line Cryo	2	2			TBD	2	3/8
	N_2 Supply Line Cryo	2	2			TBD	2	3/8
	O_2 Supply Line Cryo	2	2			TBD	2	3/8
7	Module Air Conservation System							
	H/P Supply	1				1		3/8
	Low Press Return	1				1		4

2 = Interface to be determined by heat rejection loop arrangement analysis

*Resupply of potable water

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Table A5-3. Electrical/Signal Utilities

	AREA	WIRES	CONNECTORS
POWER BUS			
PRIMARY FEEDERS		*3 WIRES 30 400 Hz	4 POWER
SECONDARY FEEDERS		*5 WIRES 30 400 Hz	10 POWER
SUBSYSTEMS ELECTRICAL	50 IN^2 SHUTTLE		
G/N - RCS	640 IN^2		
ECLSS	—		
ISS	690 IN^2 TOTAL		
(AUDIO/VIDEO/DIGITAL & ANALOG SIGNALS)			

*WIRES FOR EACH PRIMARY AND SECONDARY POWER BUS CONNECTOR AND NOT TOTAL NUMBER OF WIRES

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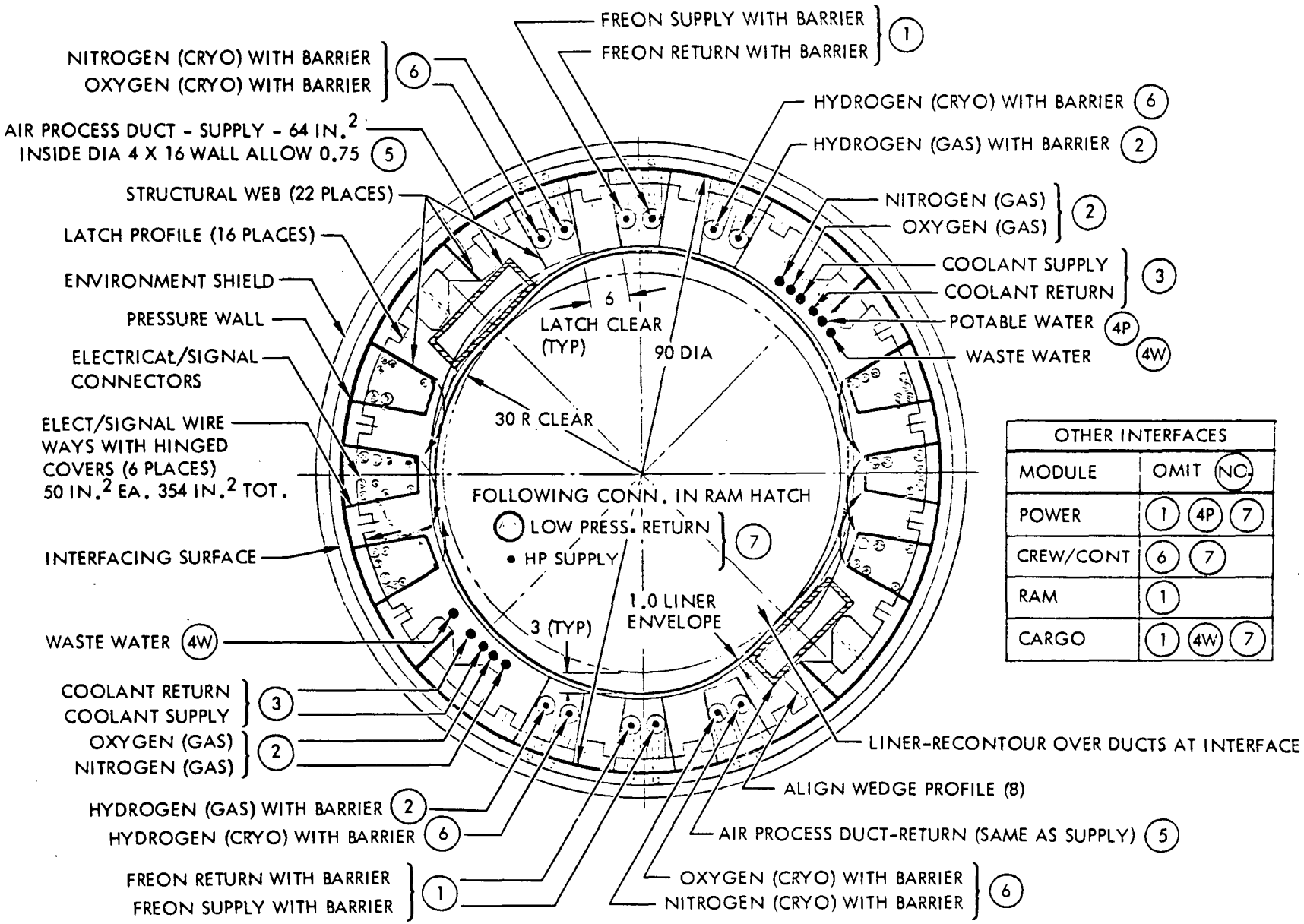
The study determined that a 64- by 70-inch oval hatch with the defined utility sizes required a 90-inch diameter pressure shell in the vestibule area between hatches. Figure A5-4 shows the utility locations at the berthing port interface between hatches. Figure A5-5 shows the utility locations at the berthing port bulkhead, and Figure A5-6 shows berthed station modules to a core module and how the utilities are routed from the bulkheads into the module's secondary structure utility ducts. The hazardous lines are routed between the environmental shield and the pressure shell and vented to space.

The 90-inch diameter vestibule pressure shell was causing problems to the space station core module design. The internal diameter volume restriction was severely restricting the arrangements of the core module subsystem equipment installations, and the core module was exceeding the 20,000-pound target launch weight. A weights comparison of the 80-inch and 90-inch diameter berthing ports made to determine the penalties is summarized in Table A5-4. The core module for the station configuration studied has two end ports and six side ports. The 90-inch diameter pressure shell opening weighs 992 pounds more than the 80-inch diameter shell. In addition, the structural stiffness of the 90-inch ring is less than the 80-inch ring and the pressure integrity of the 90-inch ring is less because of the larger interface load on the latches and the seal length.

To keep the 80-inch diameter vestibule pressure shell, the size of the hatch opening has to change to accommodate the utilities provisions. Instead of decreasing the diameter of the oval hatch, a rectangular hatch was investigated. Figures A5-7 and A5-8 show the berthing interface and the berthing bulkhead utilities interfaces, respectively, for the rectangular 42- by 66-inch hatch opening.

The conceptual design was changed from providing a five-foot nominal diameter opening to a nominal opening of five feet; primary access routes will accommodate package sizes of 40 by 40 by 50 inches.

ALL MEASUREMENTS ARE IN INCHES



OTHER INTERFACES	
MODULE	OMIT (NC.)
POWER	(1) (4P) (7)
CREW/CONT	(6) (7)
RAM	(1)
CARGO	(1) (4W) (7)

Figure A.5-4. Berthing Port Interfaces - Standard Utilities - Core Module

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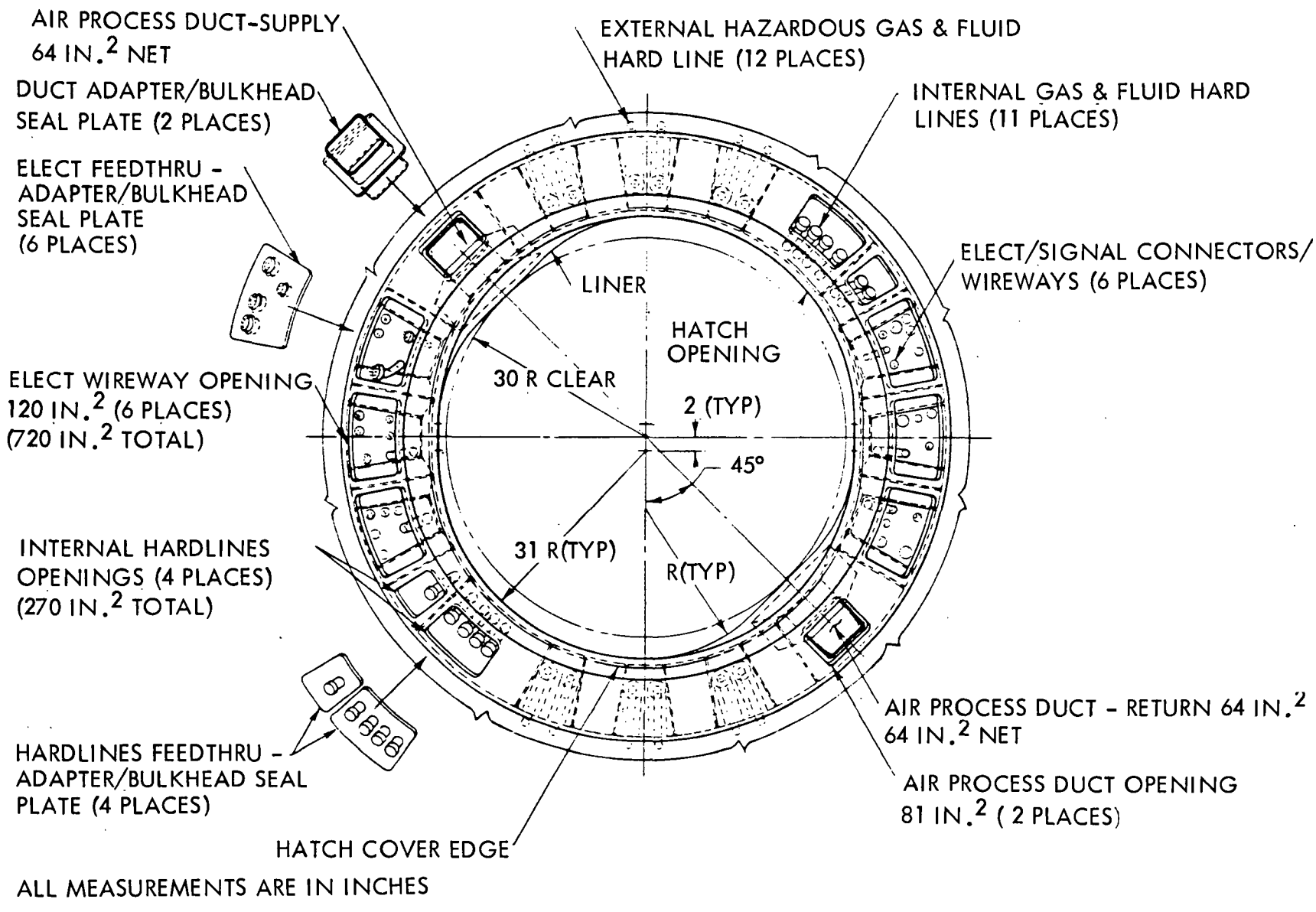
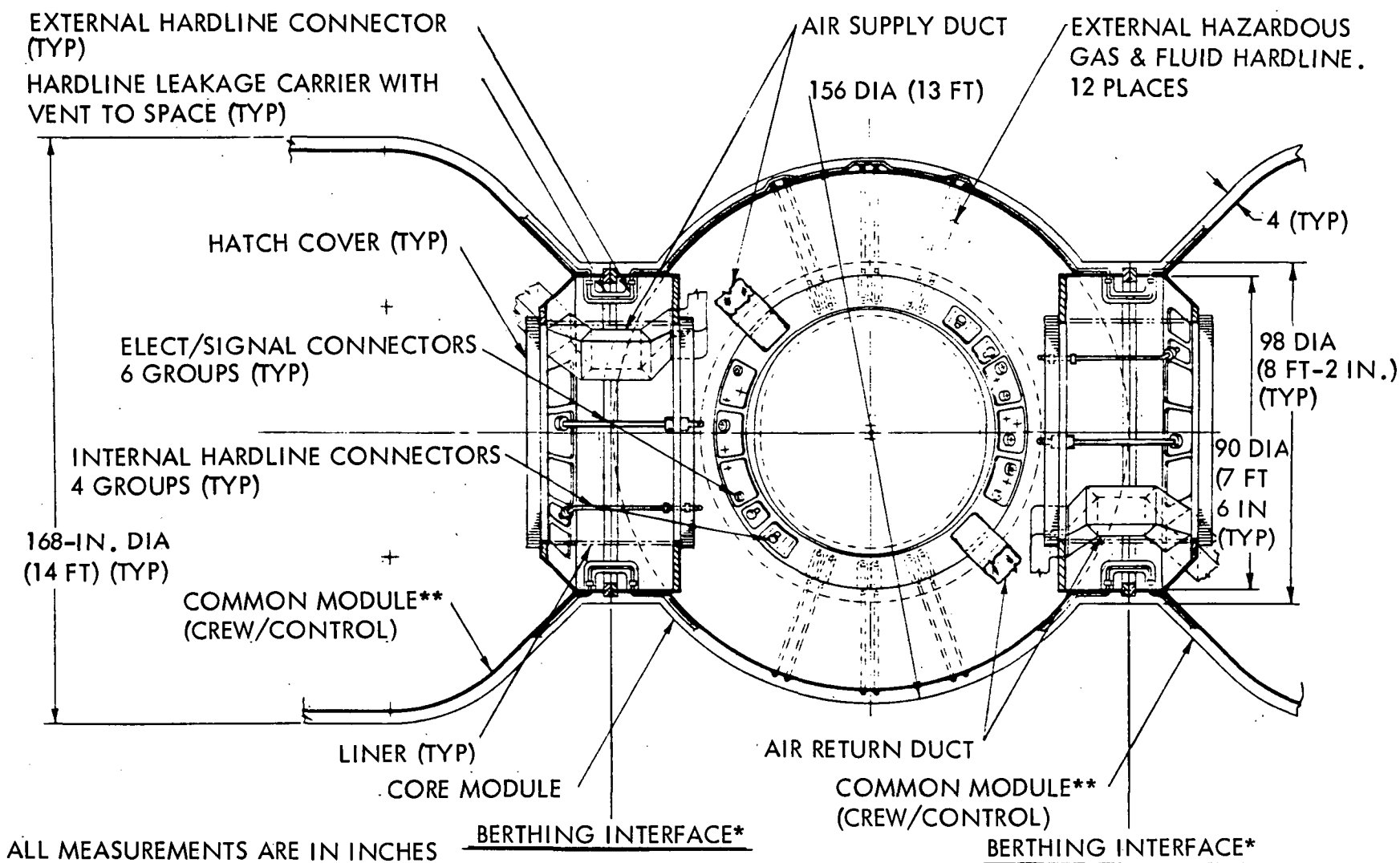


Figure A.5-5. Berthing Port Bulkhead - Standard Utilities - Core Module

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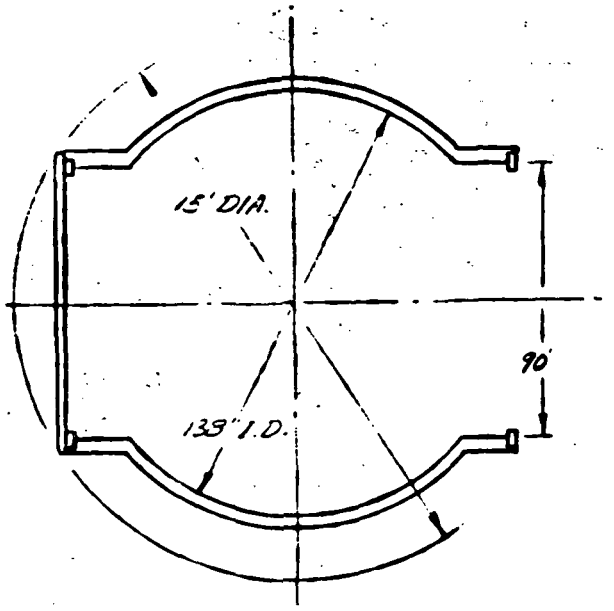
ALL MEASUREMENTS ARE IN INCHES

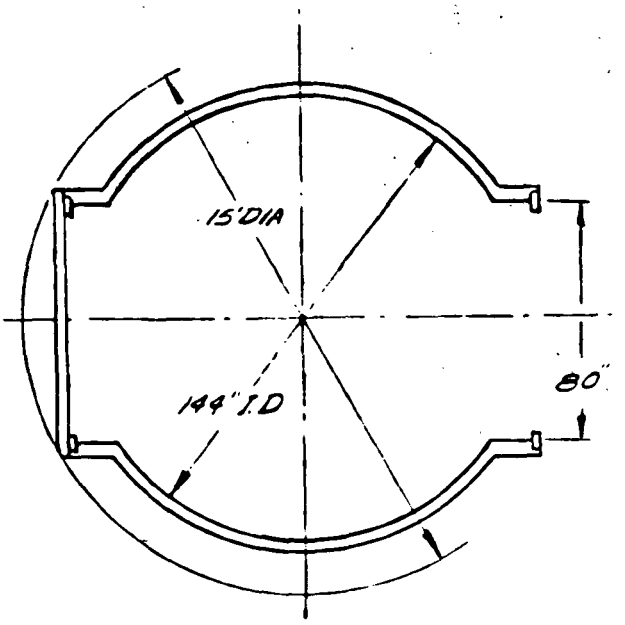
*DETAIL OMITTED: STRUCT. WEBS; WIREWAYS; LATCHES; ALIGNMNET WEDGES

**UTILITIES NOT REQD: CRYOGENIC H_2, O_2, N_2 & AIR CONSERVATION SYSTEM

Figure A.5-6. Berthed Core/Common Modules

Table A5-4. Core Module Comparison





BERTHING WEIGHTS

(pounds)

ITEMS	BERTHING PORTS 90" DIA.		BERTHING PORTS 80" DIA.	
	END PORT	SIDE PORT	END PORT	SIDE PORT
MATING RING	108	108	97	97
TUNNEL	42	98	38	82
SEALS	6	6	5	5
CONE	-	-	-	-
UTILITY LINER	20	36	20	34
ATTENUATORS/RETRACTORS	-	-	-	-
LATCHES	20	20	18	18
CAPTURE LATCHES	-	-	-	-
HARDWARE & MISCELLANEOUS	14	17	12	14
HATCH BULKHEAD	150	135	104	104
DOCKING HATCH	180	180	136	136
ENVIRONMENTAL PROTECTION COVER	60	60	46	46
Total	600	660	476	536

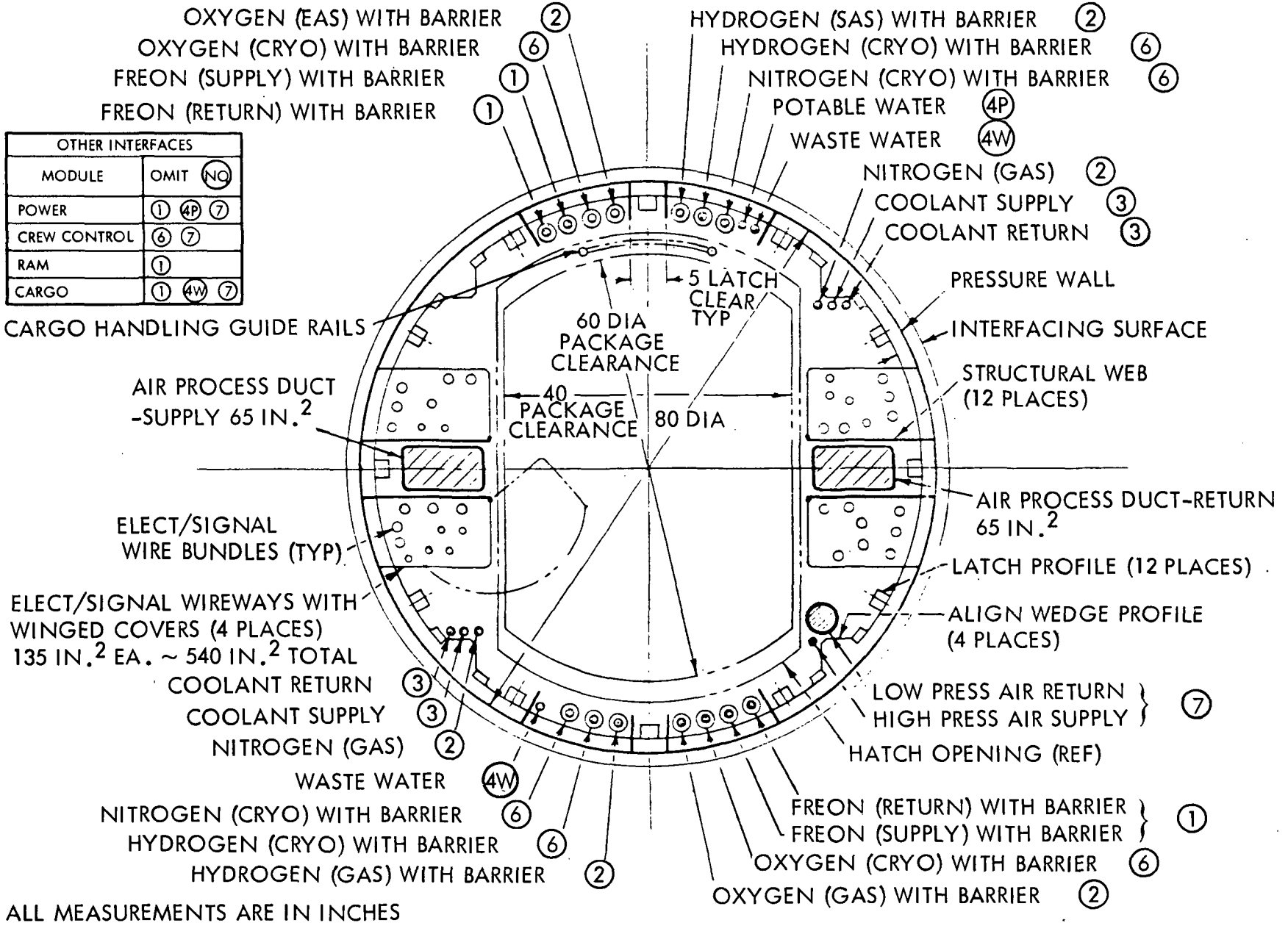


Figure A.5-7. Reduced Opening - Berthing Port Interfaces

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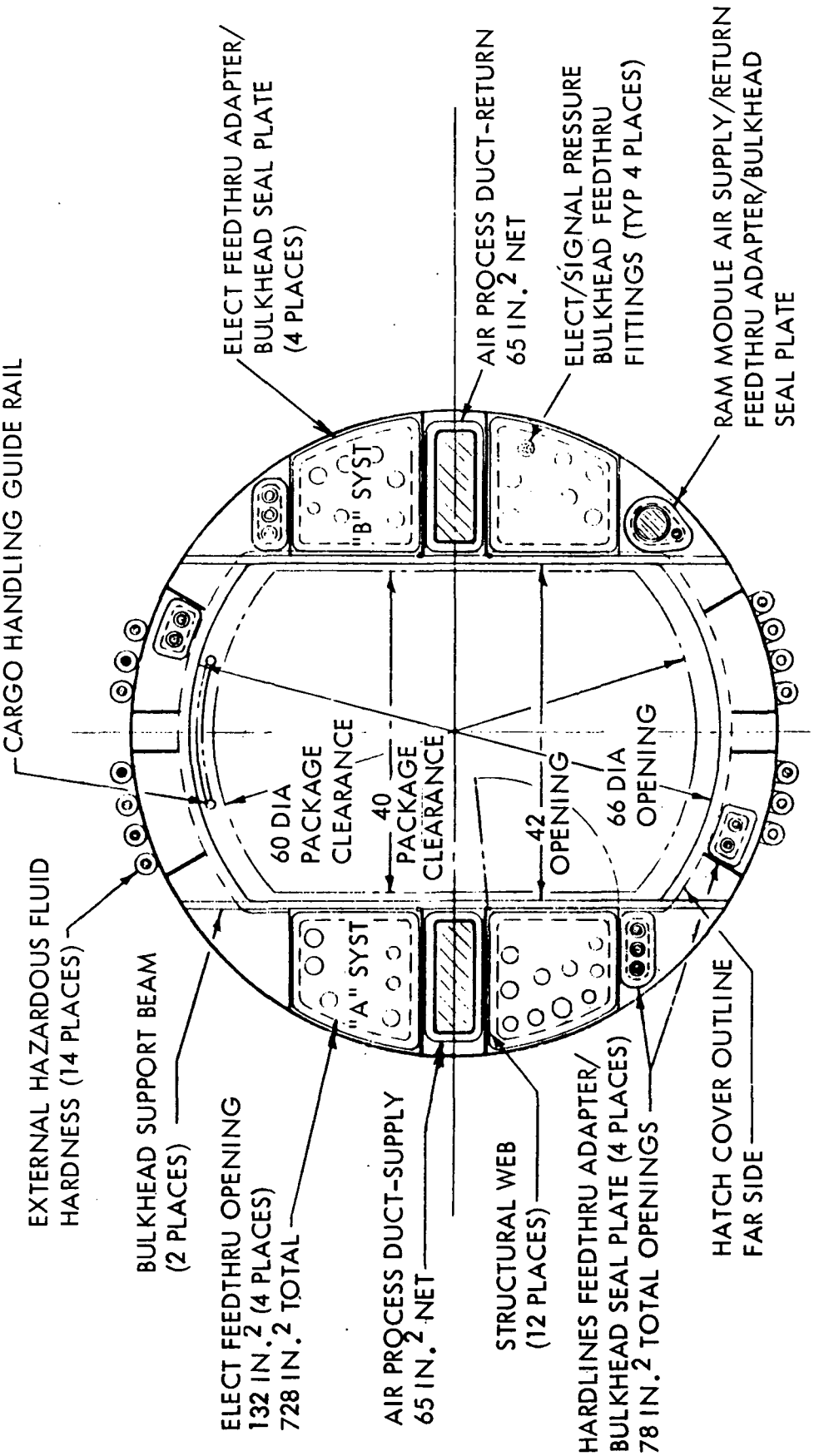


Figure A.5-8. Reduced Opening - Berthing Port Bulkhead

6. MODULE DIAMETER

The module diameter trade study was conducted to determine the volume utilization efficiency of each diameter and is evaluated based on the following guidelines:

1. The most efficient use of the module volume
2. Accessibility to equipment for maintenance, repair, and replacement
3. Installation access of utilities
4. Effective crew and cargo transfer passageways
5. Accessibility to the pressure shell
6. Equipment location

The scope of the study is to determine the length of the modules and the number of core and common modules for the 6-man initial station and the 12-man growth station. Previous studies show that the crew quarters module was the most difficult for internal arrangements and was the longest module; therefore, this study utilizes the crew module as the length and diameter driver.

6.1 GROUND RULES

A common set of requirements is used for the module diameter study:

1. 5-foot minimum width of stateroom
2. 30-inch minimum aisle width
3. 80-inch minimum floor-to-ceiling height
4. Use longitudinal floor arrangements
5. 4-inch environmental shield to pressure shell offset
6. 60-foot maximum length of shuttle cargo bay
7. Distributed subsystems concept

Four internal arrangement configurations are evaluated for the crew quarters module. Configuration 1 has staterooms for a full crew of six men, dual hygiene facilities, and a six-man environmental control and life support subsystem (ECLSS). Configuration 2 has staterooms for a split crew of three

men, dual hygiene facilities, and a six-man ECLSS. Configuration 3 has staterooms for six crewmen only and Configuration 4 has staterooms for three crewmen only. All four configurations are studied for module diameters of 9 feet through 13 feet. Fourteen- and fifteen-foot diameter modules are studied for Configurations 1 and 2 only, because module length is not critical with all the storage volume available below deck.

6.2 DESCRIPTION

Module cross sections are shown in Figures A6-1 and A6-2, which define the utility run areas, aisle locations, system equipment locations, and crew stateroom dimensions. The module cross sections and the equipment requirements of the dual hygiene and six-man ECLSS layouts determine the module lengths. Table A6-1 summarizes the module lengths for the four configurations and seven module diameters. Module lengths greater than 60 feet are rejected and omitted from further study because they are too long to fit into the shuttle cargo bay.

Figures A6-3 and A6-4 show the typical internal arrangements of the smaller diameter modules. The modules tend to look like railroad pullman cars with side aisles, compartments, and rest rooms. Figures A6-5 and A6-6 show the internal arrangements of the 14-foot diameter module. These arrangements are also typical for the 15-foot diameter module. The six-man, 14-foot diameter arrangement shows the center access tunnel from below the floor to the crew staterooms. The three-man arrangement shows a three-foot corridor along the floor to provide access to the staterooms.

6.3 SUMMARY

Figure A6-7 summarizes the number of modules for each of the study module diameters. The number of core modules and station modules required for station operations is shown for both the 6-man initial station and the 12-man growth station.

Nine-foot Through Eleven-foot-diameter Modules

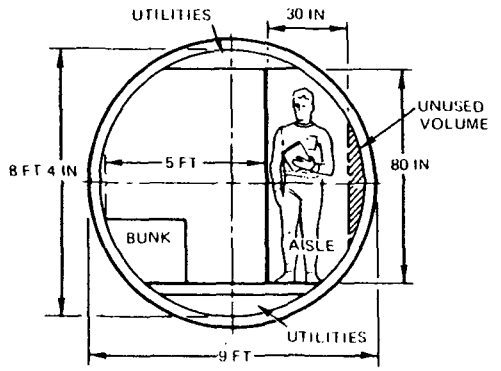
These modules require excessive length and large numbers of modules to achieve the initial and growth station requirements. All equipment is mounted on the floor as there is no area available below the floor. The equipment and dual-hygiene facilities are located in modules other than the crew quarters module; therefore, the equipment is accessible for removal and replacement and noisy equipment is not located in the crew modules.

Twelve-foot-diameter Module

The area below the floor is restrictive for system equipment locations and access. Floor access panels are required for maintenance and removal, room partitions must also be removed. The equipment is located below and adjacent to staterooms.

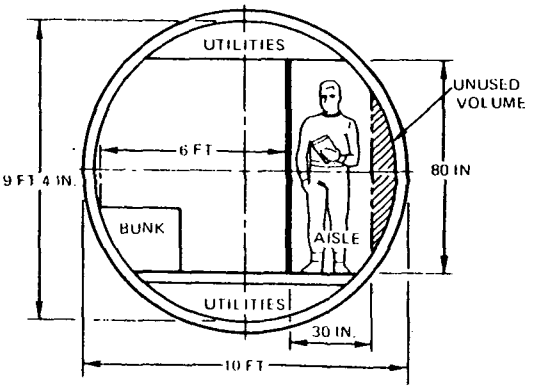
9-FT-DIAMETER MODULE

- GOOD UTILIZATION OF VOLUME
- QUESTIONABLE UTILITY PROVISIONS
- DECK SPACE REQUIRED FOR SYSTEM EQUIPMENT
- CREW STATEROOMS - 5 FT X 10 FT



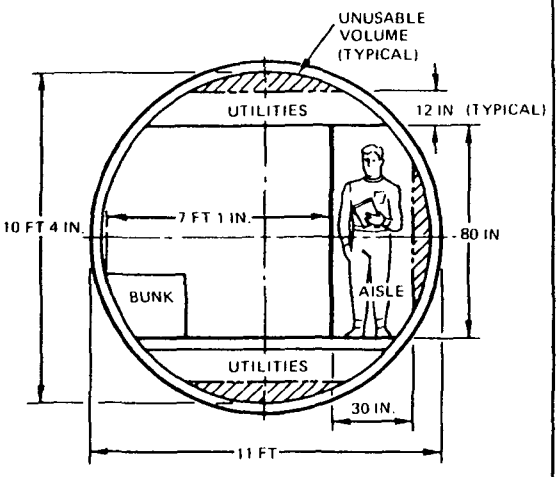
10-FT-DIAMETER MODULE

- GOOD UTILIZATION OF VOLUME
- ADEQUATE UTILITY PROVISIONS
- DECK SPACE REQUIRED FOR SYSTEM EQUIPMENT
- CREW STATEROOMS - 6 FT X 8 FT



11-FT-DIAMETER MODULE

- GOOD UTILIZATION OF VOLUME
- EXCESS UTILITIES PROVISIONS
- DECK SPACE REQUIRED FOR SYSTEM EQUIPMENT
- CREW STATEROOMS - 7 FT X 7 FT



12-FT-DIAMETER MODULE

- POOR UTILIZATION OF VOLUME
- ADEQUATE UTILITIES PROVISIONS
- LIMITED USE & RESTRICTED ACCESS TO BELOW DECK STORAGE VOLUME
- CREW STATEROOMS - 6 FT 9 IN. X 7 FT 5 IN.

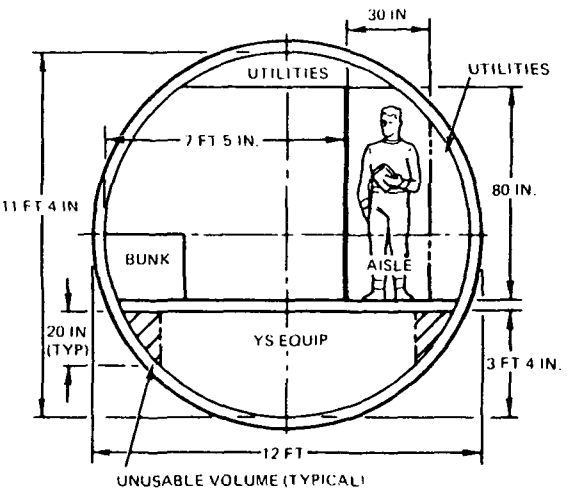


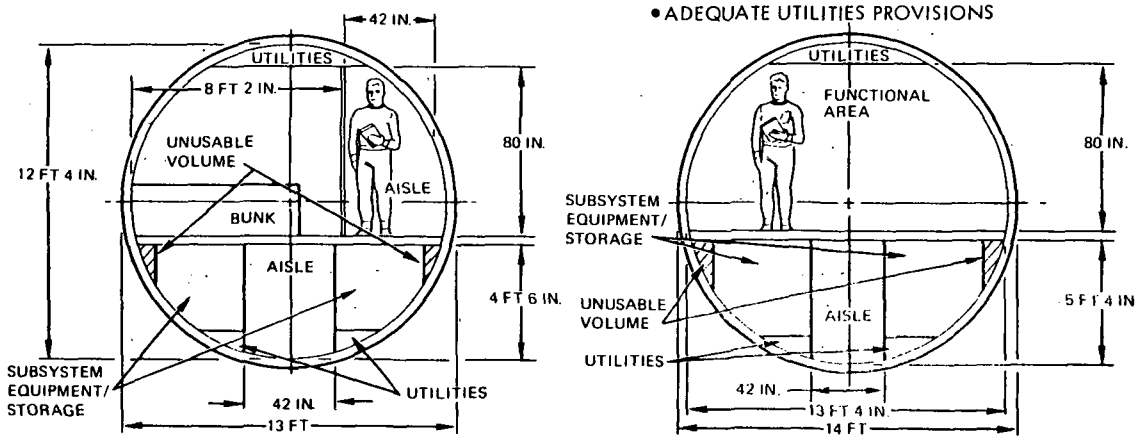
Figure A.6-1. Module Diameters Evaluated

13-FT-DIAMETER

- GOOD UTILIZATION OF VOLUME
- ADEQUATE UTILITIES PROVISIONS
- SUBSYSTEM EQUIPMENT & STORAGE AREA
  - SUFFICIENT DEPTH FOR EQUIPMENT INSTALLATION
  - RESTRICTIVE ACCESS
  - RESTRICTIVE WALL INSPECTION
- CREW STATEROOMS
  - 6 FT 1 IN. X 8 FT 2 IN.

14-FT-DIAMETER

- BETTER UTILIZATION OF VOLUME
- SUBSYSTEM EQUIPMENT & STORAGE AREA
  - SUFFICIENT DEPTH FOR EQUIPMENT INSTALLATION
  - SUFFICIENT EQUIPMENT ACCESS
  - CAPABILITY FOR WALL INSPECTION
- SIDE OR CENTER AISLE WHERE REQUIRED
- STATE ROOMS
  - NO SIZE RESTRICTION
- ADEQUATE UTILITIES PROVISIONS



15-FT-DIAMETER

- EXCELLENT UTILIZATION OF VOLUME
- LOWER DECK VOLUME
  - SUFFICIENT DEPTH FOR FUNCTIONAL UTILIZATION
  - ACCESS FOR WALL INSPECTION
- SIDE OR CENTER AISLE WHERE REQUIRED
- STATEROOMS
  - NO SIZE RESTRICTION
- ADEQUATE UTILITIES PROVISIONS

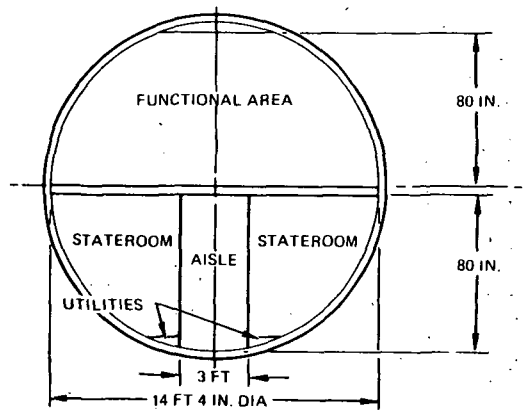


Figure A.6-2. Module Diameters Evaluated

Table A6-1. Module Diameter Evaluation

Module Diameter (Ft)	Module Length (Ft)			
	Configuration 1 Distributed Subsystem 6 Staterooms	Configuration 2 Distributed Subsystem 3 Staterooms	Configuration 3 Crew Quarters Only 6 Staterooms	Configuration 4 Crew Quarters Only 3 Staterooms
9	122	87	72	41
10	102	73	64	37
11	86	64	54	32
12	67	44	52	31
13	58	39	41	24
14	36	34	--	--
15	34	34	--	--

Modules in Excess of 60 Feet

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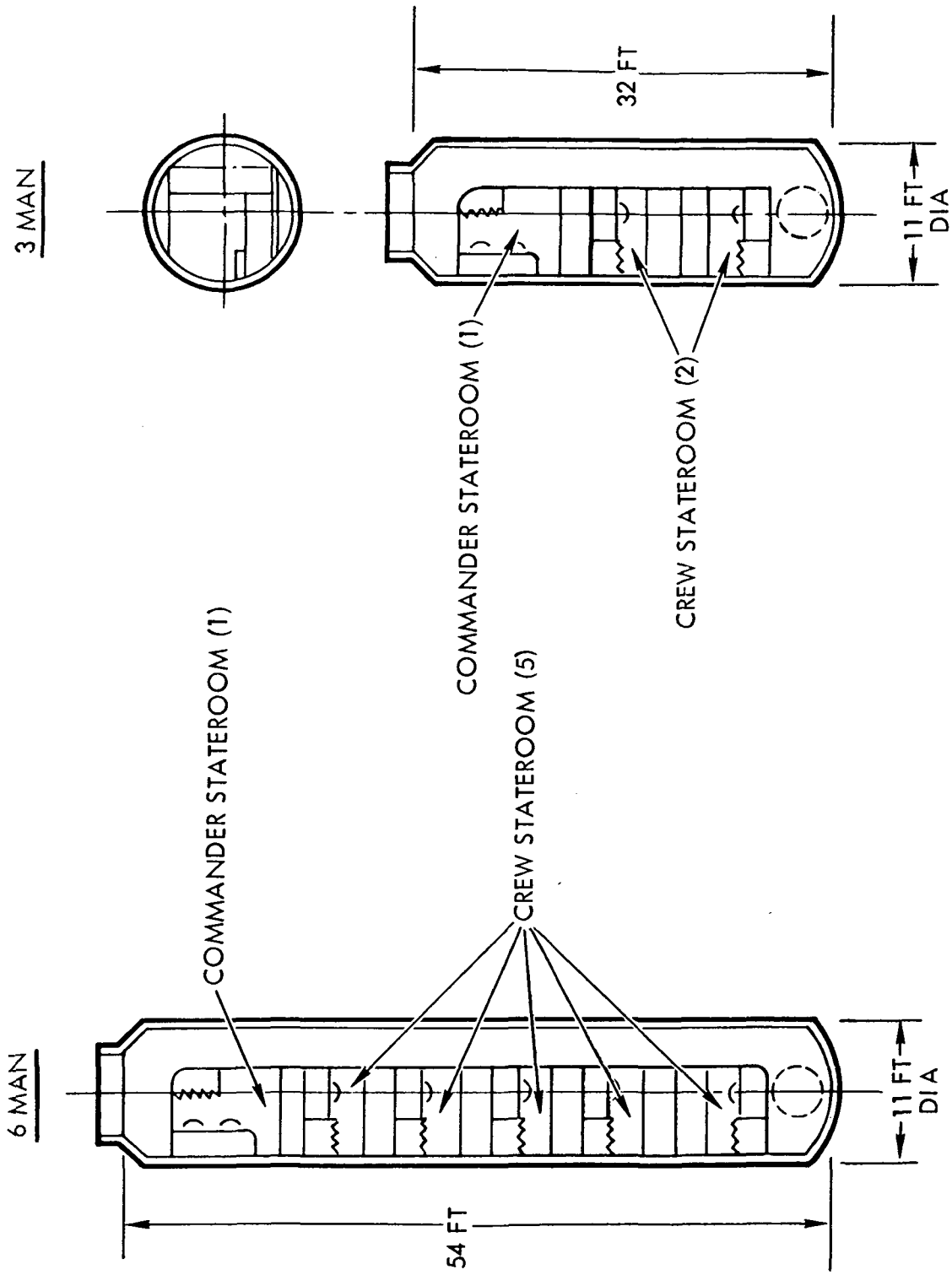


Figure A.6-3. 11-Foot-Diameter Module

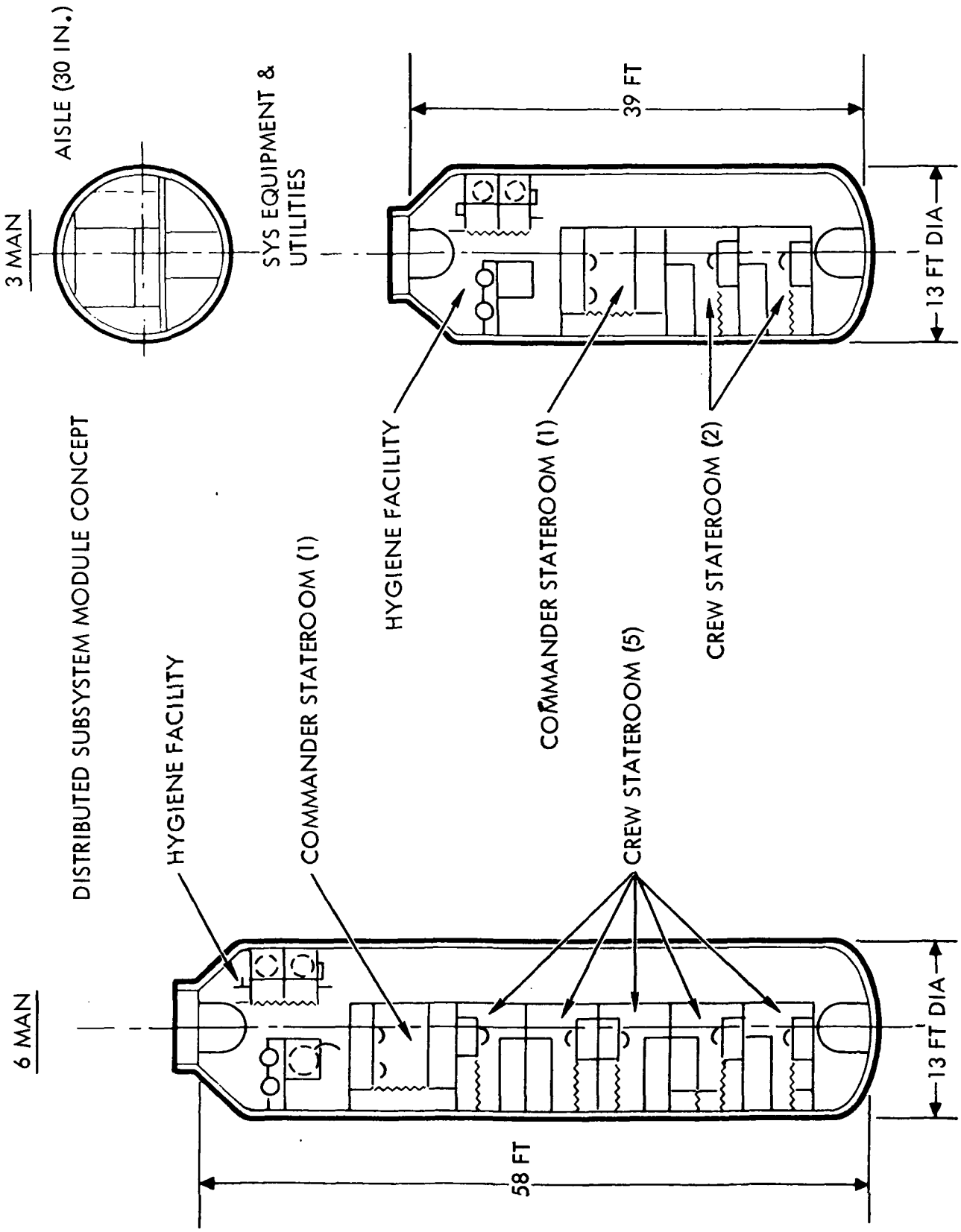
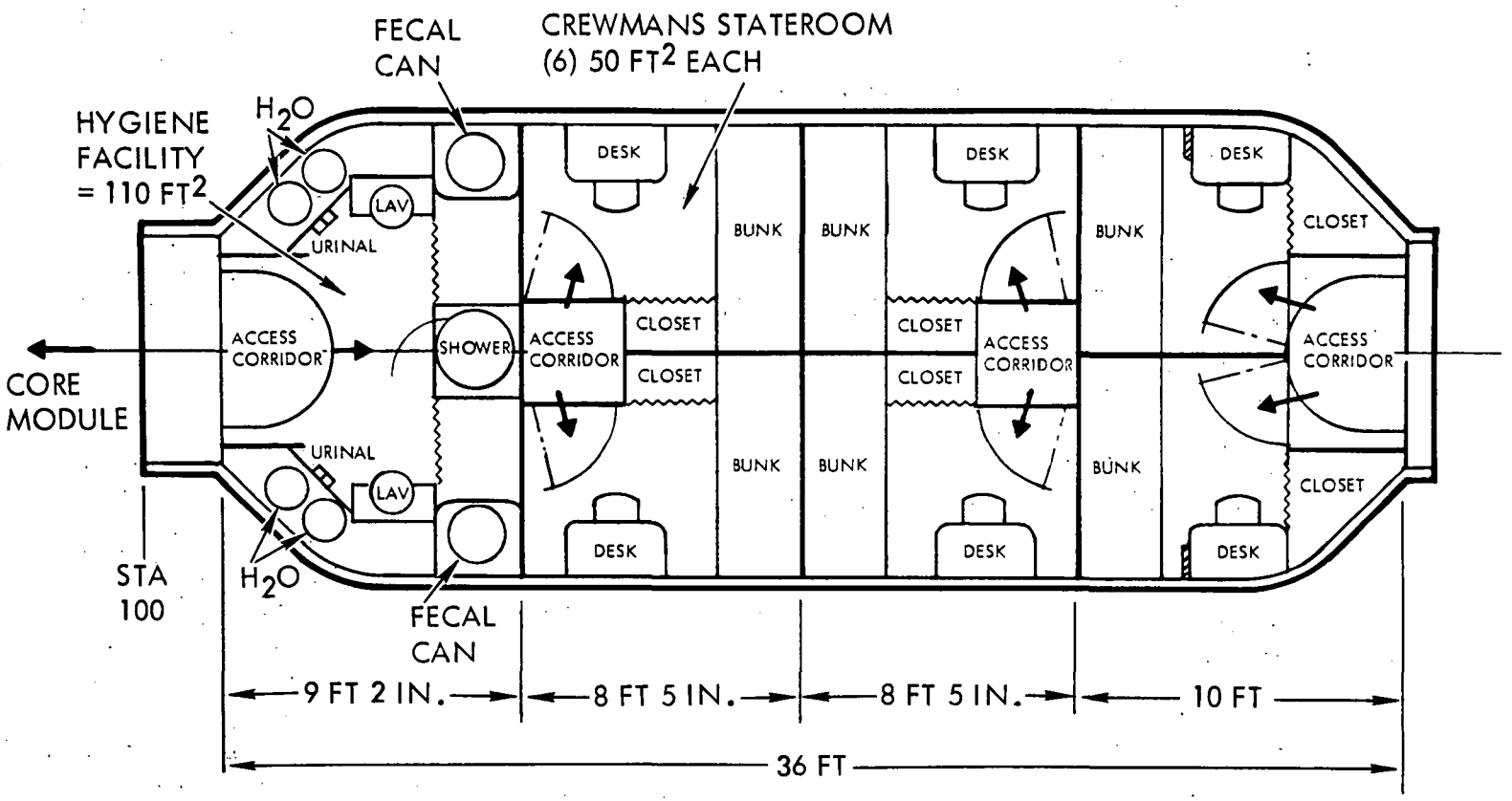


Figure A.6-4. 13-Foot-Diameter Module

DISTRIBUTED SUBSYSTEM MODULE CONCEPT

(6) CREWMANS STATEROOMS = 300 FT^2
HYGIENE FACILITY = 110 FT^2
CORRIDOR & WALLS = 40 FT^2
TOTAL = 450 FT^2



6-MAN ECLSS (LOCATED IN LOWER STORAGE VOLUME)

Figure A.6-5. 14-Foot-Diameter Module

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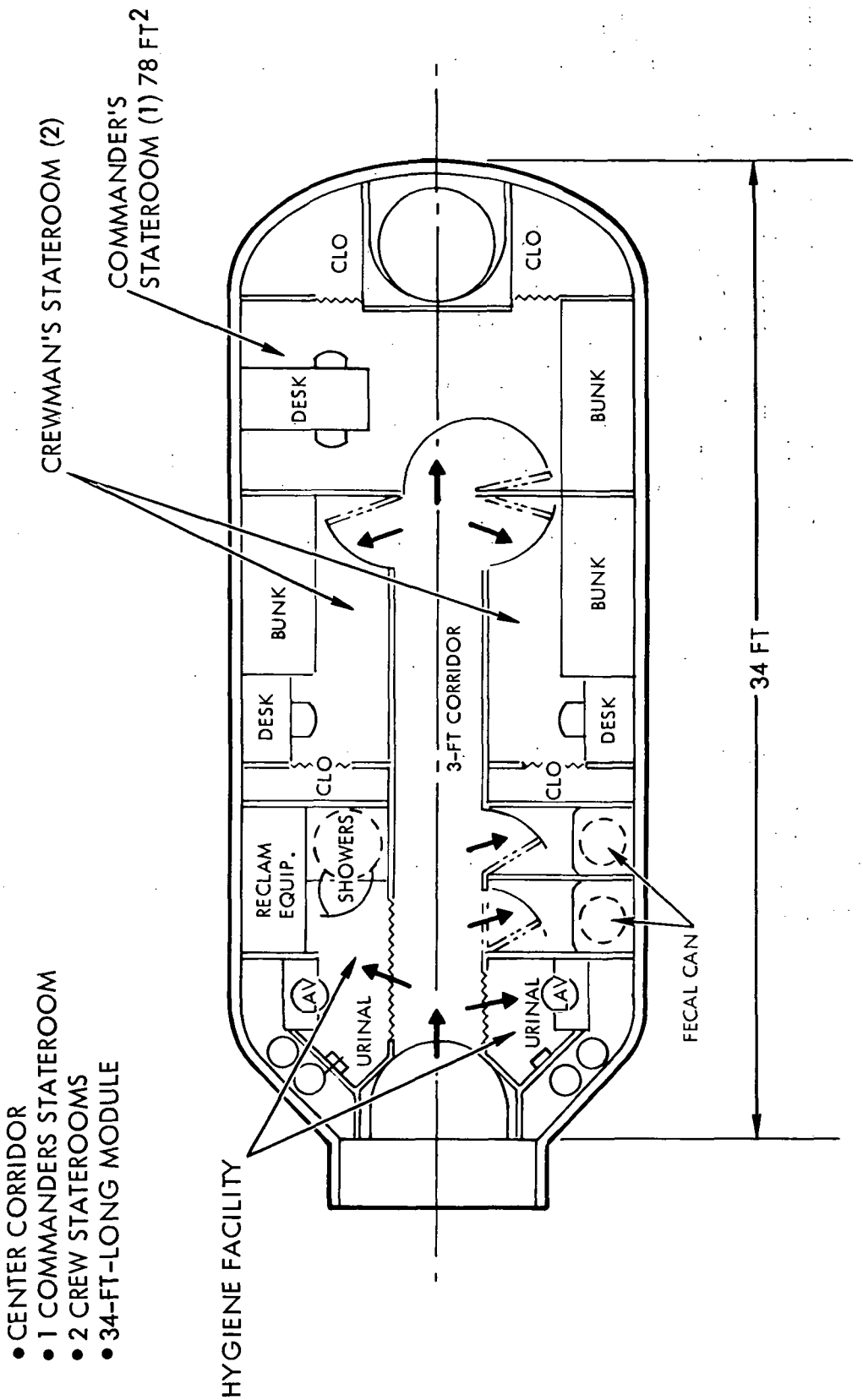


Figure A.6-6. 14-Foot-Diameter Module

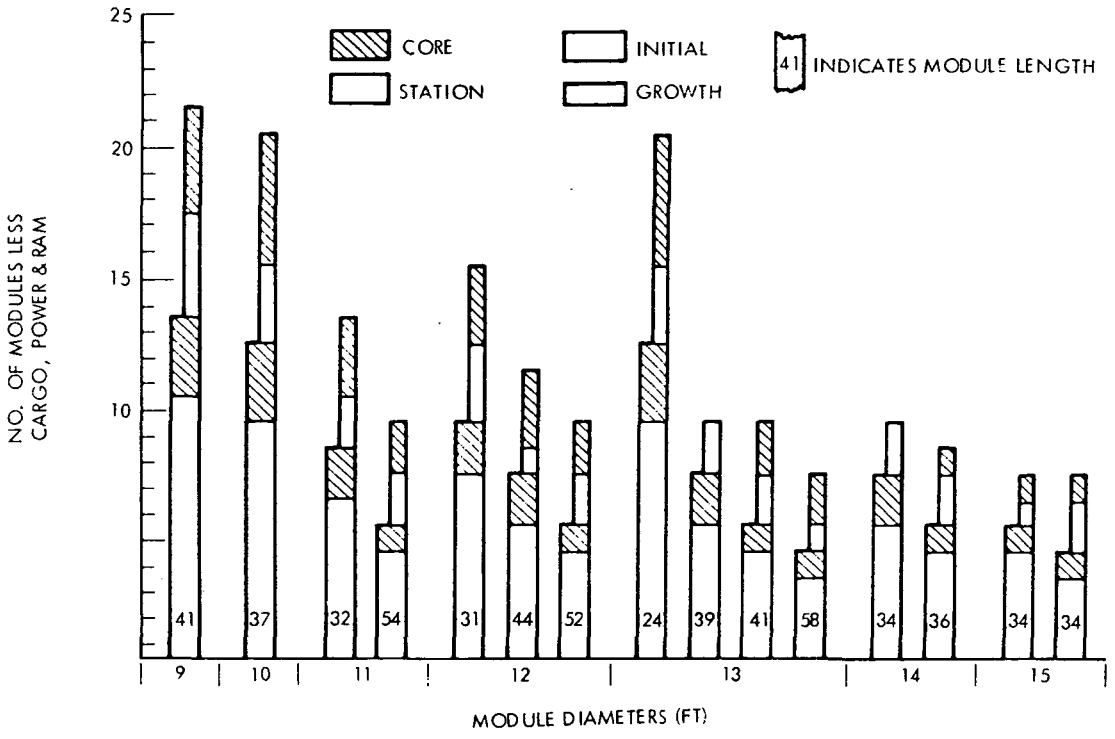


Figure A6-7. Number of Modules Versus Module Diameters

Thirteen-foot Through Fifteen-foot-diameter Modules

These diameters require fewer modules for the initial and growth station and provide good use of volume above and below the floor. System equipment is below deck, adjacent to the staterooms, and is accessible from the center aisle below the floor. The excess volume provides for growth capability and flexibility of functional groupings in modules.

7. STATION STIFFNESS

Modal analysis studies of the initial MSS cruciform configuration were performed to determine the following information:

1. The natural frequency characteristics of the initial station and methods of increasing the lower modes to approach a minimum natural frequency of 1.0 Hz required for guidance and navigation purposes.

2. Whether or not coupling exists between solar arrays and station modules.

7.1 STATION NATURAL FREQUENCY

To perform these tasks, extensive use was made of the modal analysis routine of the NR MAR-3D (Modal Analysis and Response - Three Dimensional) computer program.

Figure A7-1 shows the initial station geometry used to generate the dynamic model for the modal analysis performed for task 1 above. For modeling purposes, the mass of each module (core, station, power, RAM, and cargo) was considered concentrated at the module centroid. The elastic characteristics of the solar panels were not considered. However, the inertia properties of the fully deployed solar panels were incorporated into the power module (joint 11 of Figure A7-1). Joint coordinates and inertia properties of the dynamic model are shown in Table A7-1.

Figure A7-2 summarizes the effects on station natural frequency resulting from seven structural modifications that may be incorporated to increase station stiffness. Case 1 represents the baseline configuration selected for comparison. The core module and power boom pressure shell for Case 1 are of aluminum skin-stringer construction. Circumferential ring frames on the core module adjacent to the berthing ports stiffen the core module shell at its interfaces to the common modules. The common module pressure shells for all cases are of monocoque construction. The skin thicknesses are 0.040 inch and 0.145 inch for the skin-stringer and monocoque constructions, respectively.

Table A7-2 gives the elastic properties of the structural members used in the dynamic model for Case 1. Line representations of the first and second natural mode shapes of the initial case (Figure A7-3) have frequencies of 0.384 Hz and 0.828 Hz, respectively. The lowest mode is primarily a torsional mode about the X axis. The second mode is largely influenced by the stiffness of the core module stiffening ring frames. The use of internal transverse bulkheads adjacent to the berthing ports, as shown in Case 2 of Figure A7-2, increases the lateral shell stiffness of the core module sufficiently to raise the second mode natural frequency to 1.51 Hz. However, this does not

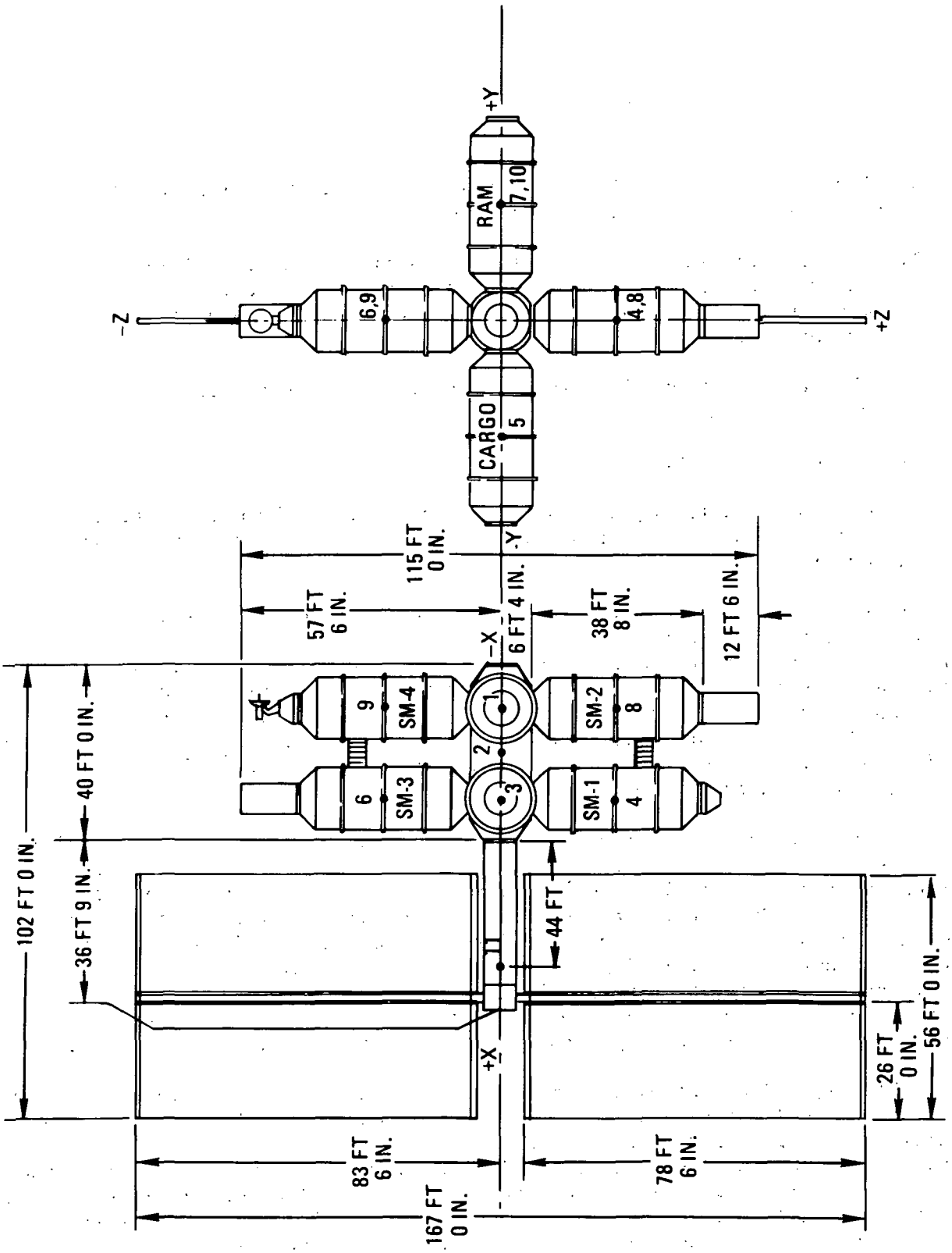


Figure A.7-1. Initial Station Stiffness Study Model

Table A7-1. Cruciform MSS - Initial Configuration Coordinates and Mass Properties

NUMBER OF JOINTS = 11 NUMBER OF MEMBERS= 10 NUMBER OF FORCING FUNCTIONS= 0

JT	X	Y	Z
1	0.0	0.0	0.0
2	120.000	0.0	0.0
3	240.000	0.0	0.0
4	0.0	0.0	308.000
5	0.0	-308.000	0.0
6	0.0	0.0	-308.000
7	0.0	308.000	0.0
8	240.000	0.0	308.000
9	240.000	0.0	-308.000
10	240.000	308.000	0.0
11	648.000	0.0	0.0

JT	M-SUB-X	M-SUB-Y	M-SUB-Z	I-SUB-X	I-SUB-Y	I-SUB-Z
1	0.12500000E 05	0.12500000E 05	0.12500000E 05	0.36100000E 08	0.77900000E 08	0.77900000E 08
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.12500000E 05	0.12500000E 05	0.12500000E 05	0.36000000E 08	0.77900000E 08	0.77900000E 08
4	0.25000000E 05	0.25000000E 05	0.25000000E 05	0.33699994E 09	0.33699994E 09	0.77200000E 08
5	0.25000000E 05	0.25000000E 05	0.25000000E 05	0.33699994E 09	0.77200000E 08	0.33699994E 09
6	0.25000000E 05	0.25000000E 05	0.25000000E 05	0.33699994E 09	0.33699994E 09	0.77200000E 08
7	0.25000000E 05	0.25000000E 05	0.25000000E 05	0.33699994E 09	0.77200000E 08	0.33699994E 09
8	0.25000000E 05	0.25000000E 05	0.25000000E 05	0.33699994E 09	0.33699994E 09	0.77200000E 08
9	0.25000000E 05	0.25000000E 05	0.25000000E 05	0.33699994E 09	0.33699994E 09	0.77200000E 08
10	0.25000000E 05	0.25000000E 05	0.25000000E 05	0.33699994E 09	0.77200000E 08	0.33699994E 09
11	0.20000000E 05	0.20000000E 05	0.20000000E 05	0.16669998E 10	0.15539999E 10	0.13360000E 09

Space Division
North American Rockwell

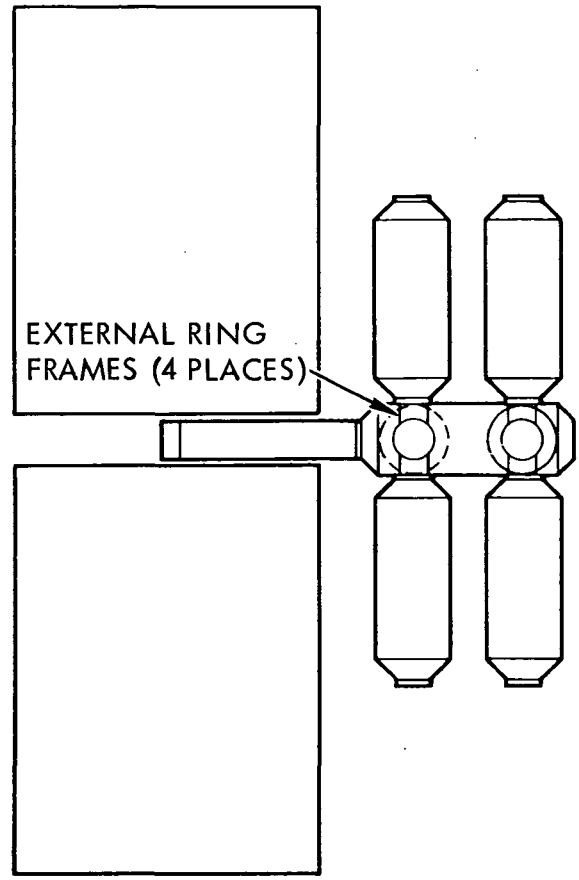
Table A7-2. MSS Initial Case Stiffness Properties

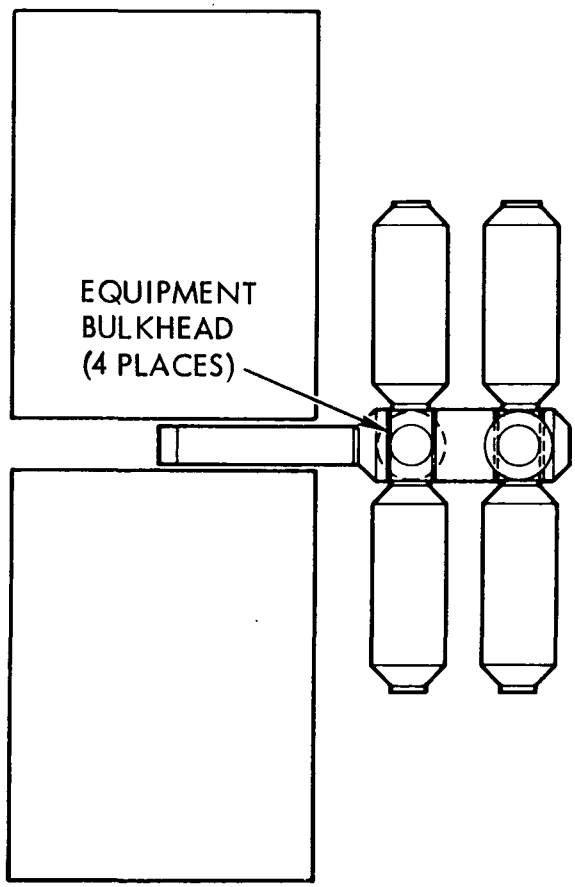
JTN	JTF	AE	EI-SUB-V	EI-SUB-W	K-SUB-U JG	K-SUB-V AG	K-SUB-W AG
1	2	0.29899981E 09	0.77299994E 12	0.77299994E 12	0.37199997E 12	0.72400000E 08	0.72400000E 08
1	4	0.26300000E 09	0.18699990E 13	0.18699990E 13	0.13099996E 13	0.22500000E 09	0.22500000E 09
1	5	0.26300000E 09	0.18699990E 13	0.18699990E 13	0.13099996E 13	0.22500000E 09	0.22500000E 09
1	6	0.26300000E 09	0.18699990E 13	0.18699990E 13	0.13099996E 13	0.22500000E 09	0.22500000E 09
1	7	0.26300000E 09	0.18699990E 13	0.18699990E 13	0.13099996E 13	0.22500000E 09	0.22500000E 09
2	3	0.29899981E 09	0.77299994E 12	0.77299994E 12	0.37199997E 12	0.72400000E 08	0.72400000E 08
3	8	0.26300000E 09	0.18699990E 13	0.18699990E 13	0.13099996E 13	0.22500000E 09	0.22500000E 09
3	9	0.26300000E 09	0.18699990E 13	0.18699990E 13	0.13099996E 13	0.22500000E 09	0.22500000E 09
3	10	0.26300000E 09	0.18699990E 13	0.18699990E 13	0.13099996E 13	0.22500000E 09	0.22500000E 09
3	11	0.21500000E 09	0.21599997E 12	0.21599997E 12	0.11799998E 11	0.51700000E 08	0.51700000E 08

1. EXTERNAL RING FRAMES AT CORE MODULE BERTHING PORTS

W_1 = 0.384 Hz
W_2 = 0.828 Hz

RING FRAME WEIGHT = 960 LB





2. LOCATE EQUIPMENT BULKHEADS ADJACENT TO BERTHING PORTS

W_1 = 0.387 Hz
W_2 = 1.51 Hz

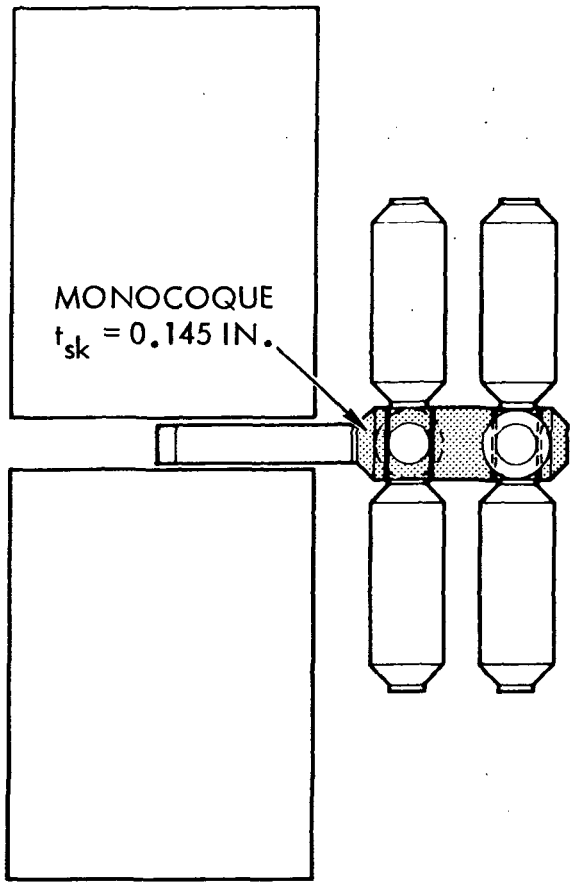
EQUIPMENT BULKHEAD WEIGHT = 1000 LB

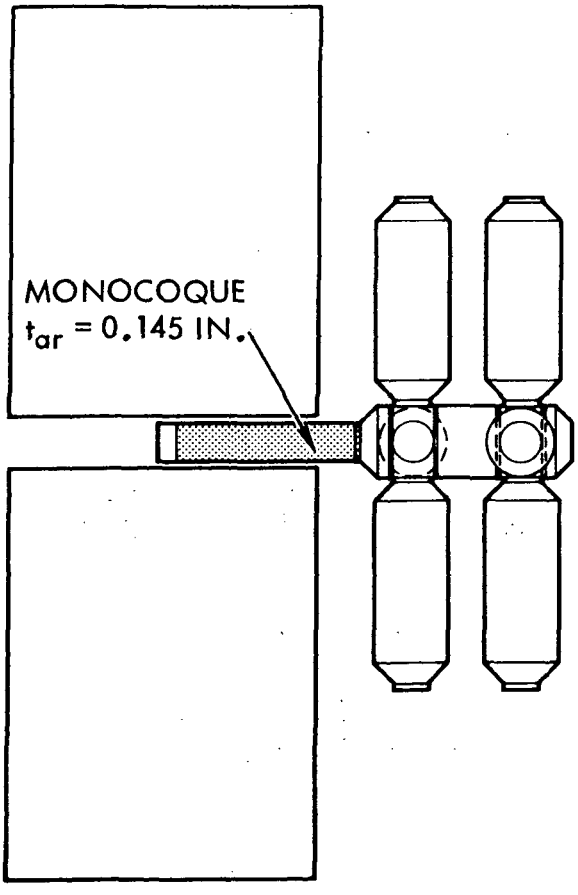
Figure A.7-2. Summary MSS Stiffness Study (Sheet 1 of 4)

3. MONOCOQUE CORE MODULE

W_1 = 0.415 Hz
W_2 = 1.63 Hz

MONOCOQUE ΔWEIGHT ≈ 1775 LB





4. MONOCOQUE POWER BOOM

W_1 = 0.610 Hz
W_2 = 1.77 Hz

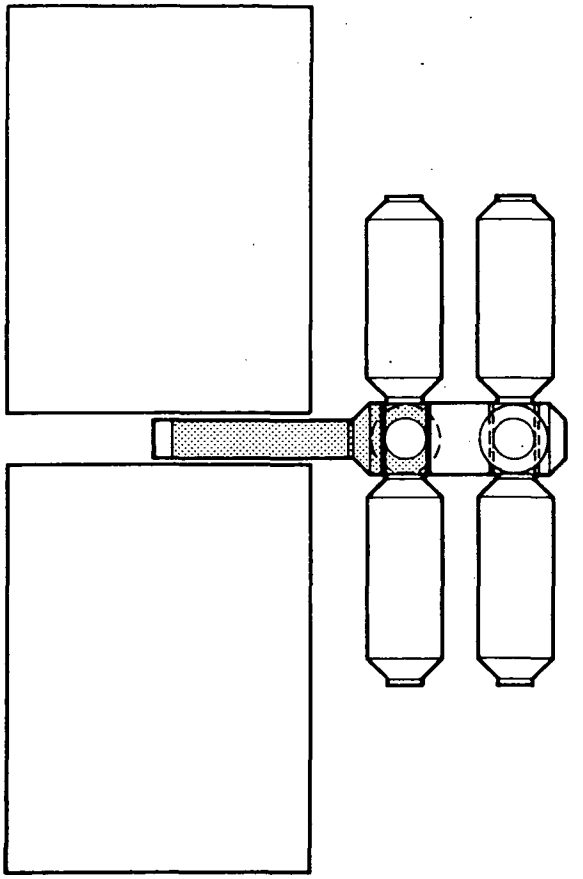
Δ WEIGHT = 900 LB

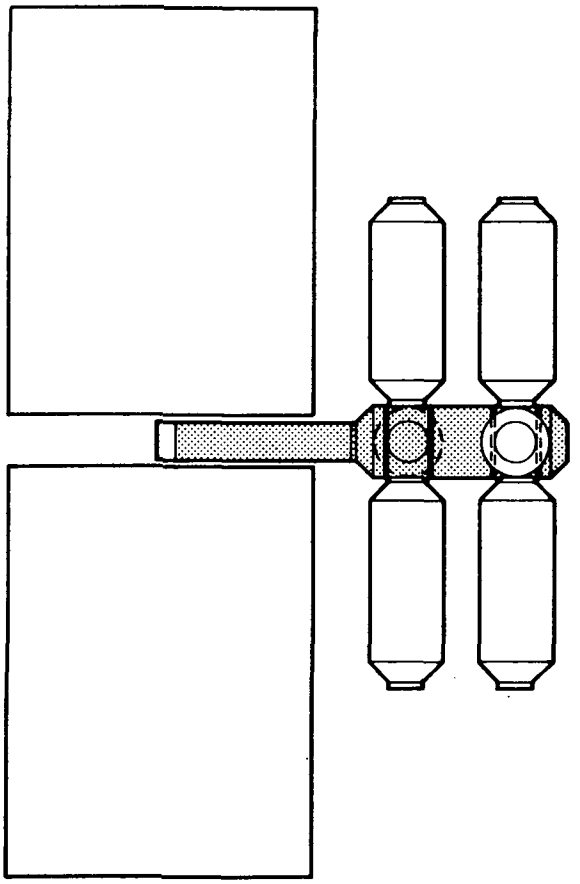
Figure A.7-2. Summary MSS Stiffness Study (Sheet 2 of 4)

5. MONOCOQUE POWER BOOM AND CORE MODULE END

W_1 = 0.808 Hz
W_2 = 1.782 Hz

Δ WEIGHT = 1480 LB





6. MONOCOQUE POWER BOOM AND CORE MODULE

W_1 = 0.816 Hz
W_2 = 2.46 Hz

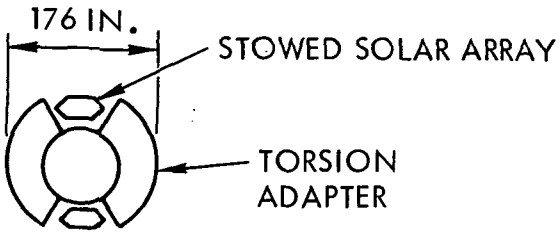
Δ WEIGHT = 2675 LB

Figure A.7-2. Summary MSS Stiffness Study (Sheet 3 of 4)

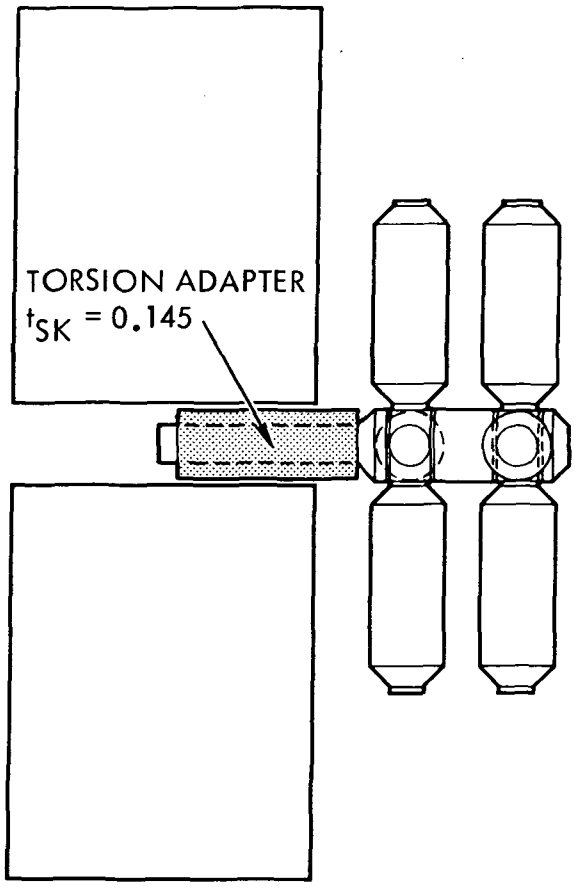
7. POWER BOOM EXTERNAL TORSION ADAPTER

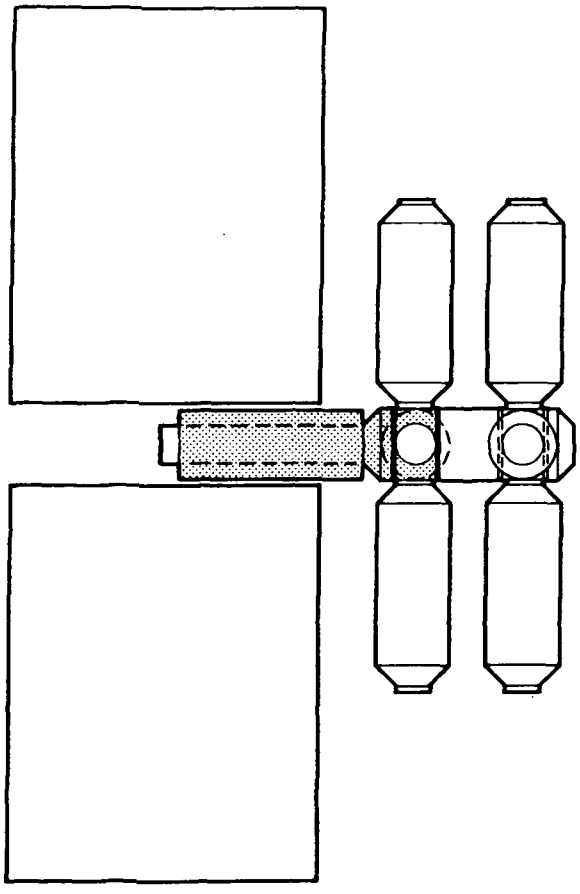
W_1 = 0.997 Hz
W_2 = 1.80 Hz

Δ WEIGHT = 3970 LB



POWER BOOM X-SECTION



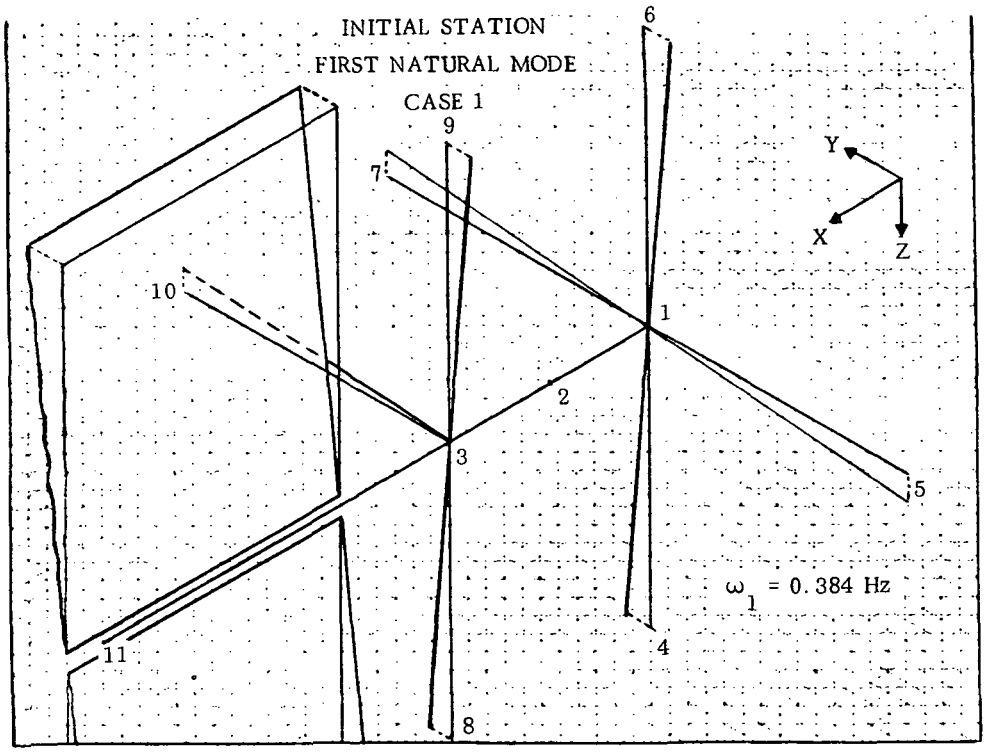


8. POWER BOOM TORSION ADAPTER AND MONOCOQUE CORE MODULE END

W_1 = 1.53 Hz
W_2 = 2.12 Hz

Δ WEIGHT = 4560 LB

Figure A.7-2. Summary MSS Stiffness Study (Sheet 4 of 4)



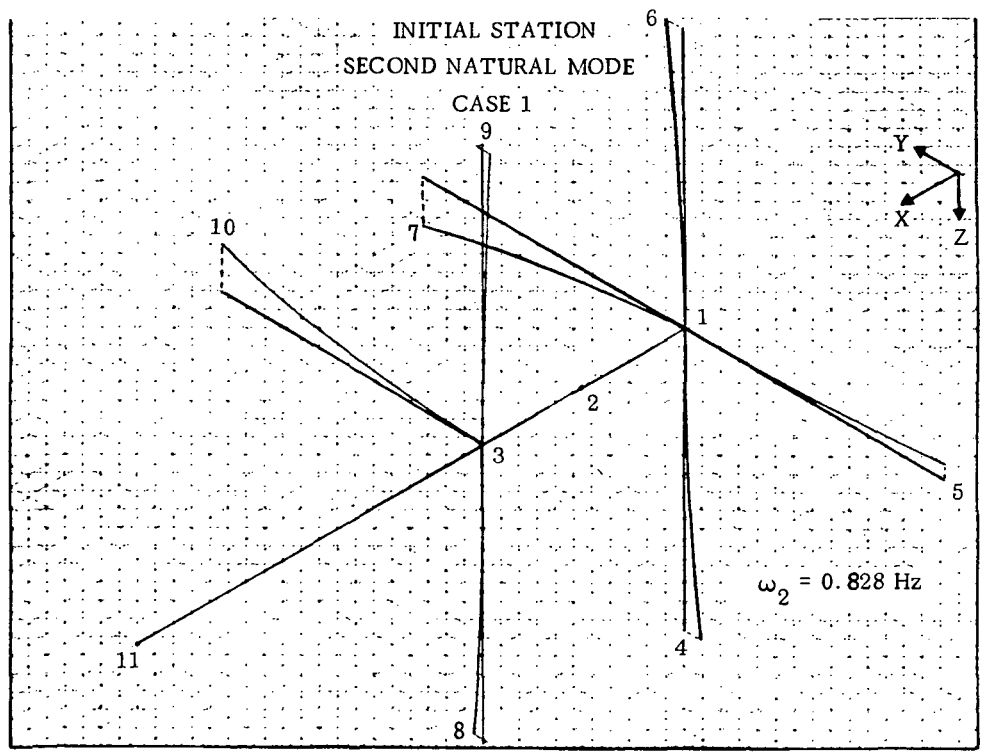


Figure A.7-3. Initial Station First and Second Elastic Modes (Case 1)

significantly change the first mode natural frequency. To raise the first mode frequency it is necessary to improve the torsional stiffness of the core module or power boom shells. Cases 3 through 7 of Figure A7-2 schematically depict the various methods of increasing the torsional rigidities of the core module and power boom shells and also list the resulting natural frequencies of the first two elastic modes. The methods considered include one or more combinations of the following:

1. Convert core module skin-stringer shell or an end section of it to 0.145 inch thickness monocoque

2. Change power boom shell from skin-stringer construction to 0.145 inch monocoque

3. Add an external trosion adapter to the power boom

From Cases 3 and 4 of Figure A7-2, it can be seen that increasing the torsional rigidity of the power boom has a larger effect on the lowest natural frequency than adding stiffness to the core module. A comparison of Cases 4, 5, and 6 indicates that converting the end of the core module next to the power boom from skin and stringer to 0.145 inch thick monocoque construction results in nearly the same increase in lowest mode natural frequency as does changing the entire core module shell to monocoque. Case 7 shows that a 1.0 Hz minimum natural frequency may be obtained by addition of an external monocoque torsion adapter. The addition of an external adapter together with a monocoque core module end, Case 8, represents nearly an upper limit torsional rigidity obtainable by modifying the initial shell structure by the three methods listed previously. The increase in weight for each structural modification is also shown in Figure A7-2.

To obtain the highest MSS fundamental frequency consistent with a minimum impact on the initial design, Case 4 of Figure A7-2 (0.145 inch thick monocoque power boom) was adopted for the Phase B design configuration.

7.2 STATION SOLAR ARRAY COUPLING

To accomplish the second task (whether or not coupling exists between solar arrays and station modules), a simplified dynamic model was used to represent the solar panels. The solar panels were considered as concentrated masses located at their centroid. The following stiffness values obtained from Astro Research Corporation were used to model the structural members connecting the solar array masses to the power boom:

Bending rigidity, $EI = 2.8 \times 10^8$ lb-in.^{2}

Torsional rigidity, $KGJ = 3.8 \times 10^6$ lb-in.^{2}

Shear rigidity, $KAG = 7.6 \times 10^4$ lb

These values are representative of the deployable "astromast" truss structure designed by the Astro Research Corporation for a space station solar array technology study currently being performed for NASA by the Lockheed Missiles and Space Company. Figure A7-4 shows the dynamic model used for the coupling study.

The results of the modal analysis show that for the simplified model of Figure A7-4, extensive modal coupling occurs between solar arrays and station modules. The effect of the coupling is to produce natural frequencies significantly less than those for a dynamic model that neglects the elasticity of the members that support the arrays from the power boom. The mode shapes for the ten natural frequencies of less than 1.0 Hz are shown in Figure A7-5.

The response routine of the MAR-3D computer program may be used by inputting the load-time history of a forcing function as a series of straight lines. The program computes the response and tabulates the results. This output includes mass velocity and acceleration histories and connecting member internal loads (shear, axial, moment). There is also a CRT option for obtaining the output data in graphic form. Because forcing function data for applicable MSS operational phases have not as yet been developed, response analyses were not performed during this study.

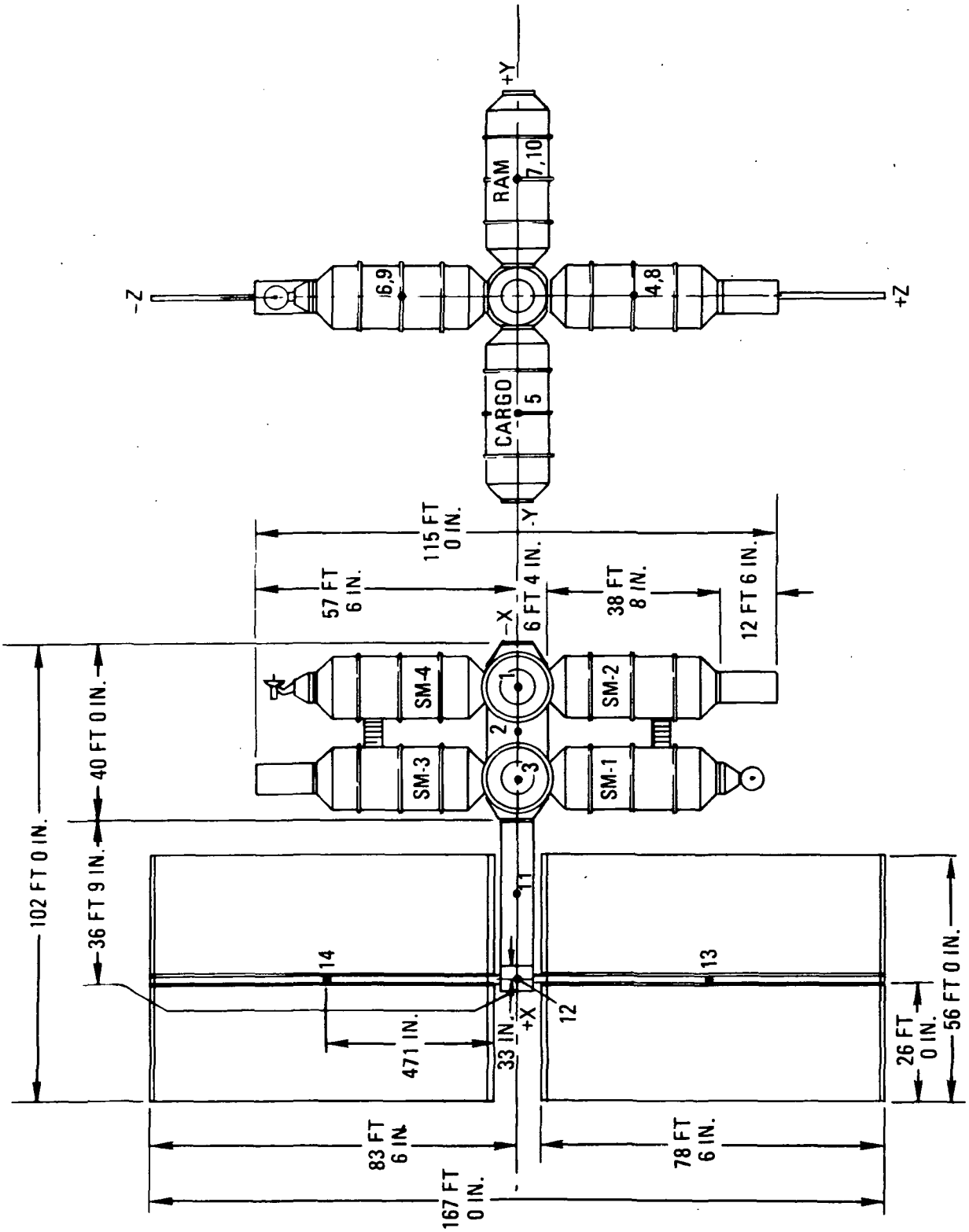


Figure A.7-4. Initial Station Coupling Study Model

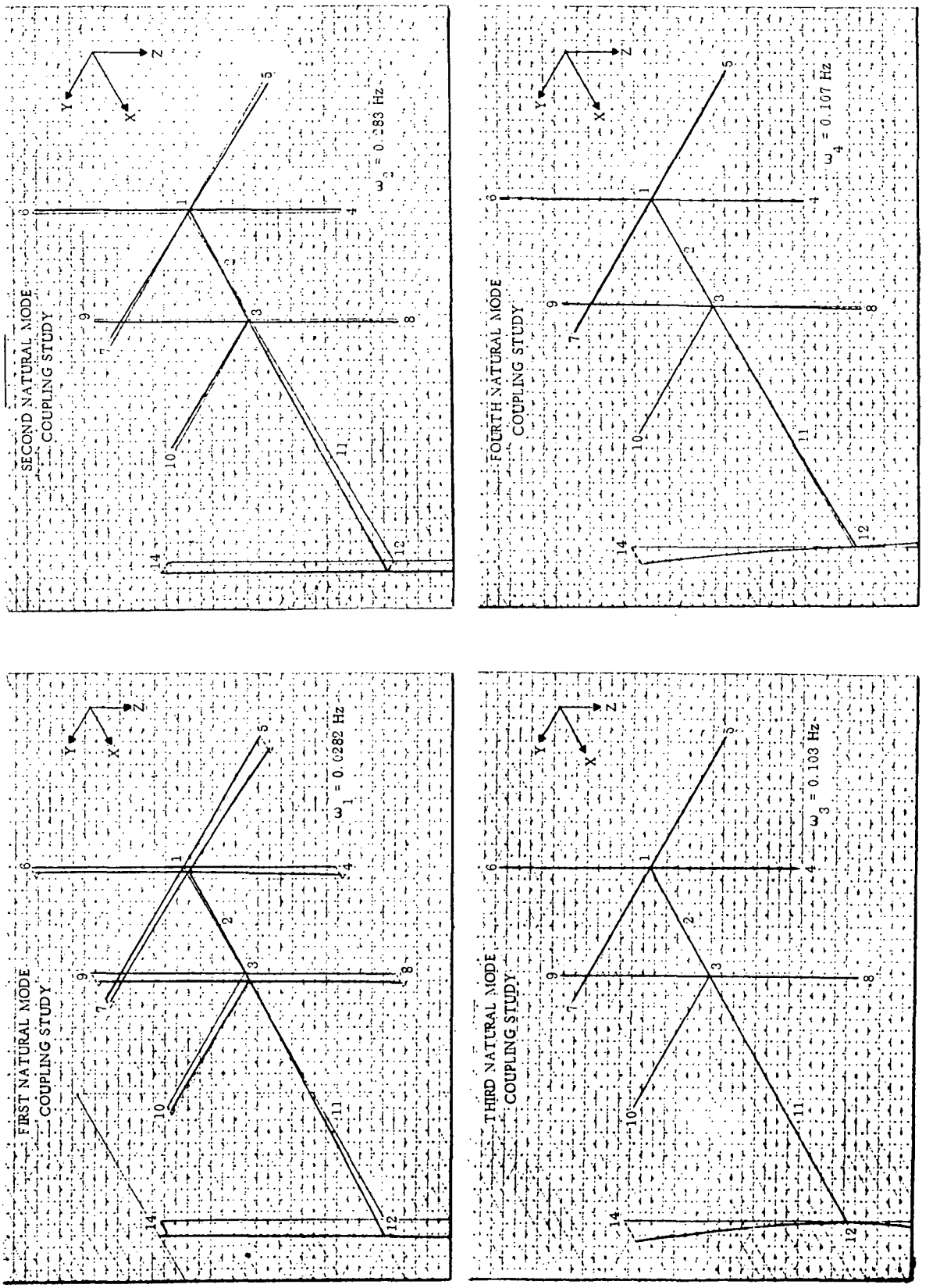


Figure A.7-5. Natural Modes Less Than 1.0 Hz - Coupling Study (Sheet 1 of 3)

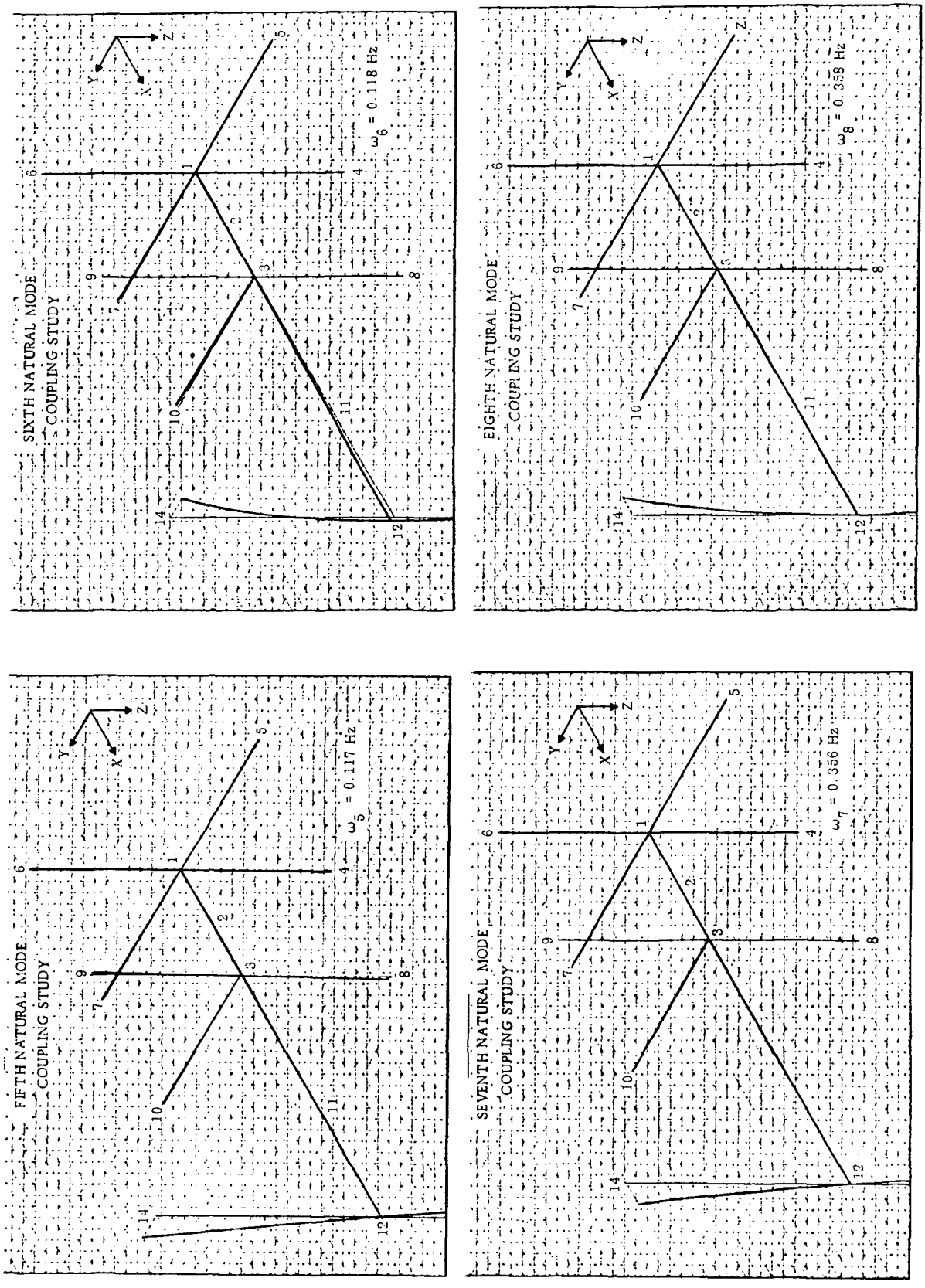
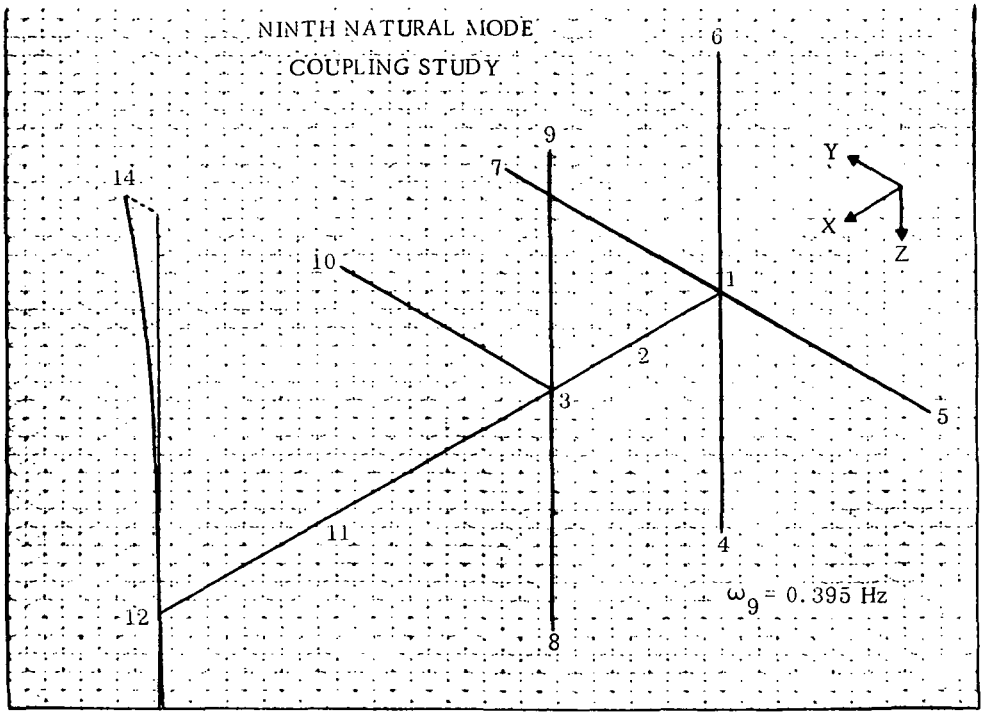


Figure A.7-5. Natural Modes Less Than 1.0 Hz - Coupling Study (Sheet 2 of 3)



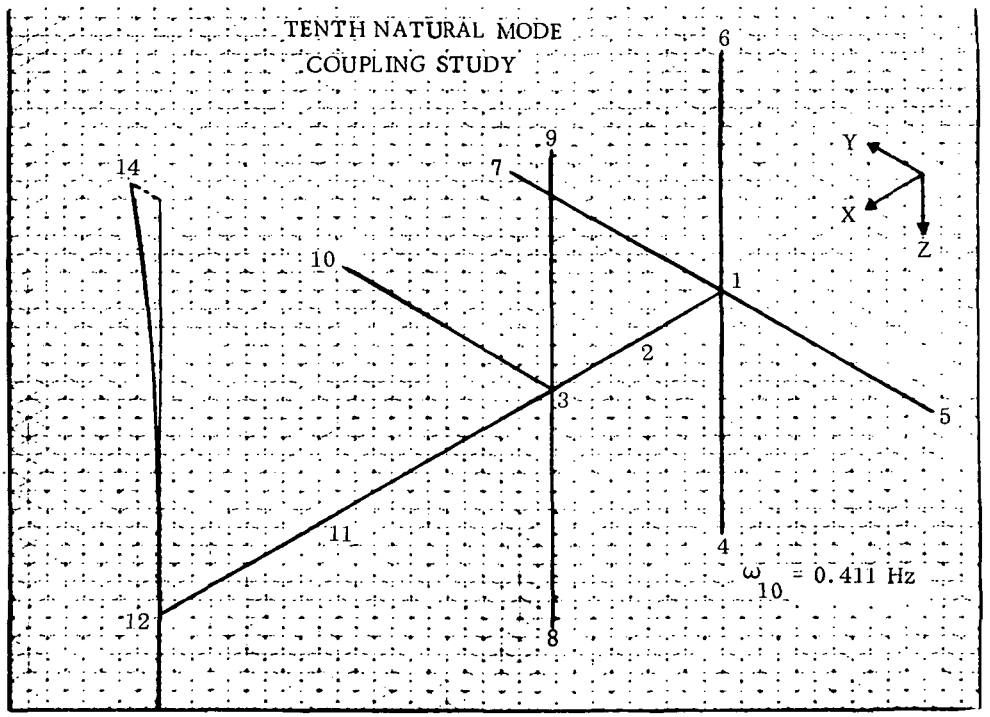


Figure A.7-5. Natural Modes Less Than 1.0 Hz - Coupling Study (Sheet 3 of 3)

8. GENERAL-PURPOSE LABORATORY EQUIPMENT

The MSS general-purpose laboratory configuration was based on a functional analysis of the NASA Blue Book. This analysis identified 305 unique functions required to achieve the Blue Book experiments at the functional program element (FPE) level. Figure A8-1 is the basic study logic followed.

A screening process was performed on the 305 functions to identify those which were provided by an MSS or RAM subsystem (such as electronic data processing). For the 119 functions that passed through the screen, the following criteria were applied to determine which would be provided by the general-purpose laboratory:

1. Commonality of functions among FPE's
2. Functions lending themselves to central support
3. Scientific/engineering discipline influence
4. Portability of equipment to support the function
5. Physical location of function performance
6. Performance characteristics of equipment required by function

This analysis resulted in the selection of 25 functions to be provided by the GPL. These 25 functions were then grouped into the following categories:

1. Photographic processing
2. Maintenance and calibration (mechanical/electrical/electronic, and optical)
3. Data analysis
4. Biomedical
5. Physics

These functional areas with their equipment items provide the means for conducting scientific experimentation by the station. These provisions will include standard equipment items which have a general-purpose application, available floor space and station utilities interface provisions for investigator-furnished equipment, and utilities interface provisions at the experiment module (RAM) berthing interfaces. The interface provisions will include electrical power, weight and volume accommodation, data bus accommodation, and attachment points. The requirements for these areas are defined in the following subsections for each of the areas identified.

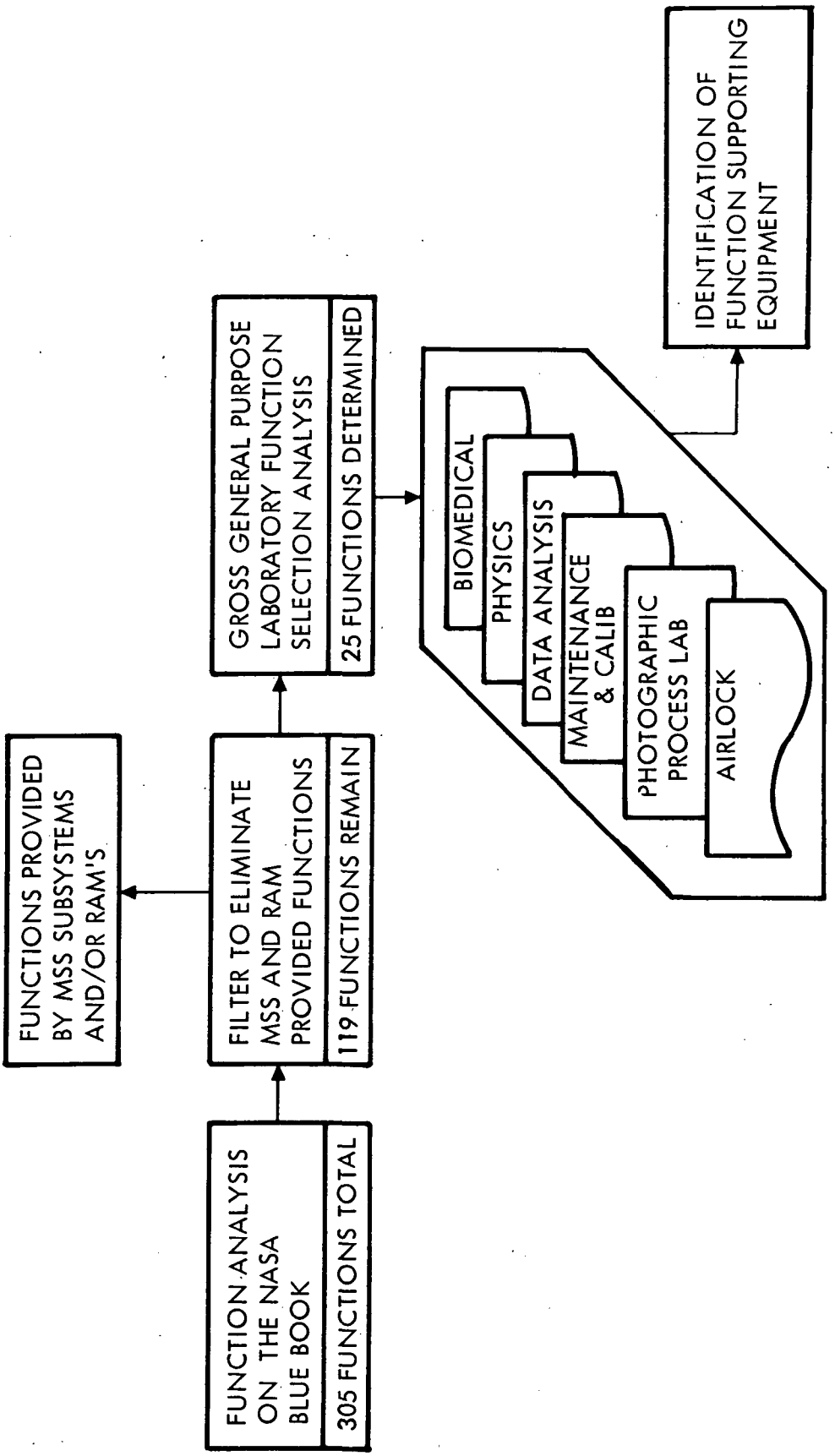


Figure A.8-1. GPL Equipment Selection and Laboratory Identification Logic

8.1 GENERAL REQUIREMENTS

Celestial and earth-viewing windows will be provided

Provisions will be made for mounting and installing an earth-viewing telescope that will be capable of obtaining bearings of earth landmarks.

Utilities will be provided at RAM berthing ports for resupply of consumables during berthing periods. These interfaces will be:

Electrical power	120/208 vac, 400 Hz, 3 phase
	Availability 4.5 kw 24-hour average, 7.0 kw peak
Data processing	Digital 0 to 5 vdc, 28 and 100 channel access
	Analog 0 to 5 vdc, 28 and 100 channel access
	Availability: Bit rate 2000 kbps Computer speed 1050 operations per second Operating memory 64,000 words Mass memory 22,000 words
Audio transmission/ reception	12 channels, 300 to 3 KHz baseband
TV transmission/ reception	(TBD) channels - color, 4,5 MHz baseband
	(TBD) channels - black and white, 2.9 MHz baseband
Nitrogen supply	300 psi GN_2 - rate (TBD)
Oxygen supply	300 psi GO_2 - rate (TBD)
Coolant supply (and return)	60 to 80 F, 200 lb/hour
Potable water supply	(TBD)
Waste water return	(TBD)
Freon supply and return	(TBD)
Air process ducts and return	(TBD)

Airlocks

Two experiment airlocks will be provided as part of the GPL configuration for deploying scientific instruments to the space environment from the station-pressurized volume. One airlock will be earth pointed and the other will be zenith pointed.

Medical/Biological Area

The biomedical area of the GPL will have the capability of performing hydrocarbon analysis, nitrogen analysis, cell counting, colorimetry, cytological stain preparation, bacterial culturing, histology, lyophilization, incubation, culture preservation, refrigerated sterilization, and clinical centrifugation.

Physics Area

The physics area will be located near the zenith-pointing experiment airlock and provide for a reflectometer that measures reflectance values of specimen contamination collectors and determines the abundance of the chemical constituents of atmospheric and biological gases by the application of mass spectrometry.

Data Analysis Area

The data analysis area will be located close to the control center and provide for the capability for film and taped data review. It will include film editing, viewing, projection onto screens, illuminated table viewing, audio taping and playback, and X-Y plotting.

Optical Supply and Maintenance Area

The optical supply and maintenance area will provide for the performance of optical tasks, including lens and other optical component cleaning, minor adjustment, calibration of optical instruments, calibration of the IR sensors, and supplemental lighting equipment. Cine cameras will be provided for high-speed, low-speed, and time-lapse photography. Still cameras will be provided for general support of the experimental areas which are adaptable for microscopic photography.

Electrical/Electronics Maintenance Area

The electrical/electonics maintenance area will provide for the performance of relatively noncomplex maintenance tasks. These operations will be limited to disassembly, repair, reassembly, calibration/adjustment, and checkout of relatively small electrical and electronic components and instruments. Repair operations will be confined to component replacement and exclude operations requiring soldering, potting, and other processes requiring handling of materials in a semi-fluid state and the use of heat processes.

Photographic Processing Area

The photographic processing area will provide for a low-level capability for photographic processing such as developing and printing of small- and medium-size formats. Provisions will be made for the shielded, temperature, and humidity-controlled storage of undeveloped film for periods up to 30 days. Film editing, splicing, and viewing areas will be provided with a lighted table.

Mechanical Maintenance Area

The mechanical maintenance area will have the capability to perform maintenance tasks of a relatively minor nature including disassembly, repair, calibration, and adjustment of simple mechanical assemblies and equipment. Tools and equipment for the installation and simple mechanical maintenance of experimental mechanical equipment throughout the station and attached and berthed detached modules will be provided.

Having identified the basic laboratory areas and their functional and performance requirements, various equipment lists were then selected or identified to provide the laboratory functional capabilities. For each of the equipment items identified, the weight, power, and size characteristics are listed in Table A8-1 along with the quantity and location.

8.2 LABORATORY FLOOR SPACE

A further analysis was performed to determine the free floor space required for experiment operations. This was done by reviewing the experiment functions to be accomplished on the initial space station, experiment equipment envelope sizes were determined which became the basis for the floor-spacing requirements. Equipment operations and astronaut mobility requirements were added to the floor space. This resulted in a required floor space of 824 square feet available within the station for GPL activities:

Functional Areas	Required Floor Area (Square Feet)
Photograhic processing	33
Maintenance and calibration	273
Data analysis	177
Biomedical / Physics (either/or)	177
Experiment operations	164
Total	824

Table A8-1. General Purpose Laboratory Characteristics

ASSEMBLY/SUBASSEMBLY	UNIT CHARACTERISTICS					LOCATION/QUANTITY					
	POWER	WEIGHT (LBS)	SIZE (INCHES) H	W	D	CORE	PWR	SM-1	SM-2	SM-3	SM-4
1.5 GPL FURNISHINGS											
Airlock	---	1200	80 I.D x 150 lgt.			-	-	-	1	1	-
Medical/Biological											
Total Carbon Analyzer	25	20	10	15	15	-	-	-	-	-	1
Nitrogen Analyzer	0.9	3	2	4	8	-	-	-	-	-	1
Colorimeter	20	10	8	12	4	-	-	-	-	-	1
**Total Weight											
Culture Chamber	---	1	1	3	6	---	---	---	---	---	1
Lyophilizer	---	10	18	8	16	---	---	---	---	---	1
Incubator	60	20	12	10	12	---	---	---	---	---	2
Work Bench	---	80	30	60	30	---	---	---	---	---	1
Mounts & Support (5%)	---	**12	-	-	-	---	---	---	---	---	x
Physics Area											
Portable Reflectometer	---	10	10	12	12	---	---	---	---	1	---
Samples & Retrieval Box	---	27	1/4	12	12	---	---	---	---	1	---
Mass Spectrometer	35	25	8	10	9	---	---	---	---	1	---
Work Bench	---	50	30	60	30	---	---	---	---	1	---
Mounts & Supports (5%)	---	**6	-	-	-	---	---	---	---	x	---
Data Analysis Area											
Control Console	---	100	72	36	24	---	---	1	---	---	---
Work Bench/Desk	---	120	36	76	24	---	---	1	---	---	---
Light Table	---	50	36	28	24	---	---	1	---	---	---
Film Viewer	---	90	48	36	24	---	---	1	---	---	---
X-Y Plotter	---	50	36	24	24	---	---	1	---	---	---
Tape Deck/Strip Chart	---	50	36	30	24	---	---	1	---	---	---
Storage Cabinet	---	100	72	30	18	---	---	1	---	---	---
Mounts & Supports (5%)	---	**30	-	-	-	---	---	x	---	---	---
Optical Supply/Maint.											
Zero 'G' Bench	---	120	36	60	30	---	---	---	1	---	---
IR Calibration Device	---	75	20 Dia. x 90 Lgth			---	---	---	1	---	---
Precision Fixture	---	50	24	12	24	---	---	---	1	---	---
Bench & Equipment	---	450	36	160	24	---	---	---	1	---	---
Floodlight	---	8	5 Dia. x 4 Lgth			---	---	---	1	---	---
Electronic Flash	---	2	2	2	3	---	---	---	1	---	---
Camera											
Cine	---	5	5	3	6	---	---	---	3	---	---
Still 35 MM	---	3	4	3	6	---	---	---	3	---	---
Still 70 MM	---	6	5	4	4	---	---	---	1	---	---
Microscope	---	12	6	6	12	---	---	---	1	---	---
Time Lapse	---	5	5	3	6	---	---	---	1	---	---
Mounts & Supports (5%)	---	**53	-	-	-	---	---	---	x	---	---
Elect/Electronic											
Electron Work Station	---	120	60	36	36	---	---	---	1	---	---
Test Bench	---	100	60	60	30	---	---	---	1	---	---
Var. Voltage Source	---	100	48	36	24	---	---	---	1	---	---
Storage for Instr.	---	200	78	48	48	---	---	---	1	---	---
Photo Processing											
Bench, Processor	---	200	30	80	24	---	---	1	---	---	---
Light Table	---	120	36	48	18	---	---	1	---	---	---
Storage Cabinet	---	75	82	40	18	---	---	1	---	---	---
Mounts/Supports (5%)	---	**21	-	-	-	---	---	x	---	---	---
Mechanical Maintenance											
Work Bench	---	175	60	70	30	---	---	---	1	---	---
Lamr Flow Glove Box	---	200	24	36	24	---	---	---	1	---	---
Tool Kit	---	100	24	48	24	---	---	---	1	---	---
Mounts/Supports (5%)	---	**25	-	-	-	---	---	---	x	---	---

These values are the total available floor space for time-sharing between GPL equipment, investigator-provided equipment used in the GPL operations area airlocks, and experiment modules attached to berthing ports. Quantities available for each of these areas will be dependent on experiment scheduling.

In addition to these floor areas, additional volumes will be provided for the storage of experiment equipment and consumables:

1. 180 cubic feet divided approximately equally among the electrical, mechanical, and optical maintenance areas.

2. 180 cubic feet divided approximately equally between the physics and biomedical areas.

3. 140 cubic feet divided approximately equally between the data analysis and photographic processing area.

8.3 EXPERIMENT AIRLOCK

An experiment airlock sizing study was also performed. The study was based on an MSS study-derived requirement indicating a need for both zenith and nadir experiment airlocks. Important factors in the study were low cost, simplicity, minimum acceptable volume, and maximum flexibility.

In order to comply with the simplicity of design and low-cost requirements, the preferred configuration is a simple cylinder with a standard berthing port interface with the MSS. Since berthing ports are 80 inches in diameter, an 80-inch internal diameter airlock seemed to be a reasonable starting point.

The next task was to review the envelope characteristics of those 1971 Blue Book experiment equipment items requiring the use of an airlock. This review uncovered the following eight items that were potential sizing drivers:

No.	Equipment Item	Identified Problem Airlock
		Deployed:
E006	Passive microwave scanner	13.4 by 13.4 by 1*
E009	Microwave radiometer	30 dia by 3
		Stowed:
C026	AMD space erectable antenna	4.5 dia by 3
T090	Maneuverable work platform	5.6 by 4.3 by 7.5
T130	Teleoperator	3.7 by 3.7 by 4
T136	Satellite	4 dia by ?
T106	Radiators (80 cubic feet)	3 by 3 by 9
T117	Experiment mounting assembly	0.25 by x by 7

*Dimensions in feet

In order to determine the possible impact, layouts were prepared using two approaches: (1) accommodating the largest single equipment items, and (2) accommodating the largest group of items working together to support a particular experiment.

The maneuvering work platform installation shown in Figure A8-2 is a sample of the largest single equipment items that must be placed into the airlock along with two EVA-suited astronauts. (Notice that the absolute minimum internal length is 10.5 feet for this installation.) The work platform is made up of modular packages assembled in the airlock and if the astronauts were not deployed along with the platform, space still would be required for assembly of the unit within the airlock.

The analysis for determining the length of the package consisting of the largest number of items operated as a group is shown in Figure A8-2. This is an earth observations package selected for the initial station. It requires a minimum internal length of 12 feet. While adequate information does not exist in the earth observations volume of the 1971 Blue Book to evaluate the feasibility of resizing or repackaging these items, it was felt that they could be scaled down to a compatible size when stowed. However, an additional 6 inches was added to the length to assure complete enclosure within the airlock.

For commonality, the basic structural shell of the experiment airlock is identical to the power module structural shell. The experiment airlock is a pure monocoque cylinder 80 inches in diameter and constructed from 0.145-inch 5052-H34 aluminum 150 inches long.

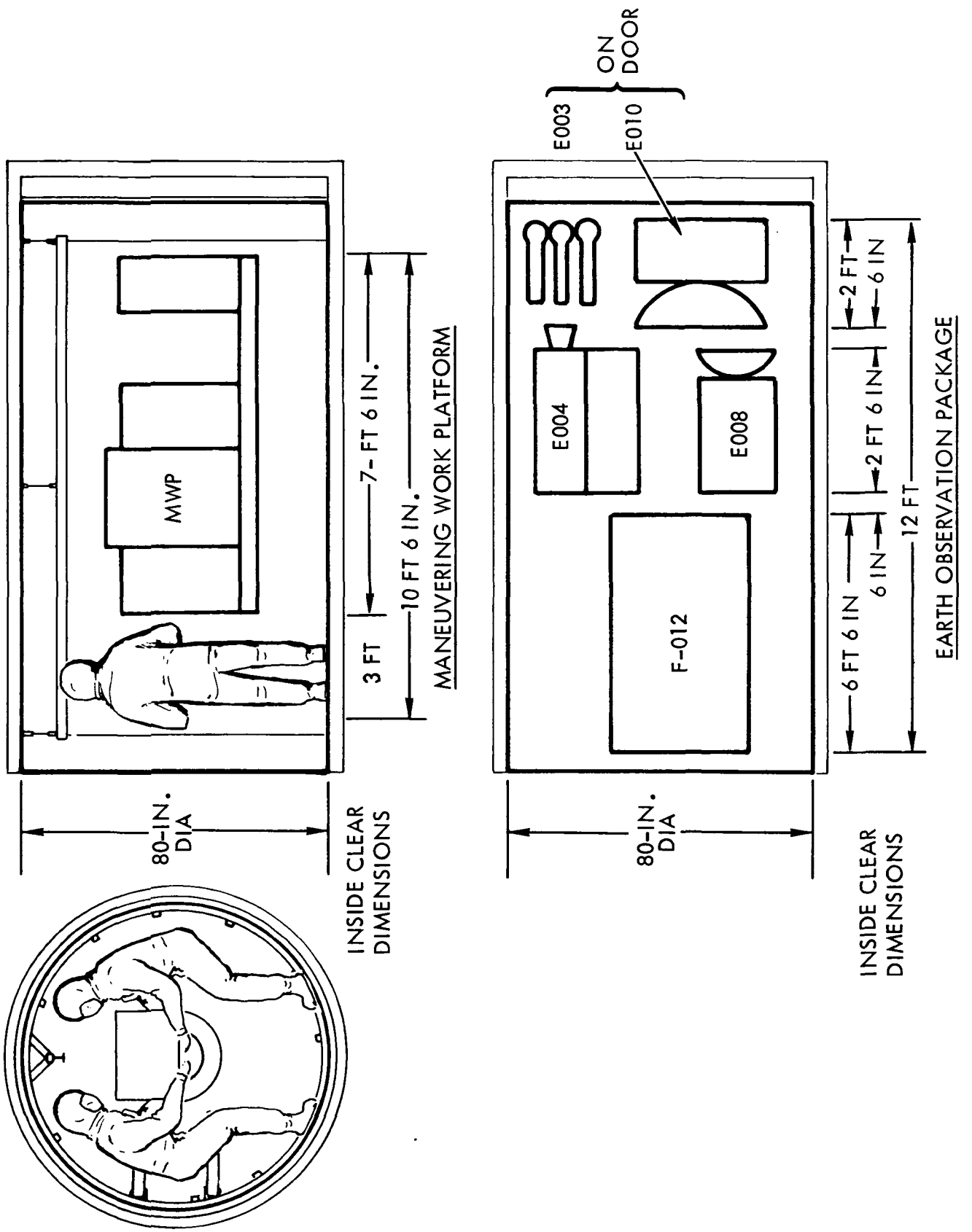
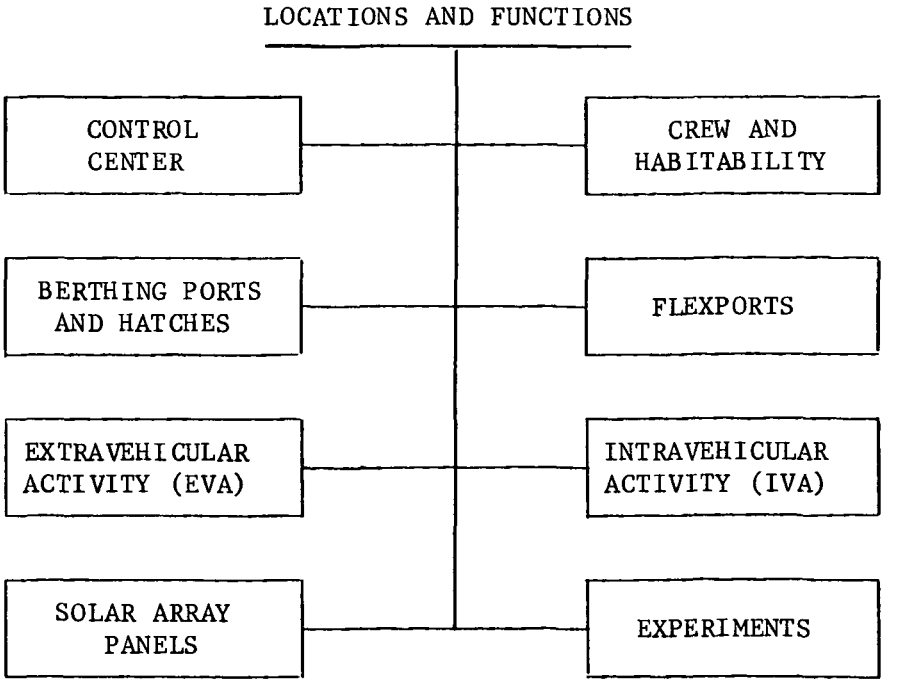


Figure A.8-2. Airlock Installations

9. WINDOW AND OPTICAL PENETRATIONS

An analysis was conducted to identify window locations, optical penetrations, and subsystem effects on the modular space station. Alternative locations and functions are identified below.



9.1 WINDOW CRITERIA

The guidelines and constraints require that the modular space station is to provide windows to meet the following requirements:

1. The MSC 14.75-inch window design will be used as a standard window.

2. Window and optical penetration design and installation will provide for shirtsleeve removal and replacement.

3. Location of windows and optical penetrations will be selected on the basis of minimizing local window optical contamination and adverse environmental conditions.

4. Heat transfer through the windows will be minimized.

9.2 WINDOW LOCATION

Control Center

Windows should be provided at the primary control center to enable the crew to confirm or control the attitude of the vehicle by reference to the external scene. Provisions should be provided at appropriate windows to allow for evaluation of the vehicle's attitudes, rates, and deadbands.

Windows on the station should enable visual contact with the shuttle or free-flying modules during their terminal phases of rendezvous (last 5000 feet) with the station.

Hatches

There will be a window in each pressure hatch that is capable of being closed for normal or emergency operation.

Crew and Habitability

There will be a window or windows in the main crew assembly area to provide viewing of the earth and space from the normal space station flight attitude.

Solar Array Panels

Provisions will be made to observe the motion of the articulated solar array panels from within the space station.

EVA

A window will be placed close to the experiment/EVA airlock to allow an observer to have visual contact with an EVA astronaut immediately after he has left the airlock.

IVA

Hatches between mdoules and flexport hatches will have windows to observe intravehicular activity.

Experiments

Windows will be provided in the hatches between the station modules and experiment/EVA airlocks to allow two-way viewing into and from the airlocks. Windows will be provided in the external hatches of the airlocks.

Optical Penetrations

The sextant/telescope will be located in the core module close to the earth observation RAM. The units will be mounted to provide both earth and celestial viewing with a field of view of 120 degrees.

The four-head horizon edge tracker will be located so that all four tracker heads can see the horizon at all times with a field of view of 9 degrees.

Two penetrations for star tracking will provide celestial viewing with a field of view of 120 degrees and be on the same X-axis coordinates as the horizon tracker assembly.

9.3 DESCRIPTION

All windows except those in the flexports are of the same MSC 14.75-inch standard window design. Figure A9-1 shows the cross section of the MSC 14.75-inch standard window. The windows provide nearly a 14-inch diameter viewing area, are adapted for installation, and have been designed for shirtsleeve removal and replacement. The window design will permit the removal of one pressure pane without disturbing the second pressure pane for replacement of seals. Each pressure pane will be designed to withstand the maximum operating pressure with an ultimate safety factor of 2.0. The pressure pane subassembly will not cause a chain failure of a second pane with the failure of one pane.

The windows are provided protection against thermal and micrometeoroid environment by movable environmental covers. The cover assembly normally remains closed and is only opened when in use. The window shield subassembly consists of the exterior environmental shield and a pressure cover. It is displaced from or returned over the window by a manually operated handle and displacement mechanism which pushes the shield outboard before it is rotated out of the way. The window shield, when returned over the window, can be latched in place by manually operated locks spaced about the periphery of the window. The window shield is locked and sealed (dual seals) in place. The window subassembly can then be removed by removing the attachement bolts about the window frame. The entire operation is done manually by a crewman in the shirtsleeve environment. The individual manual locks minimze the lock mechanism installation as compared to a possible remotely driven exterior-mounted mechanism.

Both the inner and outer hatches of the IVA/EVA airlock contain windows to observe crewman operations outside the habitable volume.

The window installation is utilized on all berthing ports and is installed in the rectangular pressure hatch to provide optical alignment for berthing operations.

9.4 THERMAL ANALYSIS WINDOW STUDY IMPACT

The effect of the windows is to increase the heat gain and heat loss to and from the internal atmosphere. The heat loss depends on the window cover, design, and structural requirements of the sealing mechanism. Heat loss through the glass is governed by the area and heat loss through the structure depends mainly on the perimeter.

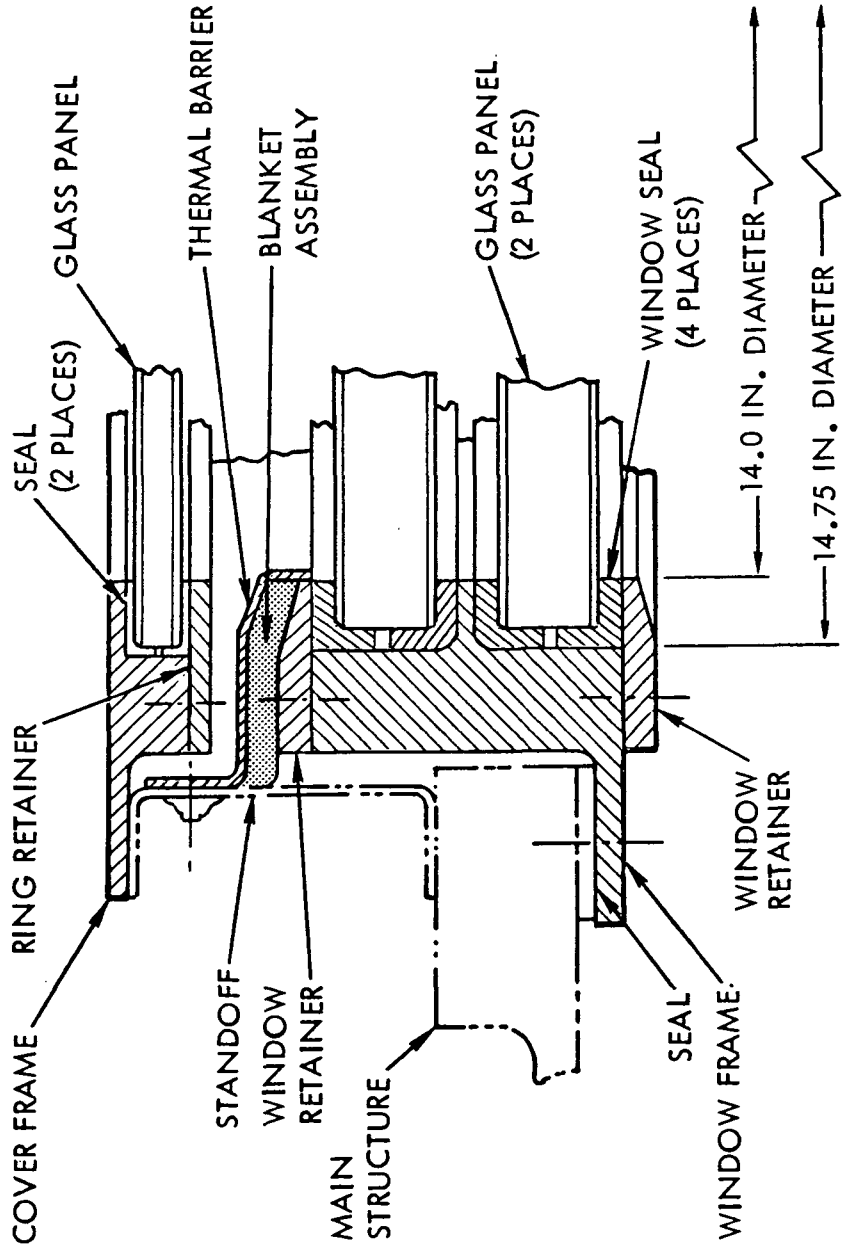


Figure A.9-1. Cross-Sectional View of MSC Window Assembly

Heat gain through the windows depends on their orientation, optical properties, and whether or not the window cover is in place. Window shades should not be used if the windows are thermally controlled passively (low emittance coatings), because the shade would interfere with thermal radiation interchange between the inner pane and the internal atmosphere or environment. Under cold environmental conditions, then, the window shade would actually stifle the passive thermal design of the window assembly and result in condensation formation on the inner pane. Hence, it is recommended that the window cover be in place (but not necessarily sealed) when the windows are not in use. In addition to minimizing the heat gain, this would also minimize the heat loss under cold conditions, provide additional micrometeorite protection, and retard the buildup of contaminants (vented gases, waste material, etc.) on the outer window surface. The added micrometeorite and contaminant protection would considerably reduce the likelihood of having to replace the outer pane and the replacement frequency.

9.5 OPERATIONAL WINDOW LOCATION STUDY

Window viewing is independent of location; i.e., is analogous to the view one would have from inside a glass sphere. Now consider the effect of enclosing the glass sphere with the space station structure (completely eliminating all external viewing) and then providing some limited viewing by placing a window on the space station outer structure. A fixed head position about 4 inches back from a 12-inch round window results in a 90-degree ($\pm 45°$) field of view. By head movement (left and right, up and down), one can increase the field of view to about 120 degrees.

9.6 FINAL SELECTION OF WINDOWS FOR THE MODULAR SPACE STATION

Berthing

A standard MSC window will be provided at each berthing port hatch.

Flexports

A four-inch-diameter window is located in each flexport hatch.

EVA

A standard MSC window is provided in the experiment airlock to allow an observer to have visual contact with an EVA astronaut immediately after he has left the airlock.

Crew and Habitability

There will be a standard MSC window in the main crew assembly area (dining facility) to provide viewing of the earth and space from the normal space station flight attitude.

Control Center

A standard MSC window is provided at the control centers to enable the crew to confirm or control the attitude of the vehicle by reference to the external scene. In the normal flight attitude, control of two of the vehicle axes may be accomplished simultaneously, without performing a mental coordinate transformation or without reference to a second window or to any instrument.

Solar Array Panels

Solar array panel articulation may be observed from the control center windows.

APPENDIX B. SUPPORTING ANALYSIS

1. STRUCTURAL ANALYSIS

1.1 INTRODUCTION

This section contains a detailed stress analysis of the primary structure for the selected Space Station design configuration. The scope of the analysis does not include coverage of all local design details; rather, its intended objective is to support the preliminary design definition as follows:

1. Assist in the definition of an efficient basic design configuration.

2. Verify structural feasibility of the selected design approach.

3. Define approximate structural sizing to serve as a basis for evaluation of structural weight, design, and manufacturing considerations.

4. Determine structural stiffness characteristics for use in analyses of deflection, dynamic modes, and dynamic response and in evaluation of pointing errors on solar arrays, antennas, experiments, etc.

Analyses of all major elements of primary structure are presented as required to satisfy the above objectives. Evaluation of secondary structure, such as tank support provisions and environmental shield and radiator panels with their attachment provisions, is not included. A limited evaluation of the environmental shield and radiator panels may be found in the "Station A" structural analysis report (Reference 11). In several cases, it was necessary to assume changes to the detail configuration to retain structural feasibility or efficiency. These revisions are not reflected on final release drawings and present schedules do not permit incorporating them in a further drawing change; consequently, the modified configuration is indicated in the individual analyses as appropriate.

Design structural loads that serve as the basis for the detail stress analysis are described and summarized in Section 1.4 of this report. These loads considered several potential critical design cases in the launch-boost, entry and landing shuttle transport operational phases.

Material design allowables have been taken from MIL-HDBK-5a where available; the North American Rockwell Space Division Materials Properties Manual was used as a supplementary source of design allowable data. Conventional

theoretical analysis methods have been employed generally. Use was made of NASA monographs for theoretical methods in areas such as shell stability analysis wherever possible.

1.2 GENERAL STRUCTURAL ARRANGEMENT

Inboard profile diagrams of the MSS common modules, core module, and power module are presented at the beginning of their respective structural analysis sections (pages 2.1.2, 3.0.1, and 4.1.1). Generally, structural components that are subjected to long term loadings such as the pressure shell or require welded joints are constructed from either 2219-T87 or 5052-H34 aluminum alloys. Components that do not require welding and are not subjected to long-term loadings are constructed from 7075-T6 aluminum alloy.

The common module is 33 feet 8 inches long. Its cylindrical (164-inch diameter) sidewall and cone-knuckle end bulkheads are .145-inch thickness 5052-H34 aluminum alloy. The .145-inch shell thickness together with the .030 inch thickness aluminum meteoroid bumper is required to meet radiation shielding requirements. Longitudinal drag members incorporated in the pressure shell to distribute the concentrated longitudinal shuttle trunnion support loads and longitudinal floor loads into the cylindrical shell are constructed from 2219-T87 aluminum. Three equally spaced ring frames made from 7075-T6 aluminum alloy are bonded to the exterior of the cylindrical pressure shell. The frames are employed to stabilize the pressure shell and distribute transverse concentrated shuttle support loads. The common modules are designed to facilitate the use of floors either parallel or normal to the module longitudinal axis. The floors are a honeycomb sandwich construction with 7075-T6 aluminum facing sheets and 5056-H38 aluminum core.

The core module is 40 feet long and has an integral skin-stringer construction outer shell which is composed of a 12-foot-diameter cylindrical section and cone-knuckle end bulkheads. Because of the relatively short time that the core module is inhabited, its radiation protection requirements are not as stringent as for the common modules. Therefore, the core module outer shell employes an integral skin-stringer construction made from 2219-T87 aluminum alloy to emphasize weight efficiency. Four bulkheads transverse to the module longitudinal axis are located immediately adjacent to the docking ports. These bulkheads serve the dual function of supporting internal equipment and providing stiffness between core module and berthed common modules. Two transverse pressure bulkheads are located centrally to the core module for the purpose of providing IVA/EVA capability and pressure compartment redundancy. Drag longerons are provided in the same manner as for common modules.

The 80-inch-diameter cylindrical power module structural shell utilizes a ring stiffened monocoque construction. The .145 inch thickness used for the 5052-H34 aluminum monocoque shell is not required for strength purposes, but was incorporated to furnish torsional stiffness to increase the station minimum natural frequency. The external circumferential rings serve the dual purpose of supporting the shell against buckling failure and reinforcing the shell to withstand concentrated loads from the supporting members for the

pressurized gas tanks located inside the power module. Longitudinal drag members are provided similar to those provided for the core and common modules.

1.3 STRUCTURAL DESIGN CRITERIA

Strength Requirements

The Modular Space Station structure must be designed to withstand ultimate design loads without failure and the yield design loads without yielding of basic structural sections. The appropriate ultimate and yield factors of safety to be applied to the limit load to determine corresponding design loads are summarized in Table B1-1 for various operating conditions.

Structural failure is considered to be either physical rupture of a member or general instability collapse, such that the load carrying capability is significantly reduced.

Table B1-1. Factors of Safety for Space Station Structural Design

Condition			Factor of Safety	
			Ultimate	Yield
Ground Operations	Personnel not present		1.50	1.20
	Personnel Present	Unpressurized	3.0	2.0
		Pressurized	4.0	2.0
Launch/Boost (Unmanned)			1.50	1.20
Orbital Operations (Manned)	Long-term sustained loads		2.0	1.50
	Short-term or transient loads		1.75	1.30

Stiffness Requirements

Space Station structure must provide adequate stiffness to maintain satisfactory vehicle stability and control characteristics in both launch and orbital configurations; to satisfy pointing accuracy requirements of solar arrays, antennas, and onboard or attached experiments; and to provide for proper operation of docking systems, hatches, covers, and other kinematic elements.

Life Requirement

The Space Station structure must be designed to maintain structural integrity and full operational capability over a 10-year orbital service life, under normal operating conditions, without requiring replacement or extensive refurbishment of primary structure.

Internal Pressure

Habitable areas of the Space Station must be pressurized to a nominal level of 14.7 psia for orbital operations. An allowance for pressure-control-system tolerance must be made to this nominal pressure to establish maximum and minimum limit pressure levels for structural design.

The Space Station must be divided into at least two separate pressure compartments in a manner that permits isolation of any single compartment should it be damaged or rendered untenable. This requirement is accomplished for the selected design configuration by either of the IVA/EVA airlock pressure bulkheads located in the core module. These bulkheads are designed to withstand full compartment pressure loading acting in either direction.

Space Station compartments that are normally pressurized during orbital operations are to be sealed prior to launch, and the corresponding compartment absolute pressure is to be considered in structural design for shuttle transport conditions.

1.4 STRUCTURAL DESIGN LOADING

A summary of structural loads for selected design conditions that occur during shuttle transport is given in Table B1-2. The loads are given in terms of accelerations experienced by a payload in the cargo hold of the shuttle orbiter during the conditions specified and include dynamic effects.

1.5 SUMMARY OF MINIMUM MARGINS OF SAFETY

A summary of minimum margins of safety for the major elements of primary structure is given in Table B1-3. This summary includes an identification of the structural component, location of critical section or region, description of type and magnitude of applied internal loads or stresses and failure mode, the critical operating condition, and the resulting margin of safety. The applied stresses indicated in this table are ultimate, unless the critical failure mode is indicated to be yielding. These stresses are based on the ultimate or yield factors of safety appropriate for the specific design condition.

The structural margin of safety is defined by the following relationship:

$$M.S. = \frac{\text{Allowable load or stress}}{(\text{Limit load or stress}) \times (\text{Safety factor})} - 1$$

Detail calculations are included in the body of this report section to support all margins of safety listed in the summary table.

Table B1-2. Shuttle Orbiter Loads

Condition	Acceleration (g's)		
	X	Y	Z
Liftoff	1.4	±0.8	±0.8
High Q Boost	2.1	±0.42	+0.6 -0.84
Booster End Burn	3.3	±0.11	-0.55
Staging	TBD	TBD	TBD
Orbiter End Burn	3.3	±0.11	-0.55
OMS Operation	0.2	±0.1	0.1
ACPS Operation	±0.1	±0.1	±0.1
Entry	±0.25	±0.6	-3.0
Fly-back	±0.25	±0.6	+1.2 -3.0
Landing and Braking	+0.96 -1.2	+0.6	-3.0
*Crash (Cargo and Equipment	-8.0 +1.5	±1.5	-4.5 +2.0

*Crash loads are ultimate. All others are limit. These accelerations act separately and shall be used in design of structure whose failure could result in injury to personnel during a crash or prevent egress from a crashed vehicle. The longitudinal (X) acceleration may act within a cone about the X axis with semi-vertex angle of 20 degrees.

Table B1-3. Summary of Minimum Margins of Safety - Modular Space Station Primary Structure

Component and Location	Type and Magnitude of Stress (ult)	Failure Mode	Design Condition	M.S.
Common Module				
Cylindrical Sidewall				
Cylindrical Shell	Longitudinal compression - 1.33 ksi	Cylinder buckling	Booster end burn	1.50
Skin	Hoop tension			
	17.7 ksi	Tensile rupture	Orbital	.96
	13.35 ksi (yield)	Tensile yielding	operations	.73
Longitudinal Welds	Hoop tension 17.7 ksi	Tensile rupture	Orbital oper.	.30
Transfer Tunnel Reinforcing Ring	Combined bending and membrane tension 42.8 ksi	Tensile rupture	Orbital operations	.19
Drag Longerons	Tension 61.7 ksi	Tensile rupture	Crash	.02
Intermediate Ring Frame	Compression 62.1 ksi	Compression yielding	Crash	.08
End Ring Frames	Compression 60.3 ksi	Crippling	Crash	.01
End Bulkheads				
Cassinian Section	Meridional tension			
	8.2 ksi	Tensile rupture	Orbital oper.	3.05
	6.15 ksi (yield)	Tensile yielding	Orbital oper.	2.65
Conical Section	20.6 ksi	Tensile rupture	Orbital oper.	.65
	15.5 ksi (yield)	Tensile yielding	Orbital oper.	.48
Longitudinal Welds	20.6 ksi	Tensile rupture	Orbital oper.	.12

Table B1-3. Summary of Minimum Margins of Safety - Modular Space Station Primary Structure (continued)

Component and Location	Type and Magnitude of Stress (ult)	Failure Mode	Design Condition	M.S.
Longitudinal Floor				
Facings	Compression - 66 ksi	Compression yielding	Crash	.02
Core	Transverse shear - 131 psi	Shear rupture	Crash	.20
Transverse Floor				
Facings	Compression - 58.5 ksi	Compression yielding	Crash	.11
Core	Shear - 50.4 psi	Shear rupture	Crash	.59
Core Module				
Cylindrical Sidewall				
Skin	Hoop tension - 53,600 psi	Tension rupture	Orbital oper.	.76
Berthing Port Reinforcement Ring	Tension - 57.5 ksi	Tension rupture	Orbital oper.	.09
Drag Longerons	Tension - 31.3 ksi	Tension rupture	Crash	1.01
Skin/Stringer Panels	Longitudinal compression	Panel buckling	Booster end burn	1.05
IVA/EVA Bulkheads				
Facings	Compression - 49.4 ksi	Compression yielding	One volume depressurized in orbit	.05
Core	Shear - 66.5 psi	Shear rupture	" "	.76

Table B1-3. Summary of Minimum Margins of Safety - Modular Space Station Primary Structure (continued)

Component and Location	Type and Magnitude of Stress (ult)	Failure Mode	Design Condition	M.S.
Equipment Support Bulkheads				
Facings	Compression - 63.5 ksi	Compression yielding	Crash	.06
Core	Shear - 64 psi	Shear rupture	Crash	.53
Power Module				
Cylindrical Shell	Shear - 3.48 ksi	Shear buckling	Crash	.38
Tank support ring frames	Direct and bending tension 62.5 ksi	Tension rupture	Crash	.23

Structural Analysis Calculations
Table of Contents

1.0 Introduction and Summary

- 1.1 Introduction
- 1.2 General Structural Arrangement
- 1.3 Structural Design Criteria
- 1.4 Structural Design Loads
- 1.5 Summary of Minimum Margins of Safety
- 1.6 References

2.0 Common Module

- 2.1 Cylindrical Sidewall
  - 2.1.1 Drag Longerons
  - 2.1.2 Ring Frames
    - (a) Intermediate Frame
    - (b) End Frame
- 2.2 End Pressure Bulkheads
- 2.3 Floors
  - 2.3.1 Longitudinal
  - 2.3.2 Split Level Deck (SM-1 & SM-4 Staterooms)
  - 2.3.3 Transverse
- 2.4 Transfer Tunnel Reinforcement Ring

3.0 Core Module

- 3.1 Cylindrical Sidewalls
  - 3.1.1 Berthing Ports
  - 3.1.2 Drag Longerons
- 3.2 End Pressure Bulkheads
- 3.3 IVA/EVA Airlock
- 3.4 Equipment Support Bulkheads

4.0 Power Module

- 4.1 Skin Analysis
- 4.2 Drag Longerons
- 4.3 Tank Supporting Ring-Frames
- 4.4 Forward Support Frame

1.6 REFERENCES

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2.0 COMMON MODULE

Figure on p. 2.1.2 represents the MSS 37-ft universal common module, which may be readily adapted for use of either transverse or longitudinal floors. Structurally it is a cylindrical pressure vessel with two end cone-knuckle bulkheads, 3 intermediate circumferential ring frames, and two longitudinal drag longerons. The ring frames distribute the shuttle support loads, and/or transverse floor loads into the cylindrical shell. The drag longerons distribute loads induced by the shuttle supports and the longitudinal floor into the shell.

2.1 CYLINDRICAL SIDEWALL

The .145 inch thickness cylindrical sidewall is analyzed as a cylinder simply supported at the ring frames. The strength capacity of the cylinder is determined by its critical buckling stress.

Buckling Load (Ref. 1)

Geometrical and material data:

Material - 5052-H34 Aluminum Alloy

$t = 0.145$ in. $\qquad E_c = 10.2 \times 10^6$ psi

$r = 82$ in. $\qquad \mu = 0.33$

$\ell = 111$ in.

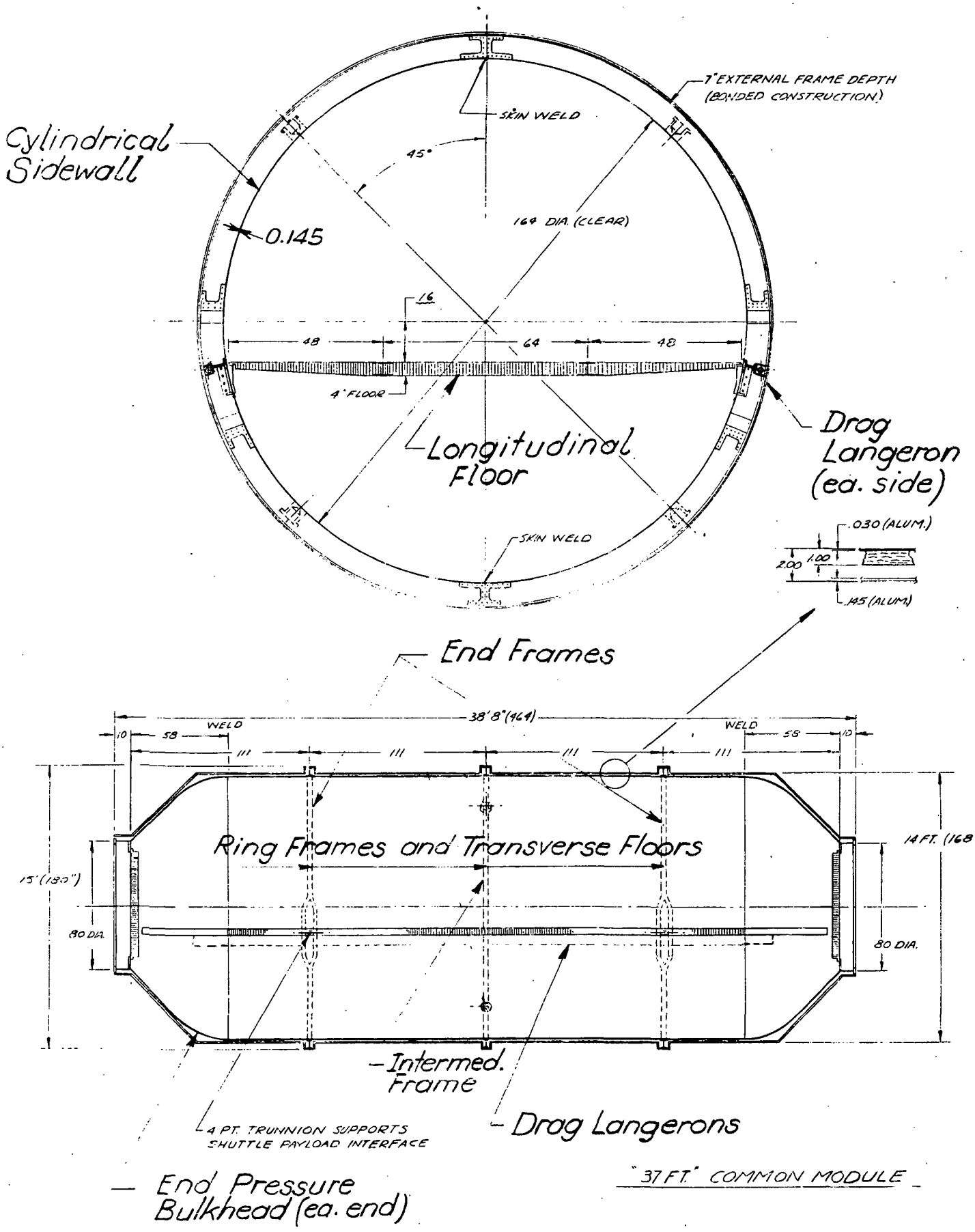
Characteristic value $Z = \dfrac{\ell^2}{rt}\sqrt{1-\mu^2} = \dfrac{111^2}{82 \times 0.145}\sqrt{1-(0.33)^2} = 975$

$r/t = 82/0.145 = 566 \Rightarrow$ from graph $\gamma = 0.3$

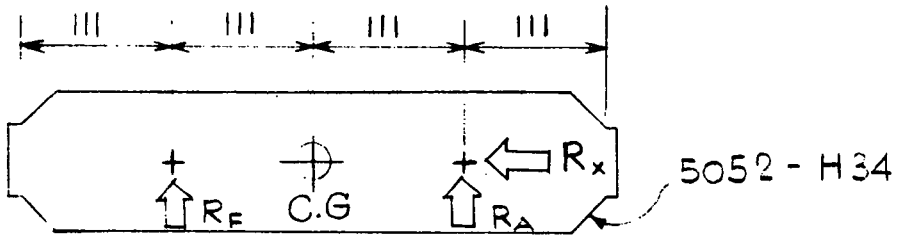
$\gamma z = 0.3 \times 975 = 293 \Rightarrow$ from graph $K_x = 207$

Critical load is given by:

$$(N_x)_{cr} = K_x \frac{\pi^2 E_c t^3}{12 \ell^2 (1-\mu^2)} = 207 \times \frac{\pi^2 \times 10.2 \times 10^6 \times (0.145)^3}{12(111)^2(0.891)} = 484 \text{ lb/in}$$


Cylindrical Sidewall
0.145
7" EXTERNAL FRAME DEPTH (BONDED CONSTRUCTION)
SKIN WELD
45°
164 DIA. (CLEAR)
16
48
64
48
4" FLOOR
Longitudinal Floor
Drag Langeron (ea. side)
.030 (ALUM.)
2.00
1.00
.145 (ALUM.)
SKIN WELD
End Frames
38'8" (464)
WELD
WELD
10
58
58
10
111
111
111
111
Ring Frames and Transverse Floors
15' (180")
14 FT. (168")
80 DIA.
80 DIA.
Intermed. Frame
4 PT. TRUNNION SUPPORTS SHUTTLE PAYLOAD INTERFACE
Drag Langerons
End Pressure Bulkhead (ea. end)
"37 FT." COMMON MODULE

End Boost Condition



Module Weight = 25,000 lb (maximum growth weight)

$$R_F = R_A = \frac{25000}{2} = 12{,}500 \text{ lb (1g)}$$

$$M_{max} = \frac{R_F}{2}\ \frac{111}{2} = \frac{12{,}500 \times 111}{4} = 3.47 \times 10^5 \text{ lb-in (1g)}$$

Limit Accelerations

$$n_x = 3.3 \times 1.5g = 4.95g$$

$$n_y = \pm 0.1 \times 1.5g = 0.15g$$

$$n_z = -0.5 \times 1.5g = 0.75g$$

$$n_{LAT} = \sqrt{0.15^2 + 0.75^2} = 0.765g$$

In following, analysis conservatively neglected internal pressure load. Assumed 3/4 of module weight to be located forward of aft reaction points.

$$(P_x)_{max} \approx \frac{3}{4} \times 25{,}000(4.95) = 93{,}000 \text{ lb} \quad \text{ultimate (compression)}$$

$$M_{max} = (3.47 \times 10^5)(0.765) = 2.65 \times 10^5 \text{ in-lb} \quad \text{ultimate}$$

$$(N_x)_{max} = \frac{93{,}000}{\pi(164)} + \frac{2.65 \times 10^5 \times 82}{\pi(82)^3} = 180 \pm \frac{265000}{21100} = 192.6 < N_{cr} = 484\#/\text{in.}$$

Margin of Safety

$$M.S. = \frac{484}{192.6} - 1 = +1.50$$

Space Operation Condition

Internal pressure p = 14.9 psi limit

ULT. F.S. = 2.0

$$f_{TU} = \frac{pR}{t} = \frac{2 \times (14.9)(86)}{0.145} = 17700 \text{ lb/in}^2$$

$$(M.S.)_{ult} = \frac{F_{tu}}{f_{tu}} - 1 = \frac{34,000}{17,700} - 1 = +0.96$$

Yield F.S. = 1.5

$$f_y = 17700 \text{ lb/in}^2 \quad \frac{1.5}{2.00} = 13350 \text{ psi}$$

$$(M.S.)_{YLD} = \frac{F_Y}{f_Y} - 1 = \frac{23000}{13350} - 1 = +0.73$$

Check of Welding

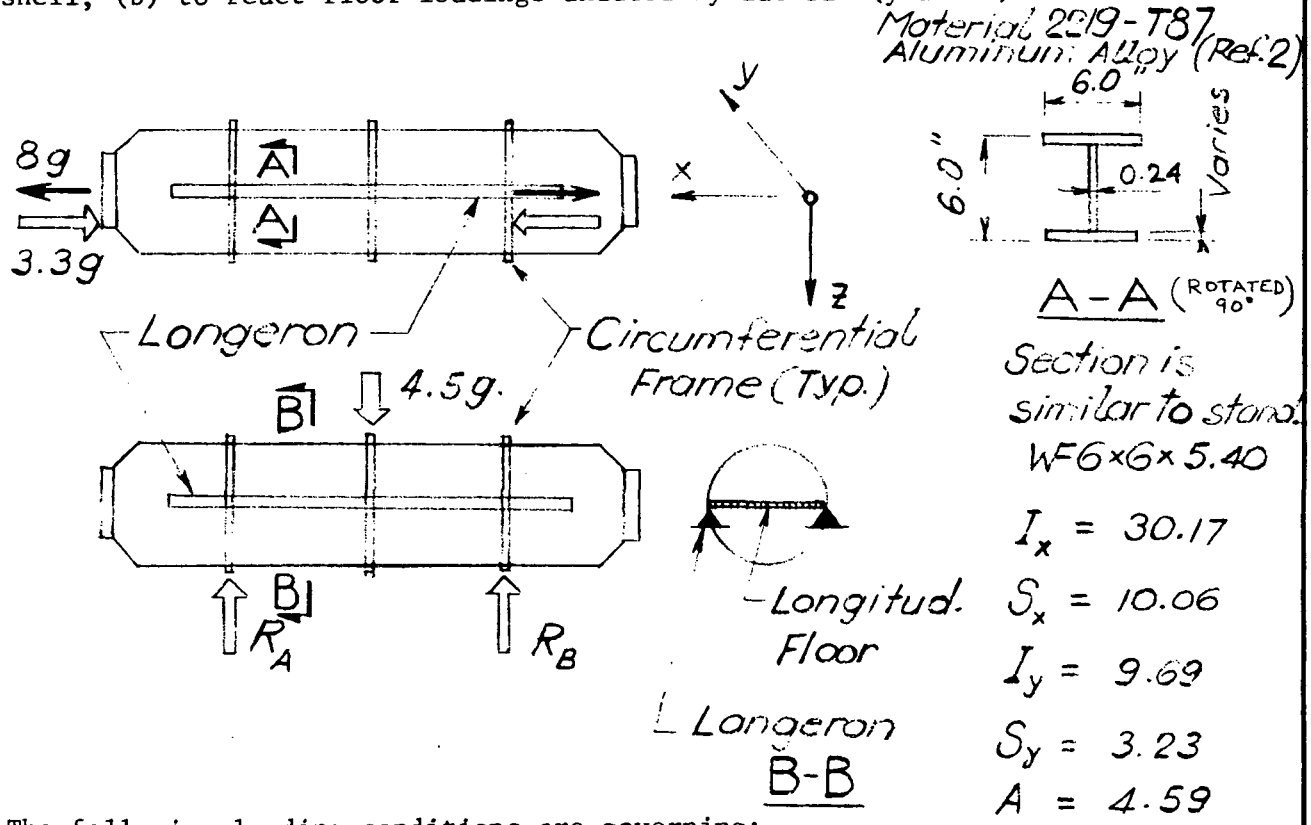
f_{TU} = 17700 psi (with S.F. = 2.0)

$$M.S. = \frac{23000}{17700} - 1 = +0.3$$

FORM M152-R-2 REV. 11-67

2.1.1 Drag Longerons

The functions of the two drag longerons are: (a) to distribute the longitudinal concentrated loads that occur at the aft trunnion supports into the cylindrical shell, (b) to react floor loadings induced by lateral (y and z) accelerations.

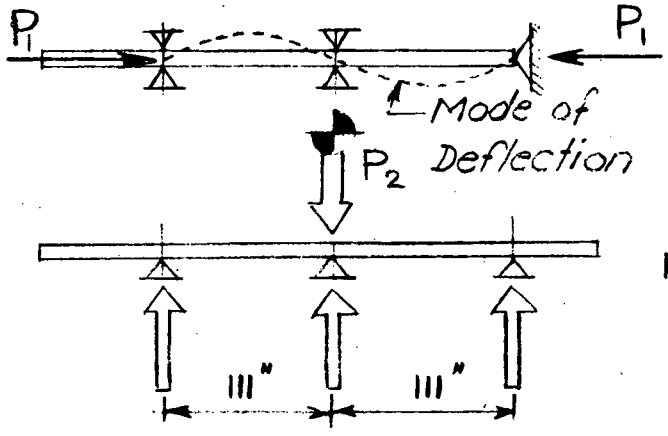


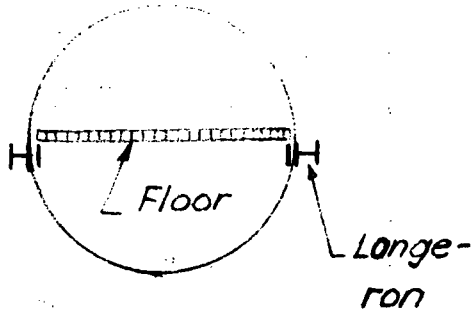
The following loading conditions are governing:

	η_x	η_y	η_z	F.S.
(1) Booster end Burn (Limit)	3.3	±0.1	-0.5	1.5
(2) Crash (Cargo & Equipment) (Ultimate)	-8.0	+1.5	-4.5	1.0

(1) Loading Condition - Booster End Burn

Structural System of Longeron:





(a) Longitudinal compression $P_1 = 25000\# \frac{1}{2} \times 3.3 \times 1.5 = 62000$ lbs Ult.

Mode of deformation is such that the critical load is

$$P_{cr} = \frac{\pi^2 E I}{L^2} = \frac{\pi^2 \ 10.6 \times 10^6 \times I}{111^2} = 8500 \ I \text{ lbs}$$

Adapted Wide-Flange Section 6 x 6 x 5.40

Area = 4.59 in^2

$I_{max} = 30.17 \ in^4$ $\quad I_{min} = 9.69 \ in^4$

$P_{cr} = 8500 \times 30.17 \ in^4 = \underline{256000\#}$

M.S. (Buckling) $= \frac{256000}{62000} - 1 = \underline{\underline{+3.13}}$ (This loading condition does not govern)

$\sigma_{cr} = \frac{256000}{4.59} = 56600\#/in^2$

$\sigma_{act} = 62000/4.59 = 13600$ psi

(b) Stability against torsion (Ref. 3, page 228)

$$\sigma_{cr} = \left(0.456 + \frac{b^2}{\ell^2}\right) \frac{\pi^2}{6(1-\nu)} \frac{Gt^2}{b^2} = (0.456) \frac{\pi^2}{6 \times 0.67} \frac{(0.24)^2}{(3.0)^2} \times 3.9 \times 10^6$$

$$= 28000\#/in^2$$

M.S. $= \frac{28{,}000}{13{,}600} - 1 = \underline{\underline{1.06}}$

FORM M152-R-2 REV. 11-67

(c) Transverse Loading

$$P_2 = 0.5 \times 25000 \times \frac{1}{2} \times 1.5 = 9300\#$$

$$w = 9300/444 = 21.0\#/in$$

$$\max M = 21 \times 111^2/12 = 21600\#in$$

$$\sigma = \frac{21600}{3.23} = 6700\#/in^2$$ } Use similar section to standard WF 6x6x5.40

$$\sigma_{long} \text{ (p. 2.1.6)} = 13600\#/in^2$$

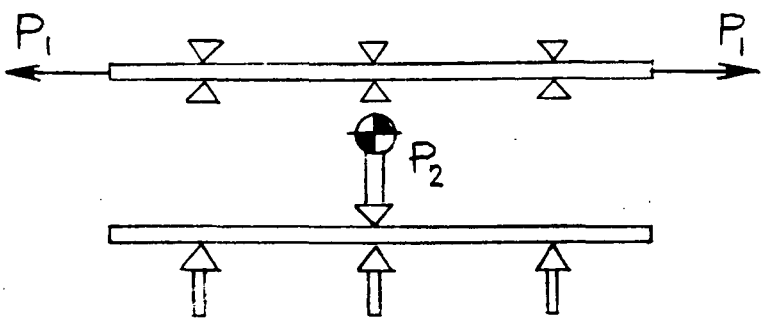
$$\sigma + \sigma_{\ell} = 20300\#/in^2$$

Assume $F_{BU} \approx F_{cy} = 51000$ psi (Ref. 2)

$$M.S. = \frac{51000}{20300} - 1 = \underline{+1.51}$$ (This loading does not govern)

(2) Loading Condition - Crash

Structural System of Longeron



(a) Longitudinal Tension

$$P_1 = 25000 \times \frac{1}{2} \times 8.0 \times 1.0 = 100000 \text{ lbs}$$

$$\sigma_{Tens} = 100000/4.59 = \underline{21700} \text{ psi}$$

(b) Transverse loading in z-direction

$$P_2 = 25000 \times \frac{1}{2} \times 4.5 \times 1 = 56000\#$$

$$w = 56000/444 = 126\#/in$$

$$\max M = 126 \times 111^2/12 = 129000 \text{ in}\#$$

$$\sigma_M = \frac{129000}{3.23} = 40000 \text{ psi}$$

(c) Loading in y-direction

Neglected, because of floor-stiffening effect

(d) Total Stress

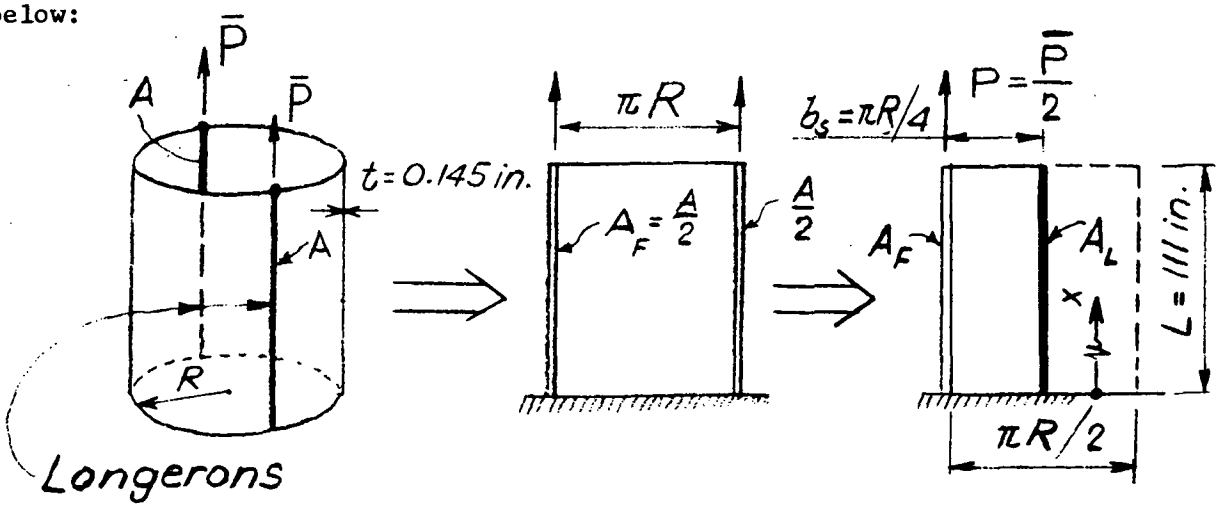
Longitudinal tension	21700 psi
Bending	40000 psi

Assume $F_{TU} \approx F_{BU} = 63000$ (Ref. 2); $\sigma = 61700$ psi

$$M.S. = \frac{63000}{61700} - 1 = +0.02$$

Shear Analysis

The stresses in the stiffened (longerons) part of the shell are computed by the "substitute-single-stringer method" of Reference 4, Section 4-6. For analysis simplification the panels are conservatively assumed as being flat. The sequence of logical assumptions for the above mentioned method is shown below:



FORM M152-R-2 REV. 11-67

$\bar{P}$ = 100000 lbs (page 2.1.7)

$P = \frac{\bar{P}}{2} = 50000$ lbs.

$b_s = \pi R/4 = 0.79 \times 82 = 64$ in

Substitute Section

$A_F = 4.59 \text{ in}^2/2 \approx 2.30 \text{ in}^2$ $\quad A_L = 0.145 \times 64 \times 2 = 18.4 \text{ in}^2$

$$K = \sqrt{\frac{Gt}{b_s E}\left(\frac{1}{A_F} + \frac{1}{A_L}\right)} = \left[\frac{4.0 \times 10^6 \times 0.145}{64 \times 10.5 \times 10^6}\left(\frac{1}{2.3} + \frac{1}{18.4}\right)\right]^{\frac{1}{2}} = 0.075$$

The distance, L_{eq}, from the lower end to the point where σ_F and σ_L (stresses corresponding to areas A_F and A_L) are equalized within 1% margin is

$L_{eq} = \frac{4.6}{K} = \frac{4.6}{0.075} = 61$ in (Ref. 4 , page 107)

$A_T = A_L + A_F = 2.30 + 18.4 = 20.7 \text{ in}^2$

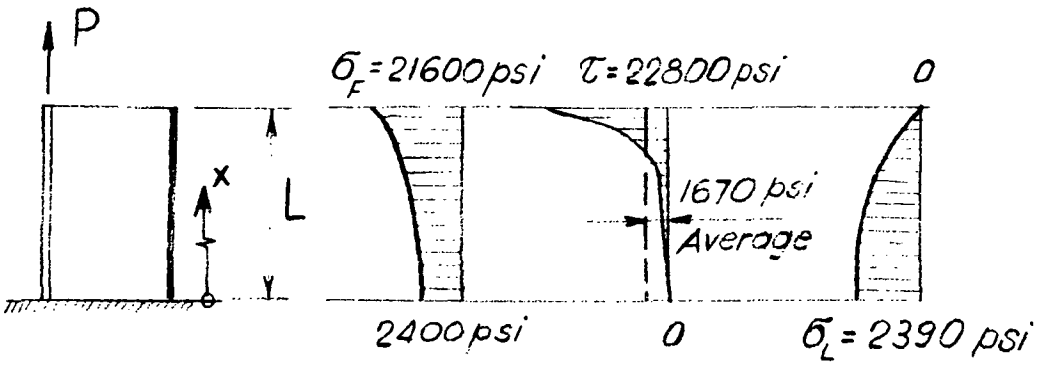
We are primarily interested in the shear stress, also in σ_F and σ_L, which were determined in accordance with the following formulas for several points along x-coordinate.

$$\sigma_F = \frac{P}{A_T}\left(1 + \frac{A_L}{A_F}\frac{\cosh Kx}{\cosh KL}\right)$$

$$\sigma_L = \frac{P}{A_T}\left(1 - \frac{\cosh Kx}{\cosh KL}\right)$$

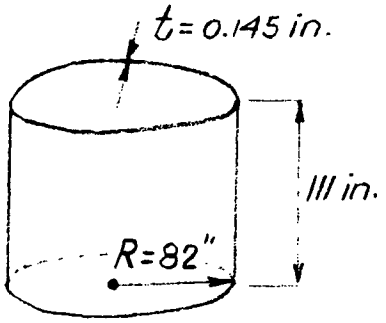
$$\tau = \frac{PKA_L}{tA_T} \cdot \frac{\sinh Kx}{\cosh KL}$$

The resulting stress distributions are shown in the following figure:



Shear Buckling: (Ref. 5, pages 9.22.08 and 09)

The maximum τ occurs at the upper edge, but the edge is well reinforced. The average shear stress is less than the buckling strength of the cylinder if internal pressurization of 14.5 psi is considered:



$R = 82;\ \frac{R}{t} = \frac{82}{0.145} = 566 \Rightarrow C_s = .535$

Pressurization of 14.5 psi:

$$\frac{p}{E}\left(\frac{R}{t}\right)^2 = \frac{14.5}{10.6 \times 10^6}\left(\frac{82}{0.145}\right)^2 = 0.435$$

$$\Rightarrow \Delta C = .400$$

$$C_{TOT} = \underline{0.935}$$

$$Z = \frac{L^2}{Rt}\sqrt{1-\mu^2} = \frac{111^2 \times 0.94}{82 \times 0.145} = 970$$

$$Z^{\frac{1}{4}} = \sqrt{\sqrt{970}} = 5.6$$

$$\frac{\tau_{cr}}{\eta} = C_s E \frac{t}{R}\frac{1}{Z^{1/4}} = 0.935 \times 10.6 \times 10^6 \frac{0.145}{82 \times 5.6} = \underline{3160\#/in^2}$$

$\therefore\ \tau_{cr} > \tau_{average} = 1670$ psi

(If pressurization is neglected $\tau_{cr} = 3160 \frac{0.535}{0.935} = 1810 > 1670$ psi)

Buckling M.S.

$$(M.S.)_{Buckl.} = \frac{3160}{1670} - 1 = \underline{\underline{+0.90}}$$

Shear Failure M.S.

$$(M.S.)_{Shear} = \frac{20000}{1670} - 1 = \text{large}$$

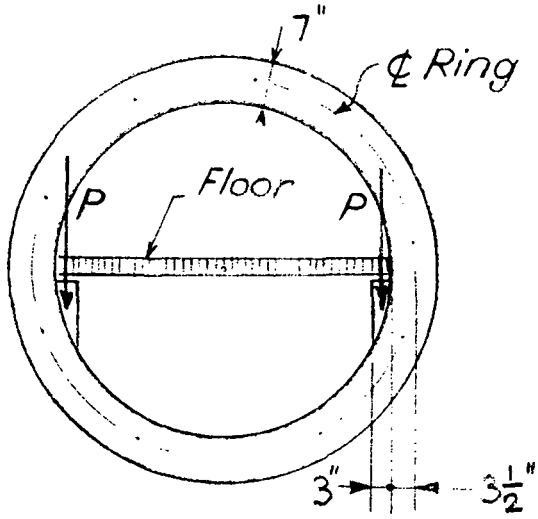
2.1.2 Ring Frames

The cylindrical shell is stabilized by three ring frames (Fig. on p. 2.1.2). These three frames distribute the floor loads into the monocoque shell. The two end frames additionally distribute the concentrated loads that are imposed on the shell at the shuttle supports.

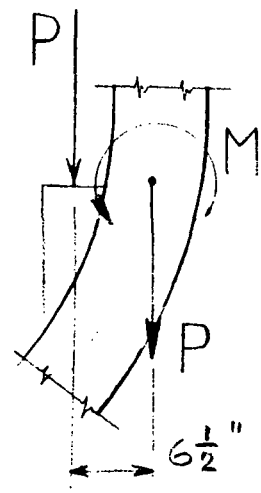
Frames are of two kinds, intermediate and end frames.

(a) Intermediate frame

External Loading System:



Actual



Idealized

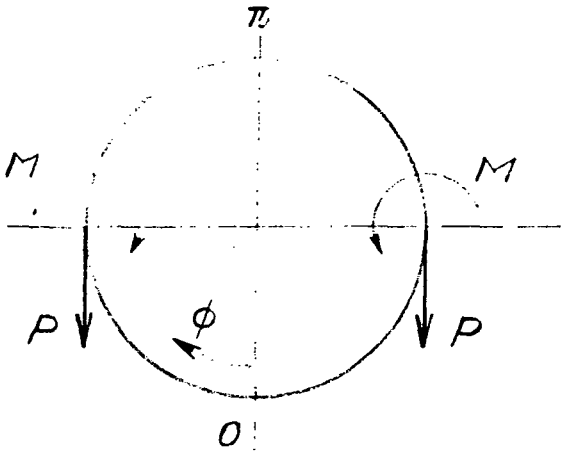
Governing loading is crash condition

Reaction at supports from floor V_{max} = 260#/in Ult. (p. 2.3.2)

P = 260 x 111 = 28800 lbs Ult.

Moment due to eccentricity:

M = P x (3" + 3 1/2") = 28800 x 6 1/2 = 187500#-in Ult.

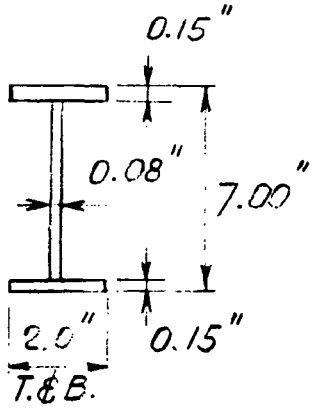


Internal Loads

A ring analysis was performed to determine the internal loads using the Free Ring curves of Reference 5, Sec. 3. By superposition of loading influences, the following maximum internal loads were computed:

At $\phi = 80°$ max M = 141000 #in Ult and N = 8620# Ult

At $\phi = 0°$ M = 85000 #in Ult and maxN = 22700# Ult



$I = 2.0 \times 0.15 \times 3.43^2 \times 2 = 7.0$

$0.08 \times 6.70^3/12 = \underline{2.00}$

$9.00\ in^4$

$A = 2 \times 0.15 \times 2 = 0.60\ in^2$

$0.08 \times 6.70 = \underline{0.54\ in^2}$

$1.14\ in^2$

Ring X-Section

Material: 7075-T6 Aluminum

$F_{cy} = 67{,}000$ (Ref. 2)

Section @ $\phi = 80°$

$$(f_{cu})_{max} = \frac{141000 \times 3.5}{9.00} + \frac{8620}{1.14} = 62100\#/in^2$$

$F_{cu} \approx F_{cy}$

$$M.S. = \frac{F_{cy}}{f_{cu}} - 1 = \frac{67000}{62100} - 1 = \underline{+0.08}$$

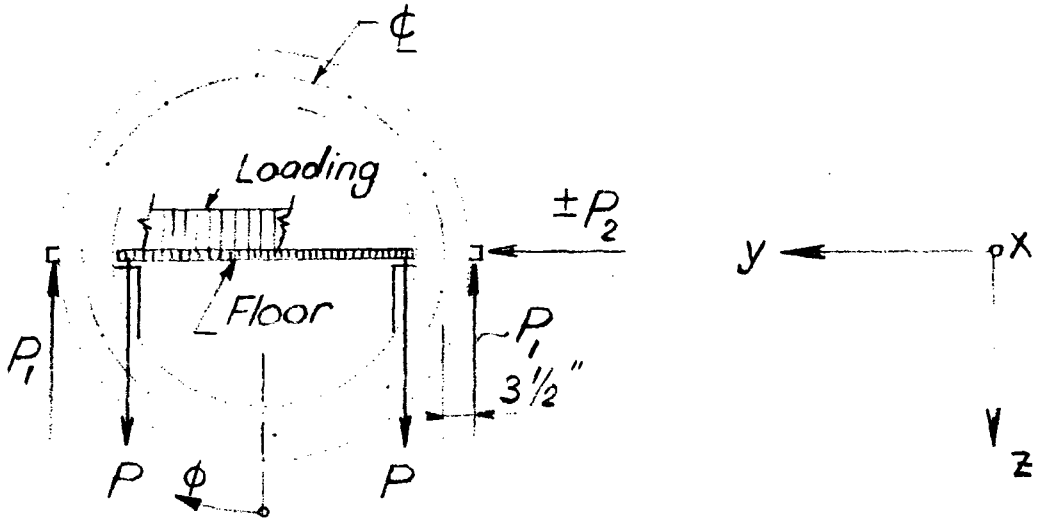
Section @ $\phi = 0°$

$$(f_{cu})_{max} = \frac{85000 \times 3.5}{9.00} + \frac{22700}{1.14} = 53000$$

$$M.S. = \frac{67000}{53000} - 1 = \underline{+0.26}$$

(b) End Frame

External Loading System



Governing loading is crash condition.

n_z = 4.5g Ult., n_y = ±1.5g Ult.

1g = 25000#

Factor of Safety F.S. = 1.0

} The load factors are conservatively applied simultaneously.

P = as before for intermediate frame = 28800 lbs Ult.

Shuttle Support Load, $P_1 = 25000 \left(\frac{1}{4}\right) 4.5 =$ 28100 lbs Ult.

$P_2 = 25000 \left(\frac{1}{2}\right) 1.5 =$ 18800 lbs Ult.

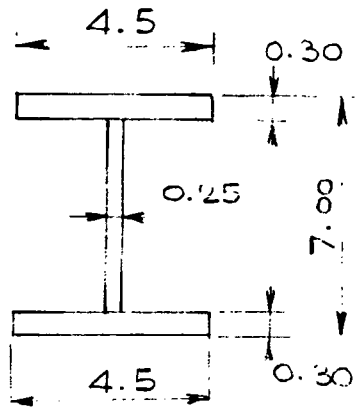
The influences of P are the same as for the intermediate frame. The influence of the load P_1 may be represented at the centerline by a concentrated load upwards (P_1) and on moment $M_1 = P_1 \times 3.5$

The maximum internal loads were determined by the same method as was used for the intermediate frame.

@ $\phi = 90°$ max M = 499500#in, N = 33100#

@ $\phi = 0°$ M = 194500, max N = 41030#

Assuming $F_{cu} \approx F_{cy}$ = 61,000 psi (Ref. 2)



(For Material 7075-T6,
for $\frac{b}{t} = 2.25/0.30 = 7.5 \Rightarrow \sigma_{cc}$ = 61 ksi)

$I = 4.5 \times 0.30 \times 3.20^2 \times 2 =$ 27.7

$\frac{0.25 \times 6.4^3}{12} =$ 5.46

33.16 in^4

Ring X-Section

$A = 4.5 \times 0.30 \times 2 =$ 2.70

$0.25 \times 6.40 =$ 1.60

4.30 in^2

Material & Allowable

@ $\phi = 90°$ $\quad (f_{cu})_{max} = \frac{499500 \times 3.5}{33.16} + \frac{33100}{4.30} = 60300\#/in^2$

M.S. $= \frac{61000}{60300} - 1 = \underline{+0.012}$

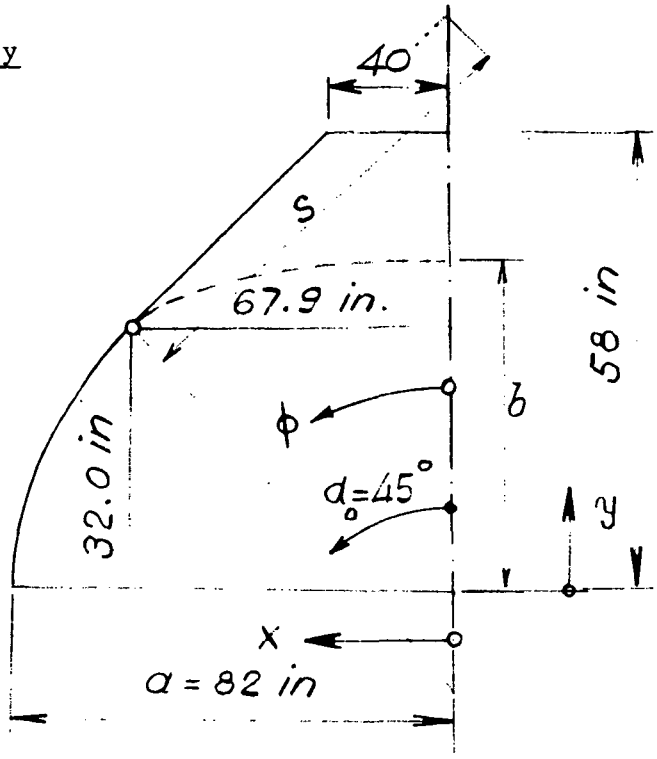
@ $\phi = 0°$ $\quad (f_{cu})_{max} = \frac{194500 \times 3.5}{33.16} + \frac{41030}{4.30} = 30100\#/in^2$

M.S. $= \frac{61000}{30100} - 1 = \underline{+1.03}$

2.2 END PRESSURE BULKHEADS

The cone-knuckle type end pressure bulkheads are formed by combining a cassinian shell and a conical shell. Because of the nature of the cassinian shell, there are no significant discontinuity stresses at the junctions with the cylindrical and conical sections.

Geometry



The meridian profile of the knuckle section is a curve of the cassini family, selected so that an aspect ratio of 1.5 could be employed (Ref. 6).

(a) For Cassinian part of shell:

$$\frac{a}{b} = 1.5; \quad a = 82 \text{ in}; \quad b = 54.6 \text{ in}$$

Equation of Cassini Curve,

$$x = 2a \sin\phi / (\sin\phi + 1)$$

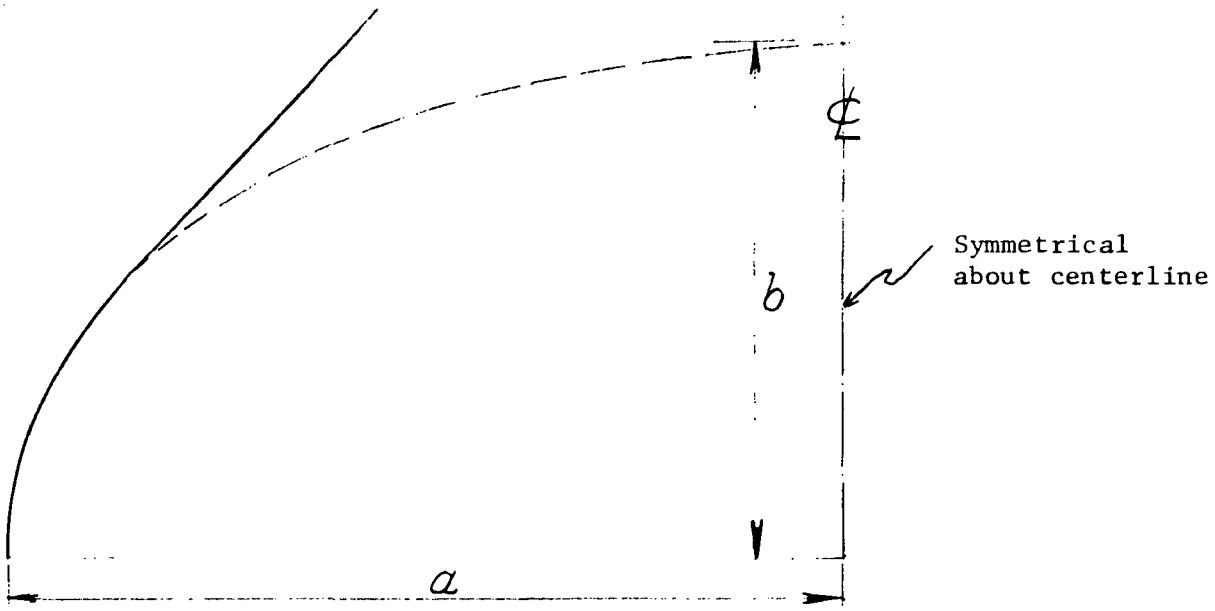
$$y = 2a \cos\phi \left[2 - \frac{1}{\sin\phi + 1} \right] \Big/ 3(\sin\phi + 1)$$

$$R_1 = \frac{2a}{(\sin\phi + 1)^2} \qquad R_2 = \frac{2a}{(\sin\phi + 1)}$$

Curve is defined with following table:

ϕ	x	y
45°	67.932	32.023
50°	71.20	28.600
60°	76.20	21.450
70°	79.50	14.300
80°	81.40	7.30
90°	82.00	0

Conical part as indicated on the sketch.



The governing loading-case is internal pressurization

$p = 14.9$ psi Limit, 29.8 psi Ultimate

Stress at junction of Cassini with cylinder:

$$N_\phi = \frac{R_2 P}{2} = \frac{82 \times 14.9}{2} = 610 \text{ lbs/in Limit}$$

$$f_\phi = 610/0.145 = 4200 \text{ psi Limit}$$

Space Operational Condition

Ult. F.S. = 2.0

$f_{Tu} = 2 \times 4200$ psi = 8400 psi ult.

$$(M.S.)_{ULT} = \frac{F_{tu}}{f_{tu}} - 1 = \frac{34,000}{8,400} - 1 = +3.05$$

Yield F.S. = 1.5

$$f_y = 8400 \frac{1.5}{2.00} = 6300 \text{ psi}$$

$$(M.S.)_y = \frac{F_y}{f_y} - 1 = \frac{23000}{6300} - 1 = +2.65$$

Check of Welding

$f_{TU} = 8400$ psi (with S.F. = 2.0)

$$M.S. = \frac{23000}{8400} - 1 = +1.74$$

(b) Conical Part of Shell

$$N_x = p \frac{s}{2} \cot \alpha_o = 14.9 \times 50 \times 1 = 745 \text{ lb/in.}$$

$$N_\theta = 2 N_x = 745 \times 2 = 1490 \text{ lb/in.}$$

Space Operational Condition

Ult F.S. = 2.0

$f_{tu} = 2 \times 1490/0.145 = 20600$ psi Ultimate

$$(M.S.)_{ULT} = \frac{F_{tu}}{f_{tu}} - 1 = \frac{34,000}{20,600} - 1 = +0.65$$

Yield F.S. = 1.5

$$f_y = 20600 \frac{1.5}{2.0} = 15500 \text{ psi}$$

$$(M.S.)_y = \frac{F_y}{f_y} - 1 = \frac{23,000}{15,500} - 1 = +0.48$$

Longitudinal Welds:

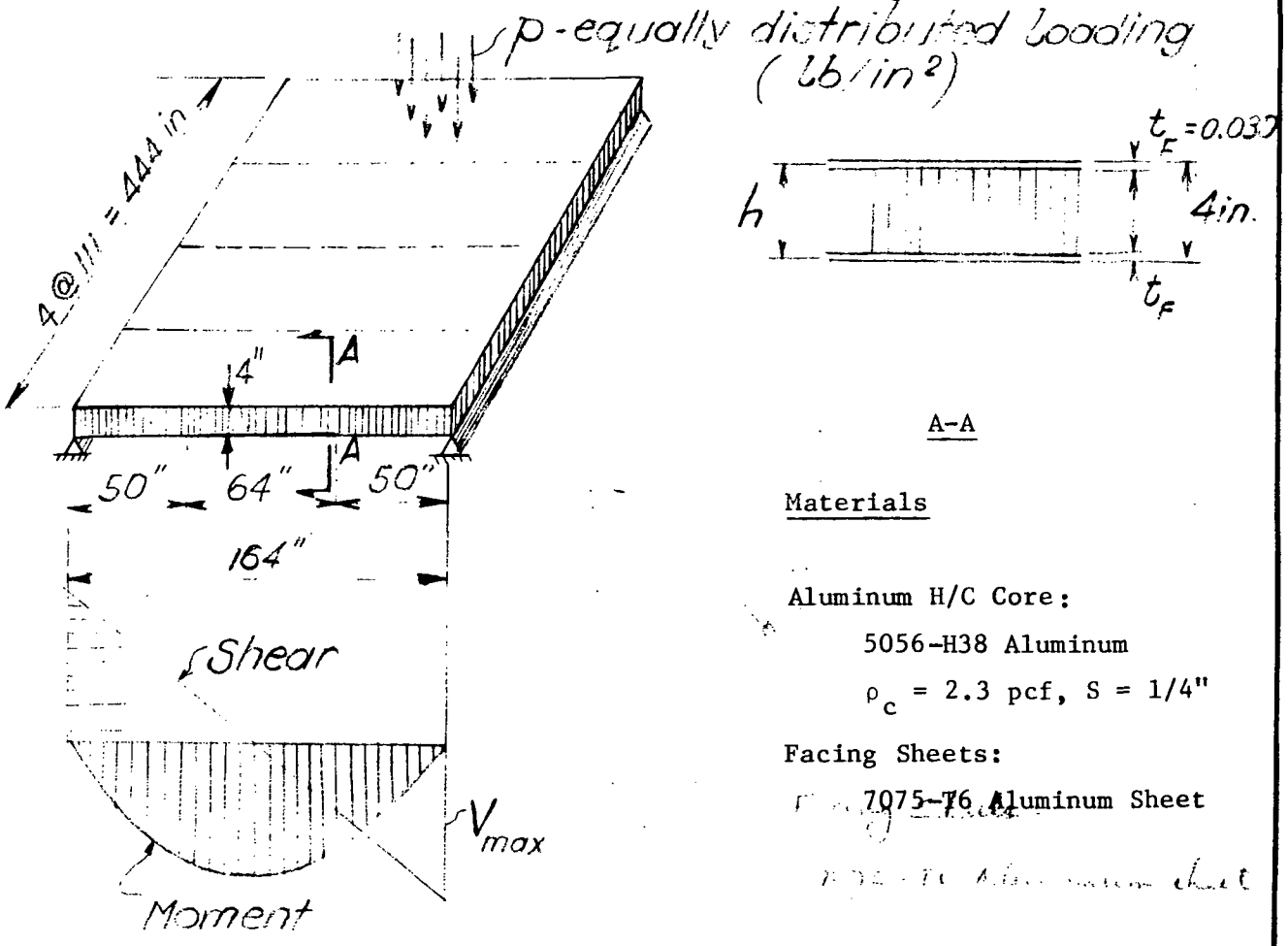
$$M.S. = \frac{23,000}{20,600} - 1 = .12$$

2.3 FLOORS

For the universal common module, there are two possible floor arrangements; one with a floor parallel to, and the other with floors transverse to the module longitudinal axis.

2.3.1 Longitudinal Floor

Floors that are continuous over the entire module length are assumed simply supported along longitudinal edges only. For the split-level floors in the crewman stateroom areas the floors are assumed simply supported on three sides. A factor of 1.5 is used to account for nonuniform pressure distribution.



A-A

Materials

Aluminum H/C Core:

5056-H38 Aluminum

ρ_c = 2.3 pcf, S = 1/4"

Facing Sheets:

7075-T6 Aluminum Sheet

Crash Condition

$n_z = -4.5g$ Ult.

$$\text{Mod. Vol.} = \frac{(406)(\pi)(82)^2}{1728} + \frac{2}{3}\pi\,(38)\left[(45)^2 + 45(82) + (82)^2\right]\frac{1}{1728} =$$

$$= 4960 + 576 = 5536\ \text{ft}^3$$

$$\text{Average Vol. Density} = \frac{25000}{5536} = 4.5\ \text{lb/ft}^3$$

It is assumed the maximum volume density for single floor bay (111 in. length) can be 1.5 x Avg. Vol. Density

$$(\rho_{vol})_{max} = 1.5(4.5) = 6.8\ \text{psf}$$

$$p = \frac{(4960)(6.8)}{4(111)(164)}\,(4.5)(1.5) = 3.15\ \text{psi Ult.}$$

$$M_{max} = \frac{(3.15)(164)^2}{8} = 11000\ \text{in-lb per inch width Ult.}$$

$$f_{bo} = \frac{Mc}{I} = \frac{11000 \times 2.00}{\frac{1}{12}(4^3 - 3.94^3)} = 66000\ \text{psi}$$

$$F_{cy} = 67000\ \text{psi (Ref. 2)}$$

$$\text{M.S.} = \frac{67000}{66000} - 1 = \underline{+0.02}$$

At Supports

$$V_{max} = 82p = 82 \times 3.15 = 260\ \text{lb/in}$$

$$\frac{V_{max}}{h} = 260/4 = 65\ \text{psi}$$

$$F'_S = 125\ \text{ksi} \times 0.6 = 75\ \text{psi} \qquad \text{(Ref. 7, page 31.13.00.05.01)}$$

$$\text{M.S.} = \frac{75}{65} - 1 = \underline{+0.15}$$

Intracell Buckling (Ref. 5, page 11.31.01):

$t/s = 0.03/0.25 = 0.12 > 0.06$

$$K_L = 2.28\left(\frac{t}{s}\right)^2 = 2.28(0.12)^2 = 0.03285$$

$$\frac{\sigma_s}{\eta} = \frac{K_L E}{1-\mu^2} = \frac{0.03285 \times 10.5 \times 10^6}{0.89} = \underline{\underline{.389 \times 10^6}} \text{ psi} >> F_{cy}$$

Dimpling (Ref. 5, page 11.31.03):

$$\frac{\sigma_o}{\eta} = 2\,\frac{E}{1-\mu^2}\left(\frac{t}{s}\right)^2 = 2\,\frac{10.6 \times 10^6}{0.89}\,(0.12)^2 = \underline{\underline{.343 \times 10^6}} \text{ psi} >> F_{cy}$$

Face Sheet Wrinkling (Ref. 5, page 11.32.02):

$$\frac{\sigma_{cr}}{\eta} = K_L \sqrt[3]{E\,E_c\,G_c} \qquad \text{For } \rho = 2.3 \begin{cases} E_c = 48 \text{ ksi} \\ G_c = 13 \text{ ksi} \end{cases}$$

(Ref. 7, pages 31.13.00.08.01 and 31.13.00.09.01)

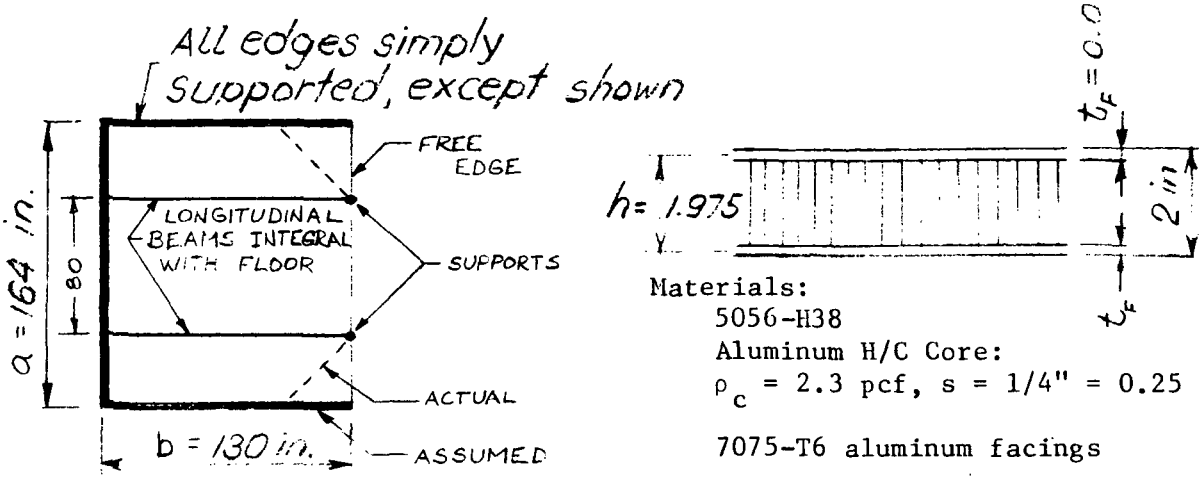
$$= 0.43 \sqrt[3]{10500 \times 48 \times 13} \qquad \begin{aligned} E &= 10500 \text{ ksi} \\ K_L &= 0.43 \end{aligned}$$

$$= 80.4 \text{ ksi} >> F_{cy}$$

Assume Max. Allow. Comp. Stress = F_{cy} = 67000 psi (Ref. 2)

2.3.2 Split Level Deck (SM-1 & SM-4 Staterooms)

The section of the split level deck that separates crewmen staterooms is supported by attachment to the pressure shell on three sides and by two parallel longitudinal beams. The longitudinal beams are supported at one end by the transverse beam at the juncture of the split levels and the ring at the juncture of the end bulkhead and berthing port.



Materials:
5056-H38
Aluminum H/C Core:
ρ_c = 2.3 pcf, s = 1/4" = 0.25
7075-T6 aluminum facings

The stateroom floor is conservatively analyzed as a rectangular plage supported on three sides. See Roark pg. 228, Case 48 (Ref. 8). The longitudinal beams serve to furnish redundant strength and stiffness.

$$\frac{b}{a} = \frac{130}{164} = 0.79 \approx 2/3$$ in order to use Timoshenko's method (Ref. 9)

Total floor load, consisting of various stateroom furnishings, is conservatively estimated to be 2000# Limit

or $$q' = \frac{2000\#}{130 \times 164} = 0.094 \approx \underline{0.1}\#/in^2$$

Uneven pressure distribution factor = 2.0

$$n_z = 4.5g \text{ Ult. (Crash Condition)}$$

Consequently:

$$q = q' \times 2.0 \times 4.5 = \underline{0.9} \text{ psi Ult.}$$

For $x = \frac{a}{2}$, $y = b$

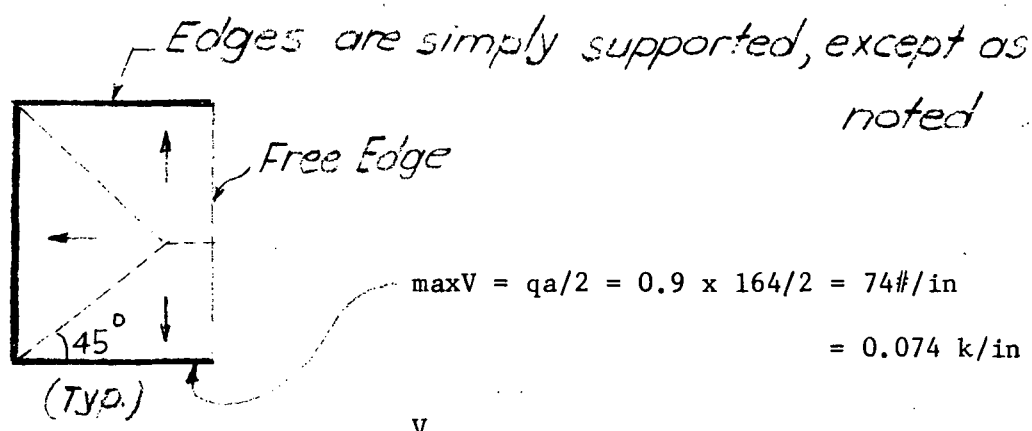
$$(M_x)_{max} = 0.083\ qa^2 = 0.083 \times 0.9 \times 164^2 = \underline{2010\#"}$$

$$f_{BU} = \frac{(2010)}{(1.975)(.025)} = 40{,}750 \text{ psi}$$

Assume $F_{BU} \approx F_{cy} = 67{,}000$ psi (Ref. 2)

$$M.S. = \frac{67{,}000}{40{,}750} - 1 = \underline{.64}$$

Distribution of reactions:



$$\frac{V_{max}}{h} = \frac{0.074 \text{ k/in}}{1.975 \text{ in}} = 0.0375 \text{ k/in}^2$$

$F_s' = 0.125$ ksi $\times$ 0.70 = 0.0875 ksi (Ref. 7, page 31.13.00.05.01)

$$M.S. = \frac{875}{375} - 1 = \underline{+1.33}$$

Intracell Buckling (Ref. 5, page 11.31.01):

$t/s = 0.025/0.25 = 0.1 > 0.06$

$$K_L = 2.28 \left(\frac{t}{s}\right)^2 = 2.28\ (0.1)^2 = 0.0228$$

$$\frac{\sigma_s}{\eta} = \frac{K_L E}{1 - \mu^2} = \frac{0.0228 \times 10.5 \times 10^6}{0.89} = \underline{0.27 \times 10^6} >> F_{cy}$$

Dimpling (Ref. 5, page 11.31.03):

$$\frac{\sigma_o}{\eta} = 2\,\frac{E}{1-\mu^2}\left(\frac{t}{s}\right)^2 = 2\,\frac{10.6 \times 10^6}{0.89}\,(0.1)^2 = \underline{\underline{0.24 \times 10^6}} \gg F_{cy}$$

Face Sheet Wrinkling (Ref. 5, page 11.32.02):

$$\frac{\sigma_{cr}}{\eta} = K_L \sqrt[3]{E E_c G_c}$$

For $\rho = 2.3$ $\begin{cases} E_c = 48 \text{ ksi} \\ G_c = 13 \text{ ksi} \end{cases}$ (Ref. 7, pages 31.13.00.08.01 and 31.13.00.09.01)

$E = 10500$ ksi

$K_L = 0.43$

$$= 0.43 \sqrt[3]{10500 \times 48 \times 13} =$$

$$= 0.43 \sqrt[3]{6550000} = 0.43 \times 187 = \underline{\underline{80.4}} \text{ ksi} \gg F_{cy}$$

Assume Max. Allow. Comp. Stress = F_{cy} = 67000 psi (Ref. 2)

2.3.3 Transverse Floors

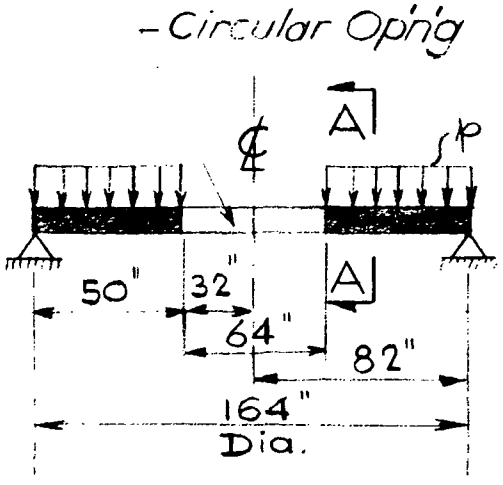
Assume: 2/3 total module weight is on floors
Factor for unequal distribution between floors = 1.5
Factor for nonuniform pressure distribution = 1.5
No. Floors = 4.0

Loading at crash condition:

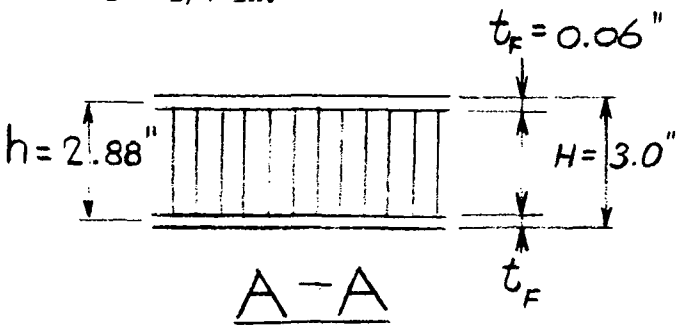
$$n_x = 8.0 \text{ g Ult.}$$

$$p = \frac{2}{3}\frac{(25{,}000)(8.0)(1.5)^2}{(4)(\pi)(82^2 - 32^2)} = \underline{4.2} \text{ psi Ult.}$$

Floor System:



Material
7075-T6 Al-F/S
5056-H38 Hexagon Honeycomb Core
ρ = 2.3 lb/cu. ft.
s = 1/4 in.



Determination of maximum stress:

Reference 8 , page 220, formula 13

$$s_{max} = s_t = -\frac{3p}{4m(6t_F h)(a^2-b^2)}\left[a^4(3m+1) + b^4(m-1) - 4\,ma^2b^2 - 4(m+1)\,a^2b^2\log_e\frac{a}{b}\right]$$

(modified for sandwich construction by substitution $t^2 = 6\,t_F h$)

$a = 82$ in $\quad b = 32$ in $\quad m = \frac{1}{\mu} = \frac{1}{0.33} = 3.03$

$$\log_e\left(\frac{a}{b}\right) = 2.3026\,\log_{10}\left(\frac{a}{b}\right)$$

Solving for s_{max} delivers $s_{max} = s_t = 58500$ psi

$$M.S. = \frac{67000}{58500} - 1 = \underline{+.114}$$

Shear at outside support

$$f_{su} = \frac{\pi(82^2 - 32^2)p}{2\pi(82)h} = 50.4 \text{ psi}$$

The lightest core with $\rho = 2.3$ lb/cu.ft. and $s = \frac{1}{4} = 0.25$ is used

$F'_s = 0.63 \times 0.127$ ksi $= 0.08$ ksi (Ref. 7, page 31.13.00.05.01)

$$F.S. = \frac{0.08}{.0504} - 1 = \underline{0.59}$$

Intracell Buckling (Ref. 5, page 11.31.01):

$$\sigma_{cr} = \frac{K_L E}{1 - \mu^2} \qquad t/s = \frac{0.06}{0.25} = 0.24 > 0.06$$

For $t/s > 0.06$, $K_L = 2.28 \left(\frac{t}{s}\right)^2 = 2.28 \times 0.24^2 = 0.131$

$$\frac{\sigma_{cr}}{\eta} = \frac{0.131 \times 10.5 \times 10^6}{0.89} = 1.54 \times 10^6 \text{ psi} >> F_{cy}$$

Dimpling (Ref. 5, page 11.31.03):

$$\frac{\sigma_o}{\eta} = 2 \frac{E}{1 - \mu^2} \left(\frac{t}{s}\right)^2 = 2 \frac{10.6 \times 10^6}{0.89} (0.24)^2 = 1.37 \times 10^6 \text{ psi} >> F_{cy}$$

Face Sheet Wrinkling (Ref. 5, page 11.32.02):

$$\frac{\sigma_{cr}}{\eta} = K_L \sqrt[3]{E\, E_c\, G_c}$$

For $\rho = 2.3 \Rightarrow \begin{cases} E_c = 48 \text{ ksi} \\ G_c = 20 \text{ ksi} \end{cases}$ (Ref. 7, page 31.13.00.08.01 and 31.13.00.09.01)

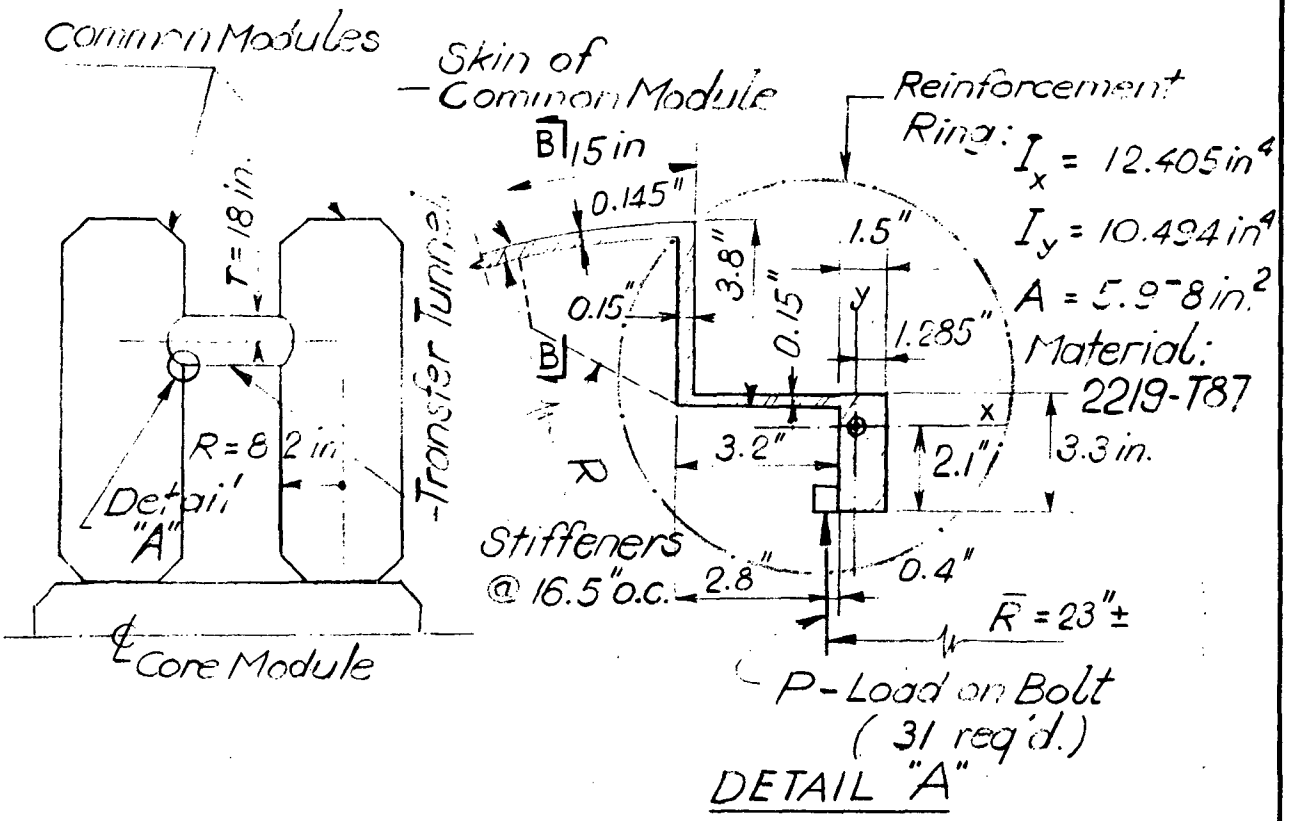
$E = 10500$ ksi

$K_L = 0.43$

$$\frac{\sigma_{cr}}{\eta} = 0.43 \sqrt[3]{10500 \times 48 \times 20} = 0.43 \times 187 = 80.4 \text{ ksi} > F_{cy}$$

Assume maximum allowable compression stress $F_{cy} = 67000$ psi (Ref.2)

2.4 TRANSFER TUNNEL REINFORCEMENT RING



The interaction between the transfer tunnel reinforcement ring and the common module shell during tunnel pressurization is of such complexity as to make an exact solution during the space station preliminary design phase impractical. To circumvent this problem, a simplified approach is used which relies on simplicity and conservatism to substantiate the structural adequacy of the common module reinforcement for the cutout required to accommodate the transfer tunnel. The simplified analysis allows the reinforcement ring to absorb the distributed moment due to the eccentric application of the tension loads in the meridional direction of the transfer tunnel. The skin of the common module reacts the direct load applied in the meridional direction of the transfer tunnel and a moment introduced by the twisting of the reinforcement ring(1) The ring and shell are conservatively assumed to react these loadings independently. If the interaction of ring and shell were considered, the stresses would be less than those for the simplified analysis presented below.

Loading:

Pressurization $p = 14.7 + 0.2 = 14.9\#/in^2$

Factor of Safety F.S. = 1.75

(1) The two loading conditions are conservatively assumed to occur simultaneously even though the moment due to eccentricity occurs after the tunnel is deployed, whereas the direct load occurs during deployment of the tunnel.

Ring

$$P = \frac{14.9 \times 1.75 \times \pi \times 23^2}{2 \pi 23} = 300\#/\text{in.}$$

Eccentricity of load:

$e = 1.5 + 0.4 - 1.285 = 0.615$ in.

Torsional moment:

$M = P \cdot e = 300\#/\text{in.} \times 0.615 = 185\#\text{in./in}$

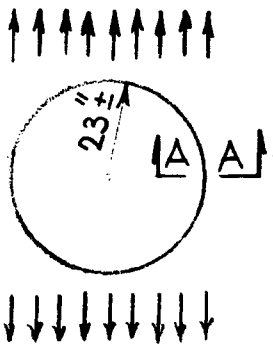
There are no torsional stresses in the ring (Ref. 8, page 231, 3rd edition).

The ring is subjected to a bending moment at every section equal to $M\bar{R}$, the neutral axis being the central axis of the cross-section in the plane of the ring. The maximum resulting stress occurs at the extreme fiber and is given by equation:

$$s = \frac{M \bar{R}}{I/c} = \frac{185 \times 23}{2.48} = 1720 \text{ psi}$$

$(I_x/c_1 = 12.405/5.00 = 2.48;\ I_y/c_2 = 10.494/3.415 = 3.05)$

Due to pressurization (membrane stresses in skin of common module):



$N_\theta = pR(F.S.) = 14.9 \times 1.75 \times 72 = 1880\#/\text{in}$

At Section A-A

$1880 \times 25.8\pm = \quad 48500\#$

$\sigma = 48500/5.978 = \quad 8130$ psi

The total stress

$$\sigma_{TOT} = 1720 \text{ psi} + 8130 \text{ psi} = \underline{9850} \text{ psi}$$

$$M.S. = \frac{51000}{9850} - 1 = \underline{+4.18}$$

Skin of Cylinder

For the purpose of analysis simplification, the skin of the cylinder is assumed to be similar to a simply supported circular flat plate.

The analysis is performed in accordance with Reference 5, pages 5.11.05 and 5.12.02.

The opening around the edge is loaded by a torsional moment which is induced from the reinforcement ring around the opening and by a concentrated load P, equally distributed along the opening.

Torsional Moment

The ring around the opening was rotated to the angle θ

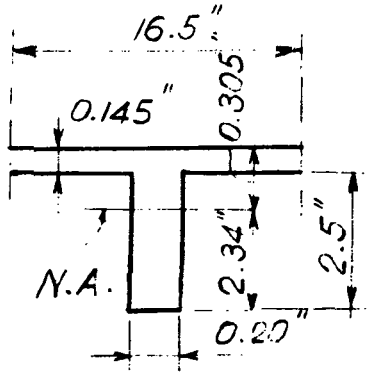
$$\theta = \frac{s\,R}{E\,c} = \frac{1720 \text{ psi} \times 23}{10.5 \times 10^6 \times 5.00} = 0.000754$$

Assuming that the edge of the opening is rotated to the same angle θ, a moment M is determined, which induces θ at the opening edge of the plage (Ref. 5, page 5.12.02).

$$\theta = \beta = \frac{Ma}{D} \frac{k_b}{1+\mu}\left(\rho + \frac{1+\mu}{1-\mu} \cdot \frac{1}{\rho}\right) = 0.000754$$

$$M = \frac{0.000754\ D\ (1+\mu)}{a\ k_b \left(\rho + \frac{1+\mu}{1-\mu}\ \frac{1}{\rho}\right)} \qquad \text{where } D = \frac{E\,t^3}{12(1-\mu^2)}$$

Section B-B



$I = 1.2962 \div 16.5 = 0.0786 \text{ in}^4 \text{ per inch}$

$$\frac{t_{eq}^3}{12} = 0.0786 \qquad t_{eq} = 0.98 \text{ in.}$$

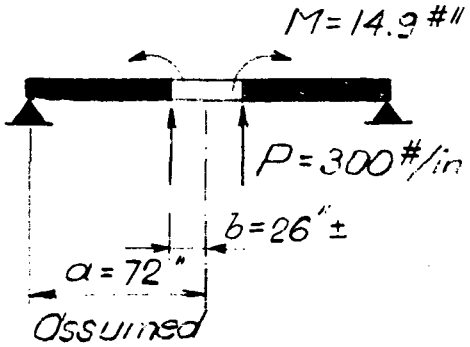
$$D = \frac{10.5 \times 10^6 \times 0.98^3}{12\ (1 - 0.33^2)} = 925000$$

$b = a\beta = 26"; \quad \beta = 0.36 \qquad k_b = \frac{\beta^2}{1-\beta^2} = \frac{0.36^2}{1-0.36^2} = 0.15$

For edge of opening $\rho = \beta = 0.36$

Consequently

$$M = \frac{0.000754 \times 925000 \times 1.33}{72 \times 0.15 \left(0.36 + \frac{1.33}{0.67}\ \frac{1}{0.36}\right)} = 14.9\#" \qquad \text{Very small.}$$



This moment will cause negligible M_r and M_t.

Due to P the influences are determined from Reference 5, page 5.11.05.

$$k_4 = (1 + \mu) \frac{\beta 2}{1 - \beta^2} \ln \beta = 0.15 \times 1.33 \times 1.0 = 0.20$$

(For the edge $\rho = \beta = 0.36$, $\ln \beta = 2.3 \log \beta = 2.3 \times 0.444 = 1.00$)

The tangential moment at the edge of the opening is governing.

$$M_t = \frac{Pa}{2} \beta \left[1 - \mu - k_4 \left(\frac{1}{\rho 2} + 1\right) - \left(1 + \mu\right) \ln \rho\right] =$$

$$= \frac{300 \times 72}{2} \; 0.36 \left[1 - 0.33 - 0.20 \left(\frac{1}{0.36^2} + 1\right) - \left(1 + 0.33\right) 1\right]$$

$$= 1000\#"$$

For Section B-B the moment of inertia is 0.0786 in^4/in. Consequently:

$$\sigma = \frac{1000 \times 2.34}{0.0786} = \qquad = 29800\#/in^2$$

Stress due to membrane influences $\frac{1880\#/in}{0.145 \text{ in.}} = 13000$ "

$$\sigma_{TOT} = 42800\#/in^2$$

Margin of safety:

$$M.S. = \frac{51000}{42800} - 1 = \underline{+0.19}$$

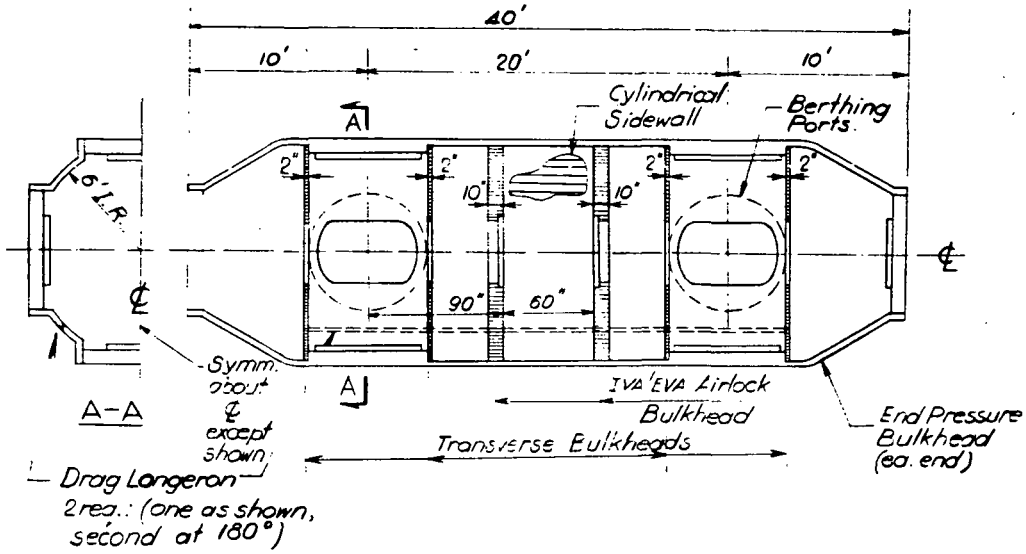
To be on safe side it was conservatively assumed that the tangential moment, $M_t = 1000\#in.$, also acts in the radial direction of the plate. By inspection it can be seen that the strength of the skin is even larger in circumferential direction than in the radial direction.

The above approximate analysis is satisfactory for the maximum stresses located around the opening. All discontinuity disturbances become negligible at distance d which is governed by an angle of 10° from the edge:

$$\frac{d}{r} = \tan 10° = 0.17$$

$$\therefore d = 0.17 \times r = 0.17 \times 82 = 13.9 \text{ in} < 15 \text{ in} \quad \text{ok}$$

3.0 CORE MODULE

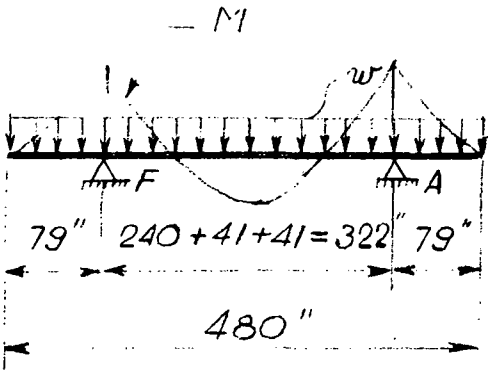


CORE MODULE
Configuration

Above figure represents the core module. Structurally, it is a cylindrical pressure vessel with two end cone-knuckle bulkheads, 6 intermediate circumferential floors, and two longitudinal drag longerons. The drag longerons distribute loads induced by the shuttle supports.

3.1 CYLINDRICAL SIDEWALL

Transverse Load System:



Influences for 1 g:

$w = 25000/480 = \underline{52}\#/in$

System (a) - 1 g loads

$M_F = M_A = 52 \times \frac{79^2}{2} = \underline{162500}\#in$

$M_{C_L} = 52 \times 322^2/8 - 162500 =$

$= 675000 - 162500 = \underline{512500}\#in$

$P_F = 25000$ lbs.

$P_{C_L} = 25000/2 = 12500$ lbs.

End Boost Condition:

η_x = 3.3g limit $\qquad$ η_y = .11g limit

η_z = .55g limit

$$\eta_{LAT} = \left[(.11)^2 + (-.55)^2\right]^{1/2} = .561g$$

Maximum running load, N_x, occurs at the aft supports.

$M_F = (162500)(.561)(1.5) =$ 137,000#in Ult.

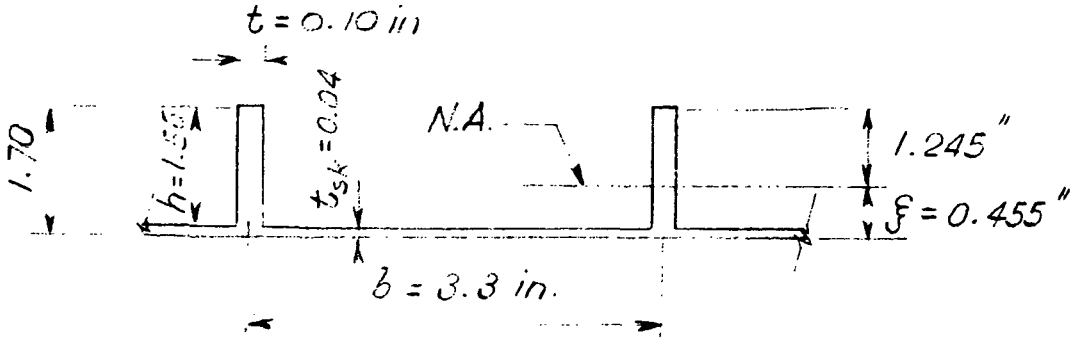
$P_F = (25000)(3.3)(1.5) =$ 124,000# Ult

$$(N_x)_F = \frac{Mc}{I} + \frac{P_F}{\pi D} = \frac{M}{\pi R^2} + \frac{P_F}{\pi D} =$$

$$= \frac{137,000}{\pi (72)^2} + \frac{124000}{\pi \times 144} = 8.4 + 274 = 282.4\#/\text{in Ult.}$$

Skin/Stringer Section:

Material: 2219-T87 Aluminum



$$\bar{t} = \frac{(3.3)(0.04) + (0.1)h}{3.3} = 0.0875$$

Stability of Skin:

$$(\sigma_x)_{cr} = K_x \frac{\pi^2 E}{12\,(1-\mu^2)} \left(\frac{t_{sk}}{b}\right)^2 =$$

$$= 4 \frac{(9.88)(10^6 \times 10.5)}{12\,(0.891)} \frac{0.04^2}{3.3^2} = 5700 \text{ psi}$$

$$\sigma_x = \frac{282.4}{0.0875} = 3230 \text{ psi}$$

$$\text{M.S.} = \frac{5700}{3230} - 1 = \underline{+0.76}$$

Panel Stability: (Ref. 10, page 6)

$$\sigma_{cr} = c \frac{\pi^2 E}{(L/\rho^2)} + \gamma \frac{E}{\sqrt{3}} \left(\frac{t_{sk}}{R}\right) \sqrt{\frac{t_{sk}}{\bar{t}}}$$

where:

L = 82 in.

R = 72 in.

t_{sk} = 0.04 in.

E = 10.5 x 10^6 psi

c = end fixity coefficient = 1.0 (pinned ends)

γ = correlation constant dependent on panel stiffness

ρ = radius of gyration

$\bar{t}$ = x-sectional area per inch of circumference

$= t_{sk} + \frac{ht}{b}$

$$\sigma_{cr} = \frac{(1)\pi^2 \times 10.5 \times 10^6}{82^2}\rho^2 + \gamma \frac{10.5 \times 10^6}{1.73}\left(\frac{0.04}{72}\right)\sqrt{\frac{0.04}{0.0875}}$$

Determination of ρ^2

$1.56 \times 0.10 = 0.156$	$\times 0.82 = 0.128$
$3.3 \times 0.04 = \underline{0.132}$	$\times 0.02 = \underline{0.00264}$
$A = 0.288$ in^2	$S = 0.13064$ in^3

$\xi = S/A = 0.455$ in.

$I_x = 0.156 \times 0.465^2 = 0.0338$

$0.132 \times 0.435^2 = 0.0250$

$3.3 \times 0.04^3/12 = 0.0001$

$0.1 \times 1.56^3/12 = 0.0315$

$\overline{0.0904}$ in^4

$\rho^2 = I_x/A = \underline{0.314}$

Determination of γ

$$\left(\frac{R}{\frac{I_x t_{sk}^2}{12\bar{t}}}\right)^{\frac{1}{4}} = \frac{72}{\left(\frac{0.0904 \times 0.04^2}{12 \times 0.0875}\right)^{\frac{1}{4}}} = 663 \Rightarrow \gamma = 0.785$$

(Fig. 7 of Ref. 10)

$\sigma_{cr} = 15500 \times 0.314 + 2260 \times 0.785 = 6630$ psi

$\sigma_x = 282.4/0.0875 = \underline{3230}$ psi

M.S. $= \frac{6630}{3230} - 1 = \underline{+1.05}$

Orbital Operations:

$p = 29.8$ psi Ult.

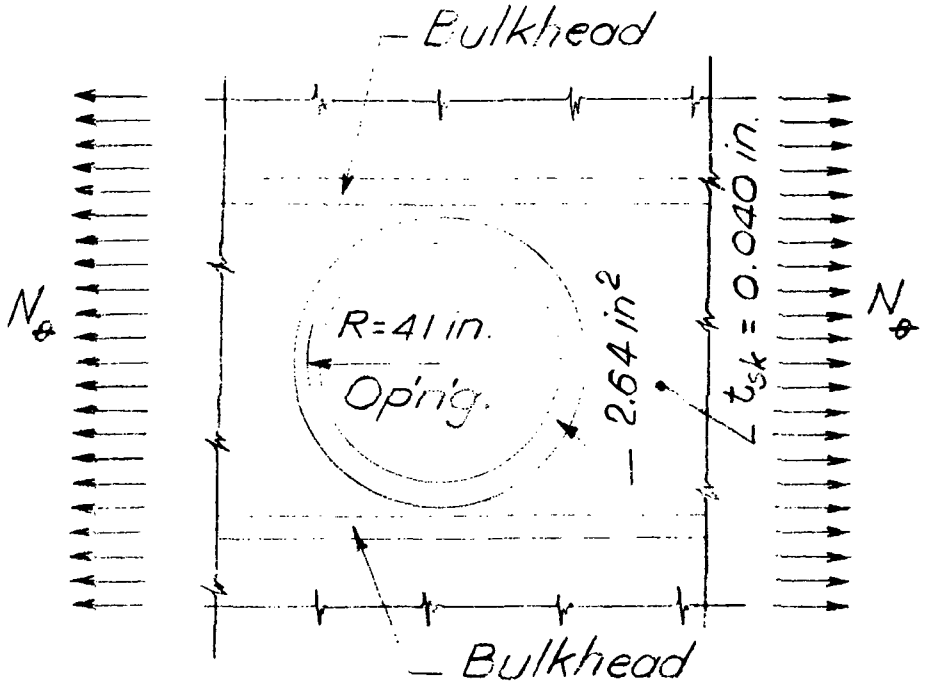
$f_{TU} = \frac{pR}{t} = \frac{(29.8)(72)}{.040} = 53{,}600$ psi

$F_{TU} = 63{,}000$ psi (Ref. 2)

M.S. $= \frac{63{,}000}{53{,}600} - 1 = \underline{.175}$

3.1.1 Berthing Ports

The maximum reinforcing ring stress occurs during the orbital condition and is due to circumferential membrane loads in the shell resulting from internal pressure. The effects of the longitudinal loads on the ring are conservatively neglected.



Internal pressure p = 14.7 ±.2 = 14.9 psi

For orbital operation long-term sustained loads

Factor of Safety F.S. = 2.0

To determine stresses due to internal pressure, the method of Ref. 4, Sec. 8.5 is used.

Circumferential Stress:

$N_\theta = p\ R\ (F.S.) = 14.9 \times 72 \times 2.0 = 2140\#/in$

$\sigma = 2140/0.04 = 53500$ psi

$$\bar{\sigma} = \frac{P}{A_s + .58A_{RG}} \approx 63{,}000$$

Where

P = Total Panel Load = N x b = 2140#/in x 82 = 175500#

A_{RG} = Ring Area (2 Sections) = is determined below.

A_S = Total Area of Skin = 0.04 (82.0 - 82) = 0

$\bar{\sigma}$ = Average stringer and skin stress

σ_{max} = Maximum stress in first stringer adjacent to cutout.

Section of ring = 5.28 $in^2/2$ = 2.64 in^2

$$\bar{\sigma} = \frac{175500}{0 + 0.58(5.28)} = \frac{175500}{3.06} = 57500 \text{ psi}$$

For Material 2219-T87

$F_{tu} \approx F_{Bu} = 63{,}000$ (Ref. 2)

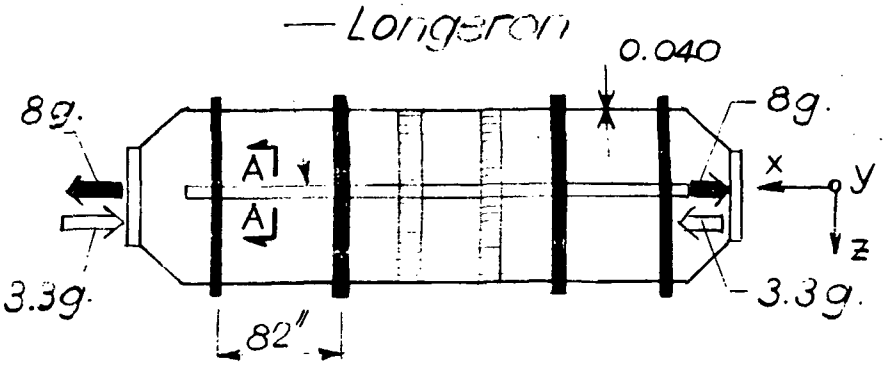
$$\text{Cutout M.S.} = \frac{F_{tu}}{\bar{\sigma}_{max}} - 1 = \frac{63000}{57500} - 1 = +0.09$$

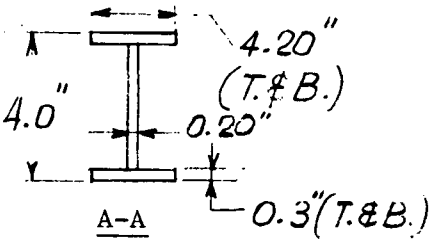
Ring Stress, $\sigma_{RG} = .58\ \bar{\sigma} = .58 \times 57500 = 33300$ psi

$$\text{Ring M.S.} = \frac{F_{tu}}{\sigma_{RG}} - 1 = \frac{63{,}000}{33{,}300} - 1 = +0.89$$

3.1.2 Drag Longerons

The functions of the two drag longerons are: (a) to distribute the longitudinal concentrated loads that occur at the aft trunnion supports, and (b) to react floor loadings induced by lateral (y and z) accelerations into the cylindrical shell.





$A = 3.20\ in^2$
$I = 9.45\ in^4$

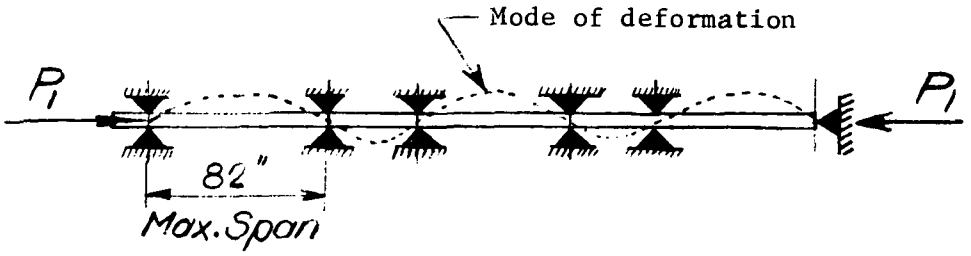
The following loading conditions are governing:

		n_x	n_y	n_z	F.S.
(1)	Booster End Burn	3.3	±0.1	-0.5	1.5
(2)	Crash (Cargo & Equipment)	-8.0	+1.5	-4.5	1.0

1 g = 25000#

(1) Loading Conditions - Booster End Burn

Structural System of Longeron:



(a) Longitudinal Compression

$$P_1 = 25000\# \frac{1}{2} \times 3.3 \times 1.5 = 62000 \text{ lbs Ult.}$$

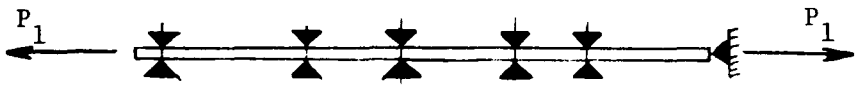
The mode of deformation for the case when transverse floors are used is such that the critical buckling load is:

$$P_{cr} = \frac{\pi^2 E I}{L^2} = \frac{\pi^2 \times 10.5 \times 10^6}{82^2} 9.45 = 144000 \text{ lbs}$$

$$\text{M.S.} = \frac{144000}{62000} - 1 = \underline{\underline{+1.32}} \text{ (not governing)}$$

(2) Loading Conditions - Crash

Structural System of Longeron



Longitudinal Tension

$$P_1 = 25000 \times \frac{1}{2} \times 8.0 \times 1.0 = 100000 \text{ lbs}$$

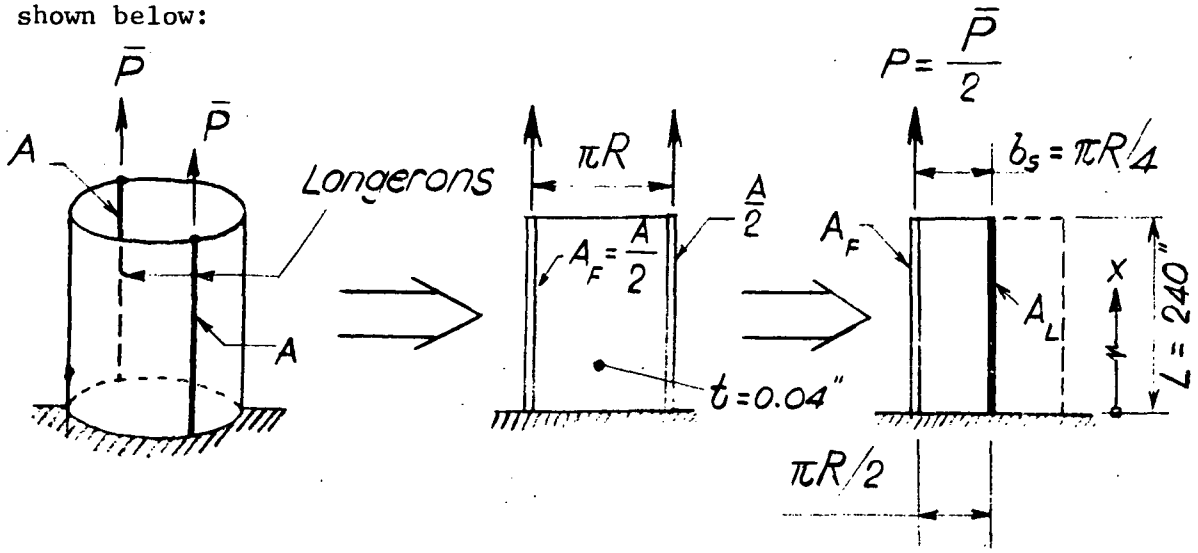
$$\sigma_{Tens} = 100000/3.20 = 31300 \text{ psi}$$

$$F_{TU} = 63000 \quad \text{(Ref. 2)}$$

$$\text{M.S.} = \frac{63000}{31300} - 1 = \underline{\underline{+1.01}}$$

Shear Analysis

The stress in the stiffened (longerons) part of the shell is computed by the "substitute-single-stringer method" of Reference 4, Section 4-6. For analysis simplification the panels are conservatively assumed as being flat. The sequence of logical assumptions for the above mentioned method is shown below:



$\overline{P}$ = 100000 lbs (page 3.1.8)

$P = \frac{\overline{P}}{2}$ = 50000 lbs

$b_s = \frac{\pi R}{4} = \frac{\pi\ 72}{4}$ = 56.5 in

Substitute Section

$A_F = 3.20/2 = 1.60\ in^2$

$A_L = 0.04 \times 56.5 \times 2 = 4.5\ in^2$

$$K = \sqrt{\frac{Gt}{b_s E}\left(\frac{1}{A_F} + \frac{1}{A_L}\right)} =$$

$$= \left[\frac{4.0 \times 10^6 \times 0.04}{56.5 \times 10.5 \times 10^6}\left(\frac{1}{1.60} + \frac{1}{4.5}\right)\right]^{\frac{1}{2}} = \underline{0.0151}$$

The distance, L_{eq}, from the lower end to the point where σ_F and σ_L (stress corresponding to areas A_F and A_L) are equalized with 1% margin, is:

$$L_{eq} = \frac{4.6}{K} = \frac{4.6}{0.0151} = 304 \text{ in}$$

$$L = 82 + 79 + 79 + 82 = 322 \text{ in}$$

$$A_T = A_L + A_F = 1.60\ in^2 + 4.5\ in^2 = \underline{6.10}\ in^2$$

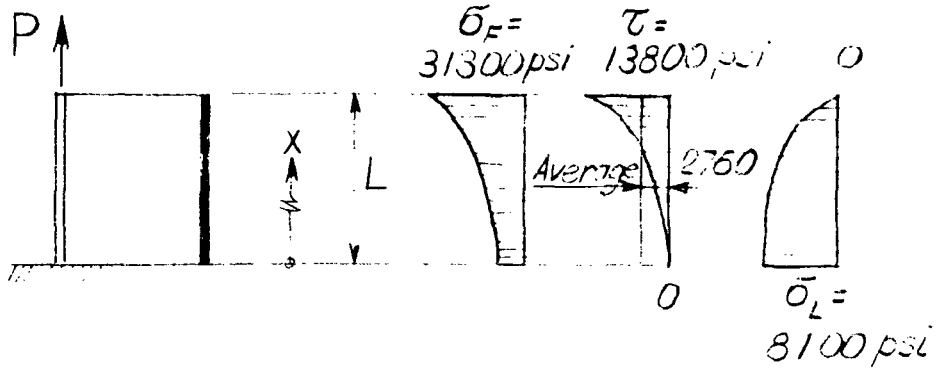
The shear stress, τ, and direct stresses, σ_F and σ_L, were determined in accordance with the following formulas for several points along the x-coordinate.

$$\sigma_F = \frac{P}{A_T}\left(1 + \frac{A_L}{A_F}\frac{\text{Cosh } Kx}{\text{Cosh } KL}\right)$$

$$\sigma_L = \frac{P}{A_T}\left(1 - \frac{\text{Cosh } Kx}{\text{Cosh } KL}\right)$$

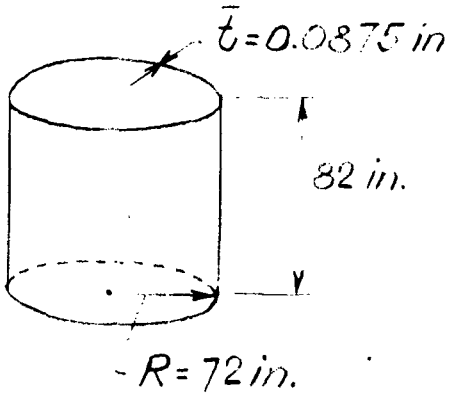
$$\tau = \frac{PKA_L}{tA_T} \cdot \frac{\text{Sinh } Kx}{\text{Cosh } KL}$$

The resulting stress distributions are shown in the following figure:



The maximum τ occur at the upper edge, but the edge is well reinforced. The average shear stress must be less than the buckling strength of the cylinder if internal pressurization of 14.5 psi is considered.

Shear Buckling: (Ref. 5, Sec. 9)



Thickness of skin panel = 0.04
(spacing of stringers 3.3)

R = 72 in.

$$\frac{R}{t} = \frac{72}{0.0875} = 830 \Rightarrow C_s = 0.505$$

Pressurization of 14.5 psi:

$$\frac{p}{E}\left(\frac{R}{t}\right)^2 = \frac{14.5}{10^6 \times 10.5}\left(830\right)^2 =$$

$$= \frac{1.38}{10^6}\ 688000 = 0.95 \Rightarrow \Delta C_s = \underline{0.75}$$

$$C = 1.255$$

$$Z = \frac{L^2}{Rt}\sqrt{1-\mu^2} = \frac{82^2 \times 0.94}{72 \times 0.0875} = \frac{6300}{6.3} = 1000$$

$$Z^{\frac{1}{4}} = \sqrt{\sqrt{1000}} = \sqrt{32} = 5.65$$

$$\frac{\tau_{cr}}{\eta} = C\,E\,\frac{t}{R}\,\frac{1}{Z^{1/4}} = 1.255 \times 10.5 \times 10^6\,\frac{0.0875}{72}\,\frac{1}{5.65} =$$

$$= 1.15 \times 10^6/406 = \frac{1150000}{406} = \underline{2840}\ \text{psi} > 2760\ \text{psi}$$

ok

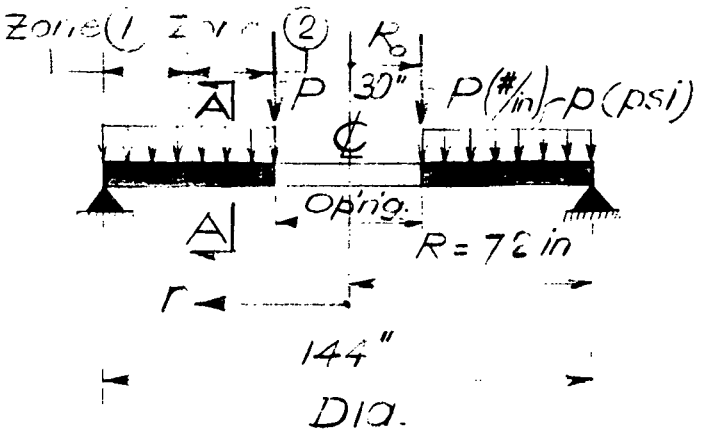
$$\text{M.S.} = \frac{2840}{2760} - 1 = \underline{+0.025}$$

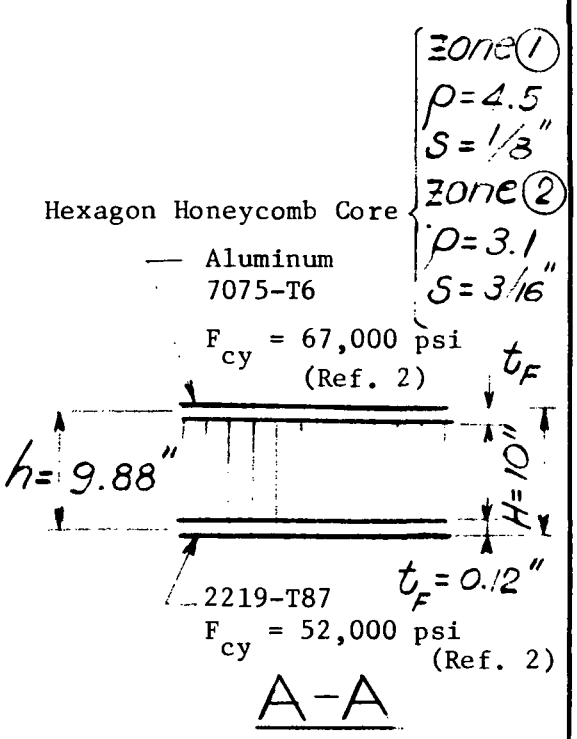
3.2 END PRESSURE BULKHEADS

End pressure bulkheads are similar to those presented under paragraph 2.2.

3.3 IVA/EVA AIRLOCK BULKHEAD

System:





The internal loads analysis was performed using the computerized solution for circular plates developed for the 33 ft diameter station, and outlined in Ref. 11.

The following values are used to compute the internal loads:

Internal Pressure $\bar{p}$ = 14.9 psi

Factor of Safety F.S. = 1.75 (short term loading - space operation cond.)

Design Pressure p = 1.75 x 14.9 = 26.1 psi

Outside Radius of Plate R = 72 in.

Inside Radius of Opening R_o = 30 in.

Circumferential Load $P = \pi R_o^2 \times p/2\pi R_o = \frac{pR_o}{2} = \frac{26.1 \times 30}{2} = 392\#/in$

The results of the internal loads analysis are tabulated as follows:

Ratio $\rho = r/R$	Radius r (in.)	Ultimate Internal Loads: Radial Moment M_r (in-lb)/in.	Ultimate Internal Loads: Circumferential Moment M_θ (in-lb)/in.	Ultimate Internal Loads: Shear Q lbs/in.
0.41667	30	0	58400.0	-392.0
0.50000	36	6450.0	48400.0	-470.0
0.60000	43.2	9320.0	40600.0	-565.0
0.70000	50.4	9250.0	34800.0	-658.0
0.80000	57.6	7400.0	29900.0	-751.0
0.90000	64.8	4200.0	25500.0	-845.0
1.0000	72.0	0	21100.0	-940.0

The governing moment is M_θ = 58400.0#in. Ult.

The governing shear is Q = 940.0 lbs/in. Ult.

$$f_{cu} = \frac{58400.0}{0.12 \times 9.88} = 49400 \text{ psi}$$

$$M.S. = \frac{52000}{49400} - 1 = \underline{0.05\pm} \quad \text{(Used 2219-T87 } F_{cy} = 52{,}000 \text{ psi)}$$

$$f'_{su_{max}} = \frac{Q_{max}}{h} = \frac{940.0}{9.88} = 95.0 \text{ psi}$$

For Zone (1) core density ρ = 4.5 lb/cu.ft., cell size 1/8".

F'_s = 0.335 ksi x 0.60 = .200 ksi (Ref. 7, page 31.13.00.05.01)

$$M.S. = \frac{.200}{.095} - 1 = \underline{+1.01}$$

Intracell Buckling (Ref. 5, page 11.31.01):

$t/s = 0.12/0.125 = 0.96 > 0.06$

$K_L = 2.28\ (t/s)^2 = 2.28(0.96)^2 = 2.1$

$$\frac{\sigma_s}{\eta} = \frac{K_L E}{1 - \mu^2} = \frac{2.1 \times 10.5 \times 10^6}{0.89} = 24.8 \times 10^6 \text{ psi} >> F_{cy}$$

Dimpling (Ref. 5, page 11.31.03):

$$\frac{\sigma_o}{\eta} = 2\,\frac{E}{1-\mu^2}\left(\frac{t}{s}\right)^2 = 2\,\frac{10.5 \times 10^6}{0.89}(0.96)^2 = 21.7 \times 10^6 \text{ psi} >> F_{cy}$$

Face Sheet Wrinkling (Ref. 5, page 11.32.02):

$$\frac{\sigma_{cr}}{\eta} = K_L \sqrt[3]{E\,E_c\,G_c}$$

For $\rho = 4.5$ $\begin{cases} E_c = 120 \text{ ksi} \\ G_c = 40 \text{ ksi} \end{cases}$ (Ref. 7, page 31.13.00.06.01 and 31.13.00.09.01)

$E = 10500$ ksi

$K_L = 0.43$

$$\frac{\sigma_{cr}}{\eta} = 0.43 \sqrt[3]{10500 \times 120 \times 40} = 0.43 \times 378$$

$$= 162 \text{ ksi} \gg F_{cy}$$

Assume maximum allowable compr. stress $F_{cy} = 52000$ psi (Ref. 2)

(Ref. 7, page 31.13.00.05.01)

For Zone (2)

$$f'_{su} = \frac{658}{9.88} = 66.5 \text{ psi}$$

Core: $\rho = 3.1\#/\text{cu.ft.}$, with nominal cell size of 3/16 = 0.187

$$F'_s = 0.195 \times 0.60 = 0.117 \text{ ksi}$$

$$\text{M.S.} = \frac{0.117}{.0665} - 1 = \underline{\underline{+.76}}$$

Intracell Buckling (Ref. 5, page 11.31.01):

$t/s = 0.12/0.187 = 0.642 > 0.06$

$$K_L = 2.28\,(t/s)^2 = 2.28(0.642)^2 = 0.940$$

$$\frac{\sigma_s}{\eta} = \frac{K_L\,E}{1-\mu^2} = \frac{0.940 \times 10.5 \times 10^6}{0.89} = 11.1 \times 10^6 \text{ psi} >> F_{cy}$$

Dimpling (Ref. 5, page 11.31.03):

$$\frac{\sigma_o}{\eta} = 2\,\frac{E}{1-\mu^2}\left(\frac{t}{s}\right)^2 = 2\,\frac{10.5 \times 10^6}{0.89}(0.642)^2 = 9.70 \times 10^6 >> F_{cy}$$

Face Sheet Wrinkling (Ref. 5, page 11.32.02):

$$\frac{\sigma_{cr}}{\eta} = K_L \sqrt[3]{E\,E_c\,G_c}$$

For $\rho = 3.1$ $\begin{cases} E_c = 75 \text{ ksi} \\ G_c = 24 \text{ ksi} \end{cases}$ (Ref. 7, pages 31.13.00.06.01 and 31.13.00.09.01)

$E = 10500$ ksi

$K_L = 0.43$

$$\frac{\sigma_{cr}}{\eta} = 0.43 \sqrt[3]{10500 \times 75 \times 24} = 115 \text{ ksi} >> F_{cy}$$

Assume maximum allowable compr. stress $F_{cy} = 52{,}000$ ksi (Ref. 2)

3.4 EQUIPMENT SUPPORT BULKHEADS

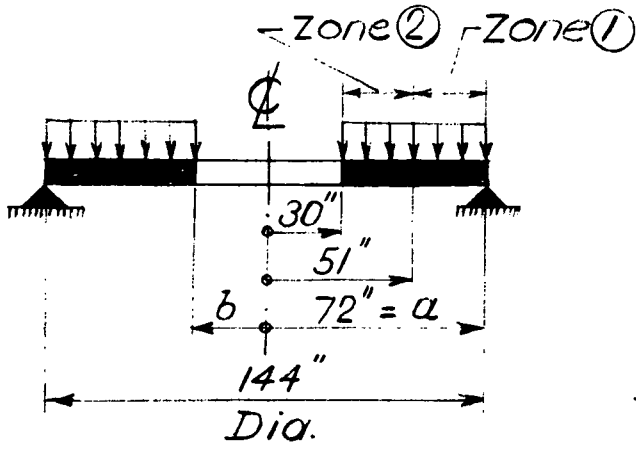
Assume: 2/3 total module weight is on floors
Factor for unequal distribution between floors = 1.5
Factor for nonuniform pressure distribution = 1.5
Ult. F.S. = 1.5
No. of Floors = 4

Loading at crash condition:

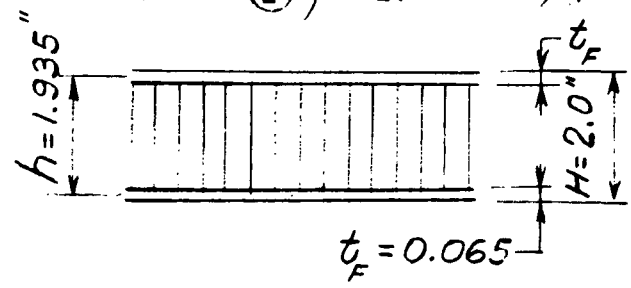
$$n_x = 8.0 \text{ g}$$

$$p = \frac{2}{3}\frac{(25{,}000)(8.0)(1.5)^2}{(4)(\pi)(72^2 - 30^2)} = 5.55 \text{ psi Ult.}$$

Floor System:



Material
7075-T6 Al-F/S
F_{cy} = 67,000 (Ref. 2)
Aluminum 5056-H38
Hexagon Honeycomb Core
zone ① ρ = 3.1 S = 3/16"
zone ② ρ = 2.3 S = 1/4"



Determination of maximum stress:

Reference 8, page 220, formula 13

$$s_{max} = s_t = -\frac{3w}{4m\,(6t_F h)(a^2 - b^2)}\left[a^4(3m+1) + b^4(m-1) - 4ma^2b^2 - 4(m+1)a^2b^2\log_e\frac{a}{b}\right]$$

(modified for sandwich construction by substitution $t^2 = 6t_F h$)

a = 72 in. b = 30 in. $m = \frac{1}{\mu} = 3.0$

$$\log_e\left(\frac{a}{b}\right) = 2.3026 \log_{10}\left(\frac{a}{b}\right)$$

Solving for s_{max} delivers $s_{max} = s_t = 63500\#/in^2$

$$\text{M.S.} = \frac{67000}{63500} - 1 = \underline{\underline{+.055}}$$

Shear (Zone (1))

At outer edge:

$V^* = \pi(R^2 - R_o^2)w = \pi \times 4300 \times w = 13500 \times 5.55 = 75000\#$ Ult.

Shear Stress

$$v = \frac{V^*}{2\pi R} = \frac{75000}{2\pi\ 72} = 166\#/\text{in}$$

(Ref. 7, page 31.13.00.05.01)

$$f'_{su} = \frac{\pi(72^2 - 30^2)p}{2\pi(72)h} = 0.086\ \text{k/in}^2$$

For area of Zone (1) aluminum core has density $\rho = 3.1\#/\text{cu. ft}$, with nominal cell size 3/16 in.

$s = 3/16 = 0.187$ in. $\quad F'_s = 0.195\ (\text{ksi}) \times (0.70) = 0.1365$ ksi

$$\text{F.S.} = \frac{0.1365}{0.086} - 1 = \underline{\underline{+0.59}}$$

(Ref. 7, page 31.13.00.05.01)

Intracell Buckling (Ref. 5, page 11.31.01):

$$\frac{\sigma_{cr}}{\eta} = \frac{K_L E}{1 - \mu^2} \qquad t/s = 0.065/0.187 = 0.348$$

For $t/s > 0.06$, $K_L = 2.28\left(\frac{t}{s}\right)^2 = 2.28(0.348)^2 = 0.276$

$$\frac{\sigma_{cr}}{\eta} = \frac{0.276 \times 10.5 \times 10^6}{0.89} = 3.26 \times 10^6\ \text{psi} >> F_{cy}$$

Dimpling (Ref. 5, page 11.31.03):

$$\frac{\sigma_o}{\eta} = 2\frac{E}{1 - \mu^2}\left(\frac{t}{s}\right)^2 = 2\frac{10.5 \times 10^6}{0.89}(0.348)^2 = 2.54 \times 10^6 >> F_{cy}$$

Face Sheet Wrinkling (Ref. 5, page 11.32.02):

$$\frac{\sigma_{cr}}{\eta} = K_L \sqrt[3]{E\, E_c\, G_c}$$

For $\rho = 3.1\#/\text{cu.ft.}$ $\begin{cases} E_c = 75\ \text{ksi} \\ G_c = 24\ \text{ksi} \end{cases}$ (Ref. 7, pages 31.13.00.06.01 and 31.13.00.09.01)

$E = 10500$ ksi

$K_L = 0.43$

$$\frac{\sigma_{cr}}{\eta} = 0.43 \sqrt[3]{10500 \times 75 \times 24} = 0.43 \times 266 = 115 \text{ ksi} > F_{cy}$$

Assume maximum allowable compr. stress $F_{cy} = 67000$ (Ref. 2)

Shear (Zone (2))

Shear Stress

$$f'_{su} = \frac{\pi(51^2 - 30^2)p}{2\pi(51)h} = 0.064 \text{ k/in}^2$$

For area of Zone (2) aluminum honeycomb core density $\rho = 2.3\#/\text{cu.ft.}$, with nominal cell size 1/4

$s = \frac{1}{4} = 0.25$ in. $\qquad F'_s = 0.14 \text{ ksi} \times 0.70 = 0.098 \text{ ksi}$ (Ref. 7, page 31.13.00.05.01)

$$\text{F.S.} = \frac{0.098}{0.064} - 1 = \underline{\underline{+0.53}}$$

Intracell Buckling (Ref. 5, page 11.31.01):

$$\frac{\sigma_{cr}}{\eta} = \frac{K_L E}{1 - \mu^2} \qquad t/s = 0.065/0.25 = 0.26$$

For $t/s > 0.06$, $K_L = 2.28\left(\frac{t}{s}\right)^2 = 2.28 \times 0.26^2 = 0.154$

$$\frac{\sigma_{cr}}{\eta} = \frac{0.154 \times 10.5 \times 10^6}{0.89} = 1.82 \times 10^6 \text{ psi} >> F_{cy}$$

Dimpling (Ref. 5, page 11.31.03):

$$\frac{\sigma_o}{\eta} = 2 \frac{E}{1 - \mu^2} \left(\frac{t}{s}\right)^2 = 2 \frac{10.5 \times 10^6}{0.89} (0.26)^2 = 1.6 \times 10^6 >> F_{cy}$$

Face Sheet Wrinkling (Ref. 5, page 11.32.02):

$$\frac{\sigma_{cr}}{\eta} = K_L \sqrt[3]{E \times E_c \times G_c}$$

For $\rho = 2.3\#/\text{cu.ft.}$ $\begin{cases} E_c = 48 \text{ ksi} \\ G_c = 13 \text{ ksi} \end{cases}$

$E = 10500$ ksi

$K_L = 0.43$ (Ref. 7, pages 31.13.00.06.01 and 31.13.00.09.01)

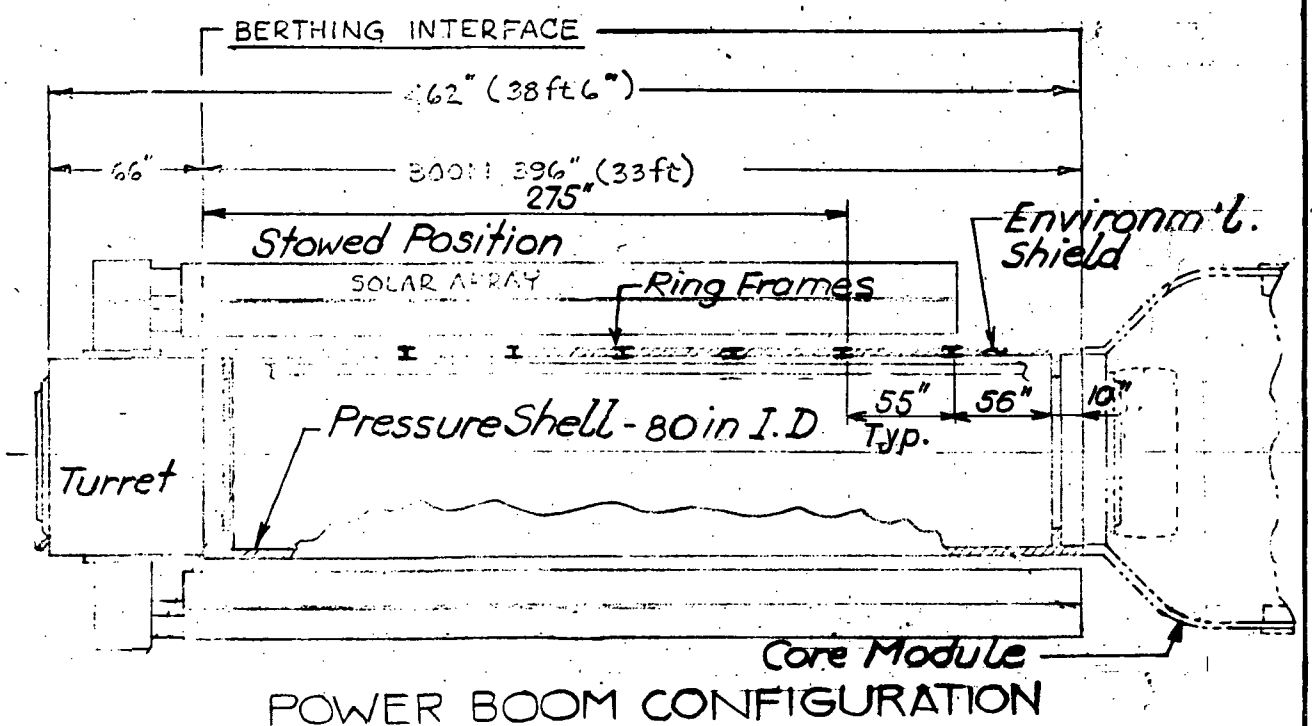
$$\frac{\sigma_{cr}}{\eta} = 0.43 \sqrt[3]{10500 \times 48 \times 13} = 0.43 \times 187 = 80.4 \text{ ksi} > F_{cy}$$

Assume maximum allowable compr. stress

$F_{cy} = 67000$ psi (Ref. 2)

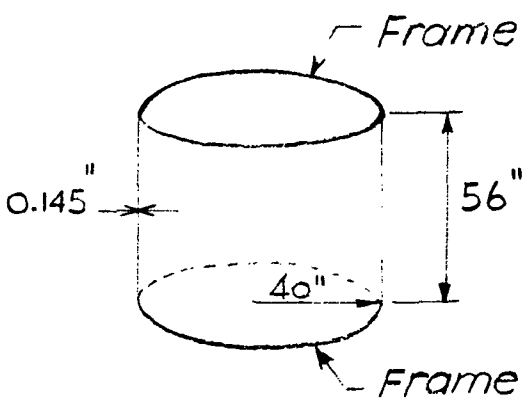
4.0 POWER MODULE

The analysis of the power module structure is confined to the boom structural pressure shell. The other major components, turret and solar array, are subcontracted items.



POWER BOOM CONFIGURATION

4.1 Skin Analysis



Material: 5052-H34 Aluminum Sheet

F_{TU} = 34 ksi
F_{TY} = 23 ksi
F_{CY} = 23 ksi
} (Ref. 2)

Total Weight of Structure (1g) = 20000 lbs

Internal Pressure p = 14.9 psi Limit

Ult. F.S. = 1.75

Design Pressure p = 1.75 x 14.7 = 26.1 psi

Stress due to pressurization:

$$f_{TU} = pR/t = 26.1 \times 40/0.145 = 6150 \text{ psi}$$

$$\text{M.S. (Tension)} = \frac{34{,}000}{7{,}170} - 1 = +3.74$$

Booster End Burn

$$\eta_x = 3.3, \text{ F.S.} = 1.5$$

$$P = 3.3 \times 1.5 \times 20000\# = \underline{-99000\#}$$

$$f_{CU} = \frac{99000}{2\pi\ 40 \times 0.145} = 2700 \text{ psi}$$

Influence of pressurization conservatively neglected.

$$\text{M.S.} = \frac{12400}{2700} - 1 = \underline{\underline{+3.6}}$$

Crash (Cargo & Equipment)

$$\eta_x = \begin{cases} -8.00g \text{ Ult (tension)} \\ +1.5g \text{ Ult (compression)} \end{cases}$$

(a) Compression - less than previous loading case

(b) Tension

$$P = 20000 \times 8.00 = \underline{160000\#}$$

$$f_{CU} = 160000/2\pi Rt = \underline{4400 \text{ psi}}$$

$$\text{M.S.} = \frac{34{,}000}{4{,}400} - 1 = \underline{\underline{+6.72}}$$

Stability (Ref. 5, pages 9.22.08 and 09):

$$Z = \frac{L^2}{Rt}\sqrt{1 - \mu^2} = \frac{56^2}{40 \times 0.145}\sqrt{1 - 0.33^2} = \frac{3140}{5.8}\,0.94 = 510.$$

$$R/t = 40/0.145 = 276 \Rightarrow \qquad C_c = 0.205$$

Increase due to pressurization

$$\frac{p}{E}\left[\frac{R}{t}\right]^2 = \frac{22.3}{10.5 \times 10^6}\,276^2 = 0.162 \Rightarrow \qquad \Delta C_c = 0.120$$

$$C_{TOT} = 0.325$$

Critical Stress:

$$\frac{\sigma_{cr}}{\eta} = C\ E\ \frac{t}{R} = 0.325 \times 10.5 \times 10^6\ \frac{0.145}{40} = \underline{12400} \text{ psi}$$

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Bending Consideration

The weight of structures for determining of bending may be reduced by ~ 3000# because of concentration of such weight at support.

Consequently weight is 20000# - 3000# = 17000# (1g)

For bending $\eta_B = 4.5g$

$$w = \frac{17000 \times 4.5}{36' \times 12} = 177\#/in$$

$$M_{actual} = 177 \times 432^2/8 = 4140000\#in.$$

$$I = \pi R^3 t = \pi \times 40^3 \times 0.145 = 29200\ in^4$$

$$C = R = 40\ in$$

$$\sigma_{act} = \frac{M}{I} C = \frac{4140000 \times 40}{29200} = 5680\#/in^2$$

Stability Consideration for Bending (Ref. 5, page 9.22.10)

For $\ell = 56"$

$$Z = \frac{\ell^2}{Rt}\sqrt{1-\mu^2} = 510$$

$$\frac{R}{t} = 40/0.145 = 276 \Rightarrow \qquad C_B = 0.285$$

$$\frac{\sigma_{cr}}{\eta} = C_B E \frac{t}{R} = 0.285 \times 10.5 \times 10^6 \frac{0.145}{40} = 10850\ psi$$

$$M.S. = \frac{10850}{5680} - 1 = \underline{+0.91}$$

Shear Consideration

The maximum shear load is at support:

V = 177#/in x 432/2 =	38300#
Additional weight @ Support ~	3000
	41300#

$$A = 2\pi Rt = 2\pi 40 \times 0.145 = 36.4\ in^2$$

$$\tau = \frac{41300}{36.4} = 1140\ psi$$

$$M.S. = \frac{20000}{1140} - 1 = \underline{+17.5}$$

Stability Consideration for Shear (Ref. 5, page 9.22.08)

$$\frac{R}{t} = 276 \Rightarrow \qquad C_s = 0.585$$

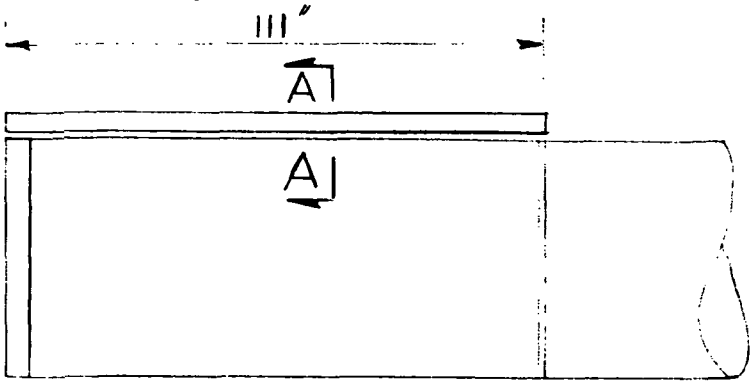
$$\frac{\tau_{cr}}{\eta} = C_s \, E \, \frac{t}{R} \, \frac{1}{Z^{1/4}} \qquad Z^{1/4} = \sqrt{\sqrt{510}} = 4.75$$

$$= 0.585 \times 10.5 \times 10^6 \times \frac{0.145}{40} \, \frac{1}{4.75} = 4740$$

$$\text{M.S.} = \frac{4740}{1140} - 1 = \underline{\underline{+3.15}}$$

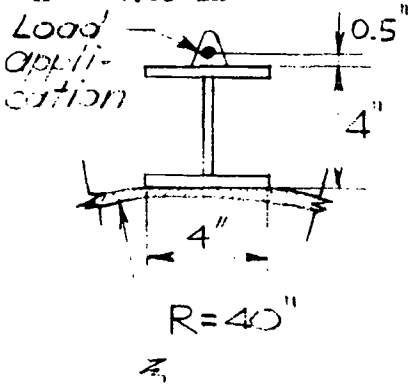
4.2 DRAG LONGERONS

Structural System



Section Similar to WF4x4x4.76

$I = 10.80\ in^4$
$A = 4.05\ in^2$



A-A

Material 2219-T87 (Ref. 2)

$E_c = 10.8 \times 10^6$ psi, $E_t = 10.5 \times 10^6$ psi

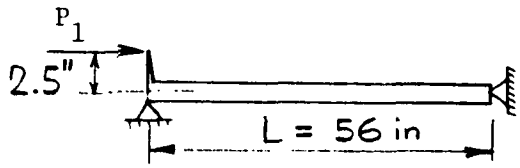
Power Module Growth Wt. = 20,000 lb

The following loading conditions are governing

	n_x	n_y	n_z	F.S.
(1) Booster End Burn (Limit)	3.3	±0.1	-0.5	1.5
(2) Crash (Cargo & Equipment) (Ultimate)	-8.0	+1.5	-4.5	1.0

(1) Loading Condition - Booster End Burn

Structural System of Longeron:



Longitudinal Compression

$$P_1 = 20000\# \times \frac{1}{2} \times 3.3 \times 1.5 = 49500\#\ \text{Ult.}$$

$$P_{cr} \approx \frac{\pi^2 EI}{L^2} = \frac{\pi^2 \times 10.8 \times 10^6 \times 10.8}{(56)^2} = 368000\#$$

(2) Loading Condition - Crash

Longitudinal Tension

$P_1 = 20000 \times \frac{1}{2} \times 8.0 \times 1.0 = 80000\#$

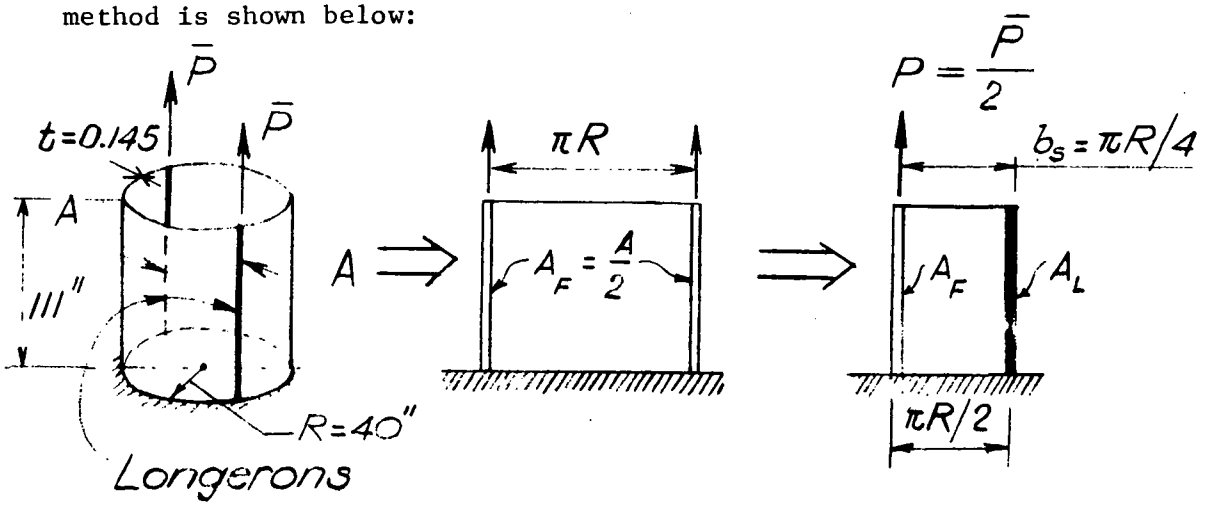
$\sigma_{Tens} = \frac{80000}{4.05} + \frac{80000 \times 2.5 \times 2}{10.80} = 55800$ psi

$F_{tu} = 64000$ psi (Ref. 2)

$M.S. = \frac{64000}{55800} - 1 = +0.114$

Shear Analysis

The stresses in the stiffened part (longerons) of shell are computed by the "substitute-single-stringer method" of Reference 4, Section 4-6. For analysis simplification the panels are conservatively assumed as being flat. The sequence of logical assumptions for the abovementioned method is shown below:



$\bar{P} = 80000$ lbs $\qquad P = \frac{\bar{P}}{2} = 40000$ lbs

$b_s = \pi R/4 = \frac{\pi 40}{4} = 31.4$

Substitute Section

$A_F = 4.05/2 = 2.025$ in^2 $\qquad A_L = 0.145 \times 31.4 \times 2 = 9.1$ in^2

$$K = \sqrt{\frac{G \cdot t}{b_s E}\left(\frac{1}{A_F} + \frac{1}{A_L}\right)} = \left[\frac{4.0 \times 10^6 \times 0.145}{31.4 \times 10.5 \times 10^6}\left(\frac{1}{2.025} + \frac{1}{9.1}\right)\right]^{1/2} = 0.0326$$

The distance, L_{eq}, from the lower end to the point where σ_F and σ_L (stress corresponding to areas A_F and A_L) are equalized within 3% margin is

$$L_{eq} = \frac{3.5}{K} = \frac{3.5}{0.0326} = 107 \text{ in. (Ref. 4, page 107)}$$

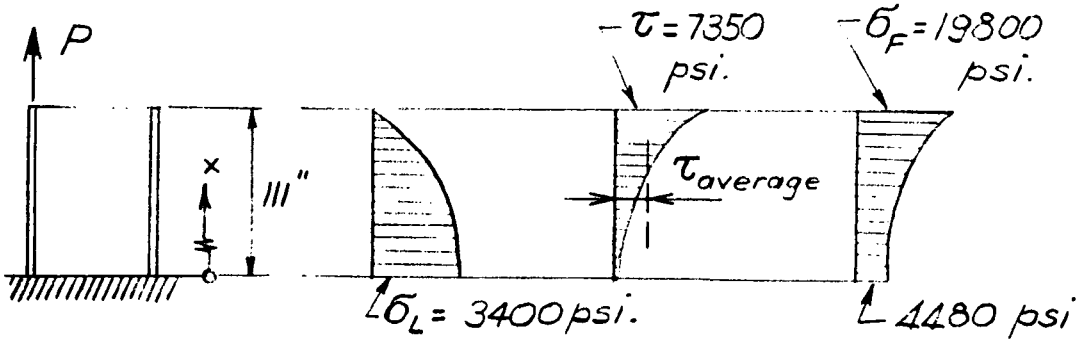
$$A_T = A_L + A_F = 9.1 + 2.025 = 11.125 \text{ in}^2$$

$$\sigma_F = \frac{P}{A_T}\left(1 + \frac{A_L \text{ Cosh } Kx}{A_F \text{ Cosh } KL}\right)$$

$$\sigma_L = \frac{P}{A_T}\left(1 - \frac{\text{Cosh } Kx}{\text{Cosh } KL}\right)$$

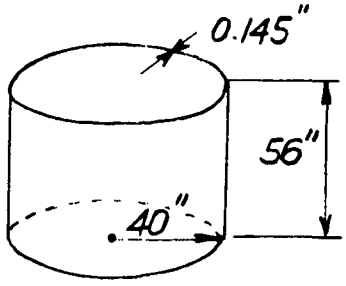
$$\tau = \frac{PKA_L}{t\,A_T}\,\frac{\text{Sinh } Kx}{\text{Cosh } KL}$$

The performed analysis led to the following results:



From calculated stress it is evident that the stress concentration occurs at the edge of shell and practically disappears at distance x = o. An average shear stress was determined and this is $\tau_{average} = 3480\#/\text{in}^2$. This stress must be smaller than the critical shear buckling stress.

Buckling Strength for Shear (Ref. 5, page 9.22.08)



$$Z = \frac{L^2}{Rt}\sqrt{1-\mu^2} = \frac{56^2}{40 \times 0.145}\,0.94 = 510$$

$$Z^{1/4} = 4.75$$

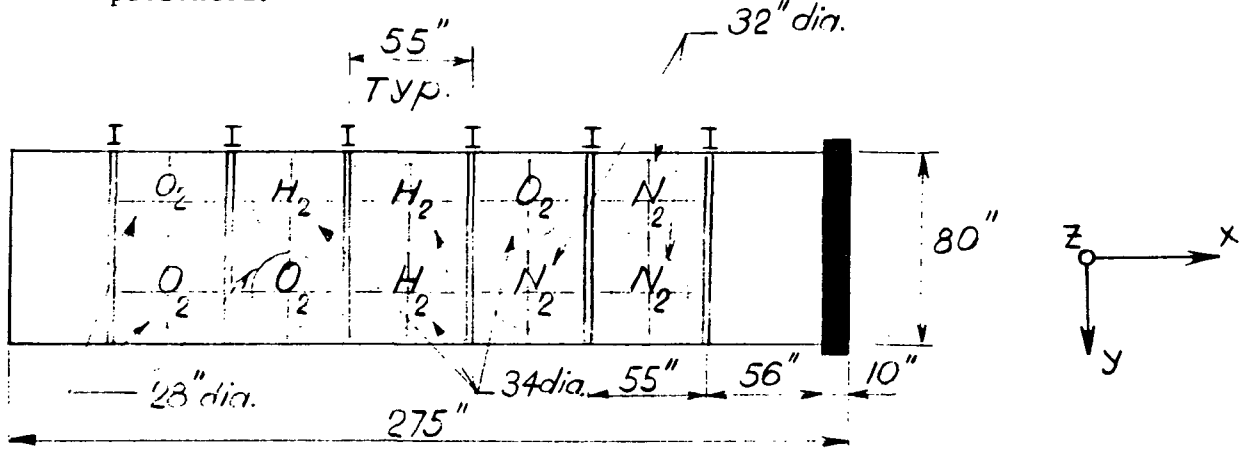
$$R/t = \frac{40}{0.145} = 276 \Rightarrow C_s = 0.582$$

$$\frac{\tau_{cr}}{\eta} = C_s\, E\, \frac{t}{R}\, \frac{1}{Z^{1/4}} = 0.582 \times 10.8 \times 10^6\, \frac{0.145}{40}\, \frac{1}{4.75} = 4800 > 3480\#/\text{in}^2$$

$$M.S. = \frac{4800}{3480} - 1 = .38$$

4.3 TANK SUPPORTING RING-FRAMES

On the figure below arrangement of tanks, which contains H_2, N_2 and O_2 is presented.



The weight of tanks is determined below:

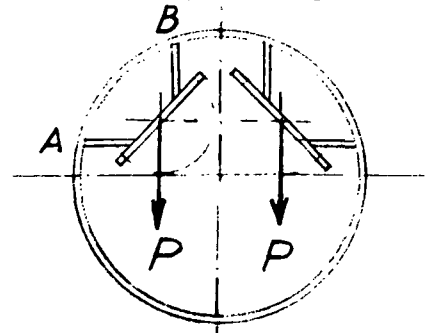
No.	Gas	Dia. (in)	Rad. (in)	Volume $4/3\ \pi R^3$	Weight per ft^3 of Volume	Total Weight (#) Net	Total Weight (#) With Connections
1	H_2	34"	17"	12 ft^3	1.085#/ft^3	13	33
2	N_2	32"	16"	10 ft^3	15.1 #/ft^3	151	171
3	O_2	34"	17"	12 ft^3	17.3 #/ft^3	208	228
4	O_2	28"	14"	6.75 ft^3	17.3 #/ft^3	117	137

The crash (cargo and equipment) - loading condition (ultimate) is governing. The loading factors are:

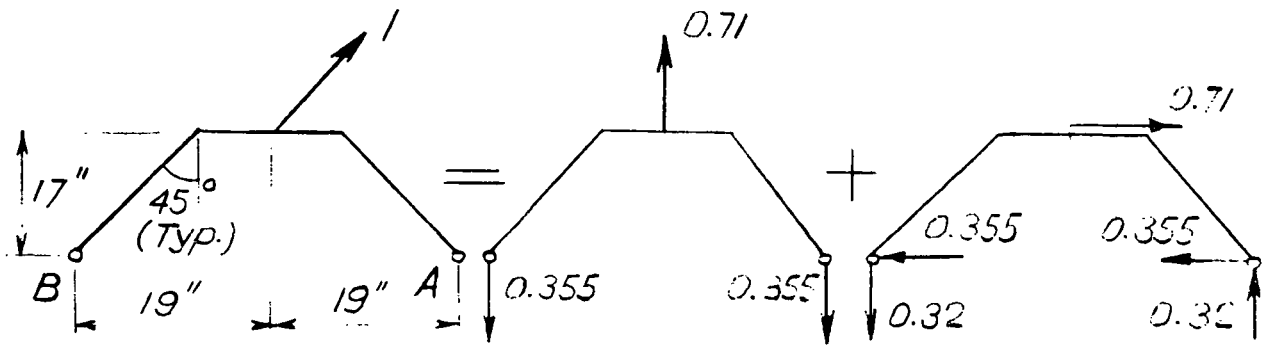
$\eta_x = -8.00$ g's $\quad \eta_y = +1.5$ g's $\quad \eta_z = -4.5$ g's

F.S. = 1.00

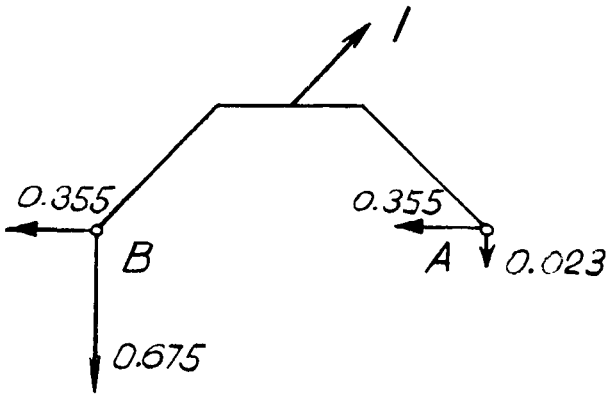
The governing loading is in z direction:

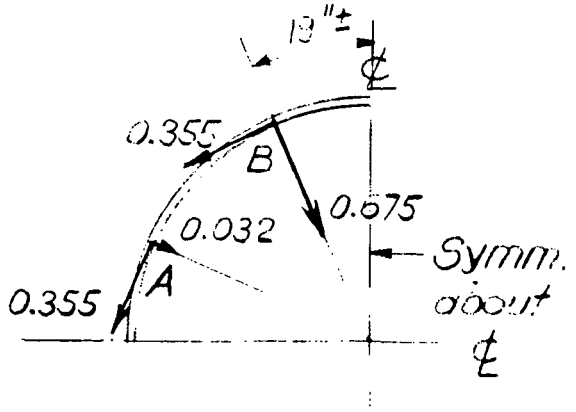


Assuming P = 1, determine reactions at point A and B as is taken by the frame



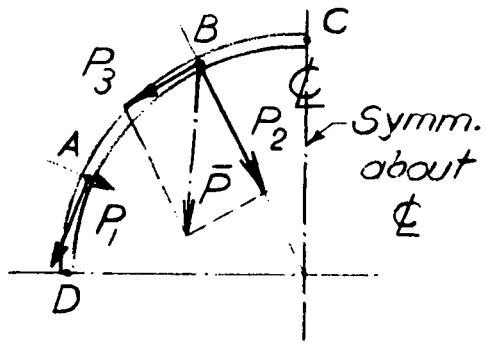
Superposition leads to the following reactions:





To simplify the analysis, vertical reactions are assumed acting radially, horizontal reactions - circumferentially.

The actual loading (crash) acting in z direction



P = (228/2 + 171/2)4.5g's = 900#

Consequently:

P_1 = 0.032 x 900 = 29#

P_2 = 0.675 x 900 = 605#

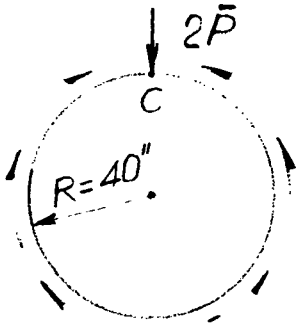
P_3 = 0.355 x 900 = 320#

P_1 is small and is neglected in future calculations.

P_2 and P_3 @ B is replaced with nearly vertical resultant:

$$\bar{P} = \sqrt{605^2 + 320^2} = 685\#$$

In order to be able to use tables in Ref. 5, page 3.11.09, both $\bar{P}$ are combined and moved to the top of the ring (point C). This loading is conservative.



$2\bar{P} = 685 \times 2 = 1370\#$

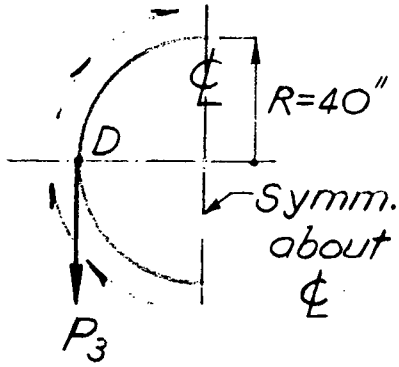
Correspondingly, from Reference 5, page 3.11.09, are taken the maximum influences.

max M = $K_M\ 2\bar{P}R = 0.24 \times 1370 \times 40 = 13200\#"$

max Q = $K_Q\ 2\bar{P} = 0.50 \times 1370 \times 40 = 680\#$

max N = $K_N\ 2\bar{P} = 0.44 \times 1370 \times 40 = 605\#$

Remaining load P_3 acting at point A is moved to point D as shown in order to make possible the use of the method in Ref. 5, page 3.11.25. This loading is conservative.



Load P_3 is reacted by shear.

From the above reference, the following maximum values are obtained:

max M = $K_M\ P_3\ R = 0.028 \times 320 \times 40 = 358\#"$

max Q = $K_Q\ P_3 = 0.4 \times 320 = 128\#$

max N = $K_N\ P_3 = 0.3 \times 320 = 95\#$

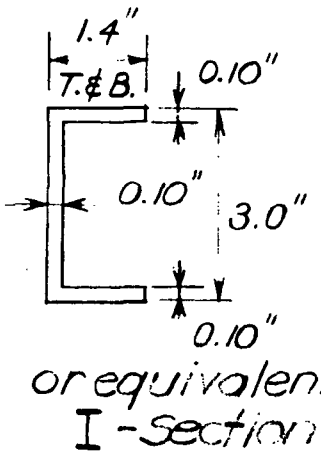
Conservatively, the ring section is checked for the following loading:

M =	Q =	N =
13200#"	680#	605#
358#"	128#	95#
13558#"	808#	700#

These extreme values do not occur at the same section, but are here added together in the interest of conservativeness.

The ring frames are of 7075-T6 aluminum material: F_{tu} = 77000 psi (Ref. 2)

F_{su} = 46000 psi



$A = 0.1 \times 1.4 \times 2 = 0.28$

$0.10 \times 2.8 = 0.28$

0.56 Sq. in.

$I = 0.10 \times 1.4 \times 1.45^2 \times 2 = 0.590$

$0.10 \times 2.8^3/12 = 0.183$

0.773

$$\sigma_{act} = \frac{13558 \times 1.5}{0.773} + \frac{700}{0.56} = 27650 \text{ psi}$$

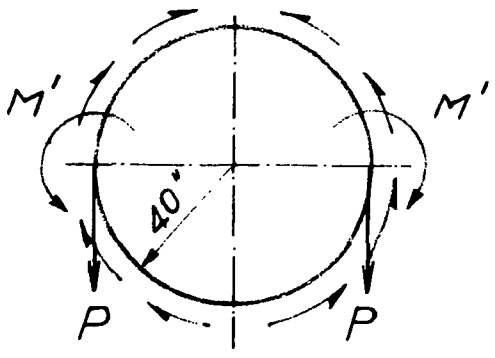
$$M.S. = \frac{77000}{27650} - 1 = \underline{+1.79}$$

$$\tau_{act} = 808/0.56 = 1440 \text{ psi}$$

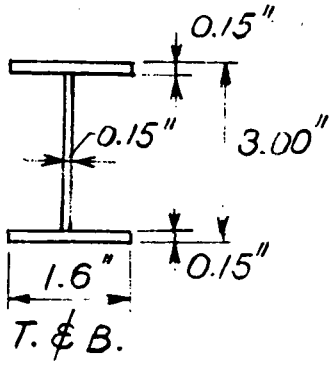
$$M.S. = \frac{46000}{1440} - 1 = \text{large}$$

4.4 FORWARD SUPPORT FRAME

Structural System



Section



Material

7075-T6 (aluminum)

F_{tu} = 77000 } (Ref. 2)
F_{su} = 46000 }

$I = 1.352 \text{ in}^4$

$A = 0.945 \text{ in}^2$

Loading

$P = \frac{20000\#}{4} \times 4.5 \times 1.0 = \underline{22500\#}$ Ultimate

From Reference 5, page 3.11.25, the following extreme influences are obtained:

$\max M = K_M PR = 0.028 \times 22500 \times 40 = 25200\#''$

$\max Q = K_Q P = 0.4 \times 22500 = 9000\#$

$\max N = K_N P = 0.3 \times 22500 = 6750\#$

The moments due to eccentricity

$M' = P \cdot e = 22500 \times 2 = \underline{45000\#''}$

From Reference 5, page 3.11.37 the following extreme influences are obtained:

$\max M = K_M M' = 0.5 \times 45000 = 22500\#''$

$\max Q = K_Q \frac{M'}{R} = 0.32 \times \frac{45000}{40} = 360\#$

$\max N = K_N \frac{M'}{R} = 0.32 \times \frac{45000}{40} = 360\#$

The section is sized for the following loading (conservatively):

M	Q	N
$25200\#''$	$9000\#$	$6750\#$
22500	$360\#$	$360\#$
$47700\#''$	$9360\#$	$7110\#$

$\sigma = \frac{47700 \times 1.5}{1.352} + \frac{7110}{0.945} = 62530$ psi

$M.S. = \frac{77000}{62530} - 1 = \underline{+0.23}$

$\tau = \frac{9360}{0.945} = 9900\#/in^2$

$M.S. = \frac{37000}{9900} - 1 = \underline{+2.74}$

ENVIRONMENTAL PROTECTION ANALYSES

The environmental protection subsystem provides three basic functions; thermal protection, meteoroid protection, and radiation protection. Protection for the subsystem assemblies exposed to the external environment must be included for all phases of the mission operations. The primary purposes of the thermal protection system are to establish thermal independence of attitude, to preclude condensate formation on interior surfaces, and to prevent excessive limit external environment heat loads to the station and losses from the station. The major considerations in insulation design are installation and mounting provisions, structural heat shorts, and insulation venting provisions. Long term protection from meteoroids is required for all external structures. The meteoroid bumper is supported with nonmetallic fasteners for thermal isolation. A double-bumper configuration offers maximum efficiency for meteoroid protection. The outer bumper is a structural element to attach the insulation and the second bumper is incorporated as a protective inner covering for the high-performance insulation. The protection of the crew from radiation includes evaluation of the natural sources, earth trapped, cosmic-galactic and solar flare radiation. The radiation shield utilizes the primary bumper and the mass of the structure and furnishings for protection of the crew from the natural radiation environment.

THERMAL PROTECTION

1.0 REQUIREMENTS

The environmental shield assembly, together with the thermal isolating structural supports, provides passive thermal control of the MSS modules. From the performance specifications (DRL 66, Volume I), passive thermal control requirements comprise limiting the heat loss from a module to 2000 Btu/hour, and the heat gain to 1000 Btu/hour. In addition, a requirement exists to preclude condensation on internal surfaces during manned operation of the station.

1.1 INSULATION

The basic insulation assembly is the same as for the 33 foot space station as reported in DRL 13, Volume 4, SD 70-159-4, consisting of approximately one inch of multilayer aluminized Mylar located between the pressure wall or primary structure and the primary micrometeoroid bumper. The insulation assembly will have provisions for layer spacing control and boost and molecular venting. The major difference between the assembly for the MSS and that for the 33 foot space station is that aerodynamic considerations during boost no longer drive the design of the boost vent system.

1.2 HEAT LOSS/GAIN THROUGH INSULATION

An analytical investigation of the insulation assembly is contained in DRL 13, from which the estimated heat loss per unit area was calculated to be 0.27 Btu/hour-ft^2 (assuming areas without radiators, or with radiators inoperative). Thus, the maximum heat loss through the insulation for a module is 419 Btu/hour. The net gain was estimated to be 160 Btu/hour for the 33 foot space station, and will be somewhat less on the average for a station module. Since most of the station module area is covered by radiators, very little heat transfer between the pressure wall and the bumper is expected in the operational mode.

1.3 STRUCTURAL PENETRATIONS

Structural penetrations of the core and station module are shown in drawings V030-942102 and V030-942205, SD 71-216, respectively. On the core module, the major penetration comprise berthing ports (10), RCS thrusters (4), the airlock, sextant/telescope antenna and star trackers. Other penetrations include running lights and feedlines. In addition, stringers, stiffeners, closeouts, wiring, and radiator tubes will penetrate through the insulation assembly. Extensive use of passive thermal control materials and thermal isolation techniques will be required to prevent condensation in the vicinity of and/or excessive heat loss through such penetrations.

Insulation will be required to prevent excessive heat loss from the docking ports. Estimated heat loss for different degrees of insulation are shown below:

Case	Heat Loss/Port (assuming 57 F structure)
1. Station A type thermal covers	100 Btu/hr
2. Entire port insulated except for docking ring	640 Btu/hr
3. 42" x 66" door insulated only	2300 Btu/hr
4. No insulation on door or utilities interface	3800 Btu/hr

Case 3 and case 4 are not acceptable designs for thermal control for either the buildup core or the normal all up station. Insulation of the entire berthing port except for the berthing ring as per Figure B1-1 is potentially acceptable for the core buildup.

Structure temperature in the vicinity of the berthing port is estimated at a minimum of 40 F. For the normal all-up station, condensation on the structure will occur at the vacant RAM and cargo module ports unless supplementary heating to provide 57 F structure is supplied.

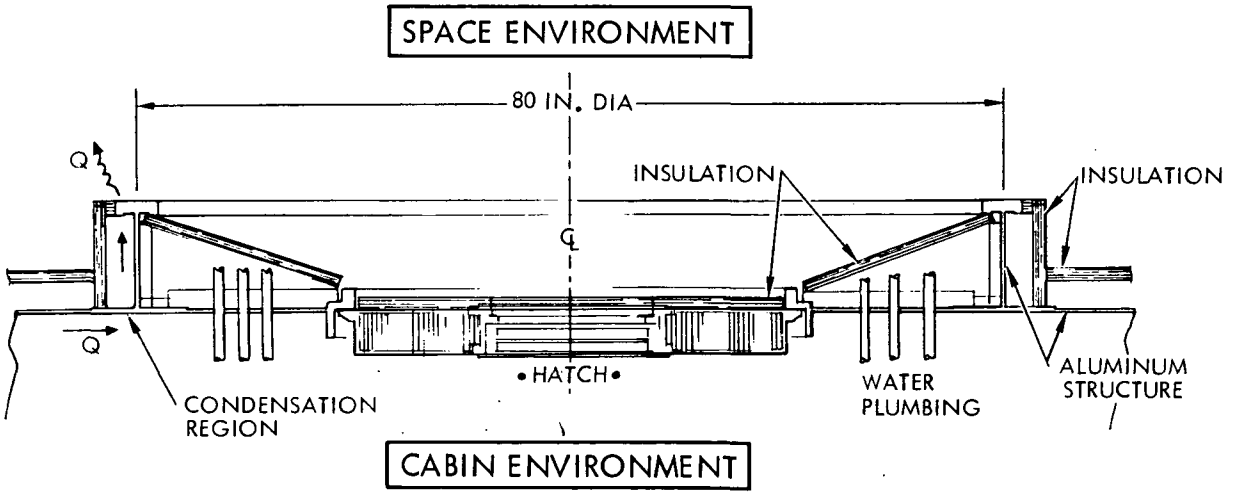


Figure B.1-1. Berthing Port

The recommended approach is for the RAM and cargo ports to have Station A type covers (swing away door type) as a minimum. The other berthing ports could suffice with a partially insulated door (case 2) as shown in Figure B1-1, but supplementary heating may have to be supplied in the vicinity of the water lines. Removable covers which insulate the entire door and are removed prior to berthing would be preferred from a thermal standpoint, but would necessitate a remote removal mechanism (e.g., shuttle manipulator) and storage or earth return accommodations.

Analyses and discussion of thermal control requirements and techniques for the other penetrations are discussed in DRL 13, with the exception of the intramodule flexports. For these, a telescoping insulation system is conceptually depicted in drawing V030-942205. Heat loss through insulation in these areas will be somewhat higher than on the module sidewalls due to the lower efficiency of the insulation in this configuration.

1.4 INSULATION DEGRADATION

As reported in DRL 13, SD 70-159-4, insulation performance is expected to degrade over long periods due to micrometeorite punctures of the outer bumper (hence, loss of insulation area). An analysis of insulation degradation due to micrometeorite damage over a ten year period is discussed in DRL 13, SD 71-159-4. The results of the analysis show that heat loss through the insulation after the years increased from 1680 Btu/hour to 3470 Btu/hour, an increase of about 100 percent. A similar increase would be expected on the MSS.

1.5 PRELAUNCH/LAUNCH REQUIREMENTS

The type of insulation proposed for the environmental shield assembly is extremely sensitive in terms of handling and conditioning. Degradation of the surface properties of the insulation layers will occur if the insulation is exposed to moisture. Thus, conditioning of the environment to which the insulation is exposed will be required from the time the insulation is assembled until it reaches orbit. Current conditioning provisions within the shuttle cargo bay are expected to be adequate. A small insulation repressurization system may be required for cargo modules in order to prevent crushing of the insulation, or atmospheric moisture condensation during entry. The pressurization system would maintain a slight positive pressure in the insulation during entry. Test data on insulation panels will be required to determine if such a system is necessary.

METEOROID PROTECTION

2.0 ENVIRONMENT AND APPROACH

The meteoroid environment used for the Modular Space Station hazard analysis is taken from NASA TMX-53865.[1] This environmental model encompasses particles of only cometary origin and considers a cumulative average flux of both sporadic and stream meteoroids, with the following major characteristics:

Particle Density:

Mass Density = 0.5 gm/cm^3 for all meteoroid particle sizes

Particle Velocity:

Average meteoroid particle velocity = 20 km/sec

Flux-Mass Model:

Average annual cumulative meteoroid flux-mass model is given by the following equations:

$$\log N_t = 14.37 - 1.213 \log m \qquad 10^{-6} \leq m \leq 10^{0}$$

$$\log N_t = 14.339 - 1.584 \log m - .063(\log m)^2 \qquad 10^{-12} \leq m \leq 10^{-6}$$

where

N_t = number of particles/m^2/sec of mass m or greater

m = mass in grams

The flux described above is gravitationally focused and unshielded, and must be multiplied by a defocusing factor and a shielding factor to account for the Space Station orbital altitude.

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[1] Natural Environment Criteria for the NASA Space Station Program, NASA TMX-53865 (31 October 1969).

The Space Station modules are protected from meteoroid penetration by environmental shield panels mounted external to the primary structural wall. These panels incorporate dual bumpers to fragment the meteoroid particles and thus greatly reduce their capability to penetrate the structural wall. Analysis of meteoroid impact onto this bumper arrangement is based on discrete particle penetration mechanics theory developed at Space Division.[1] This theory is based on the model that during hypervelocity impact the meteoroid particle perforates the outer shield and is fragmented into many smaller particles which form an expanding cloud which includes debris particles from the bumper as well as from the original meteoroid. The theory describes the mass of each type particle and the velocity with which the leading particles of the cloud impact the second bumper. The analysis of this impact is performed in the same manner as for the original meteoroid-first bumper impact. The presence of this second bumper will result in the fragmentation of the impacting debris particles and the formation of numerous clouds composed of debris from the second bumper plus debris from either the original meteoroid or the first bumper. The impact of these clouds on the surface of the primary structural wall will cause penetration damage, the severity of which depends upon the mass and velocity of the fragmented particles in the clouds.

Analysis of Space Station structures was accomplished by using the Discrete Particle Analysis - Three Sheet Version - Computer program (DPA3S) which was developed by Space Division for the analysis of hypervelocity impact on dual bumper and three sheet structures. This program checks the spacing between first and second bumpers using the above model to ascertain there is no overlap of impacts on the second bumper; it accounts for debris particle velocity reduction effects due to insulation located between these bumpers, and for second bumper and rear sheet spacing effects on penetration damage to the rear sheet.

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[1] Richardson, A. J., Theoretical Penetration Mechanics of Multisheet Structures Based on Discrete Particle Modeling, Journal of Spacecraft and Rockets, April 1970.

2.1 MODULAR PROTECTION SYSTEMS ANALYSIS

There are four basic types of Space Station modules: core, power, station-with radiators, and station-without radiators. For the purpose of the analysis, all station modules were conservatively assumed to be of the type without radiators. Figure B2-1 illustrates the various wall sections analyzed.

The reliability of each module was found by the equation

$$P_i \cong 1-N_iA_iT_i$$

where

N_i = number of particle impacts/ft^2 - day of mass equal to or greater than the critical mass

A_i = total vulnerable surface area per module, ft^2

T_i = total exposure time, days

The critical mass is the mass of that meteoroid particle that will just perforate the pressure wall of a module by causing a rear sheet penetration of

$$P_1 = \frac{t_3}{f_f}, \text{ cm}$$

where

t_3 = rear sheet thickness

f_f = spall factor for the rear sheet material

This mass was computed for each wall type using the DPA3S program.

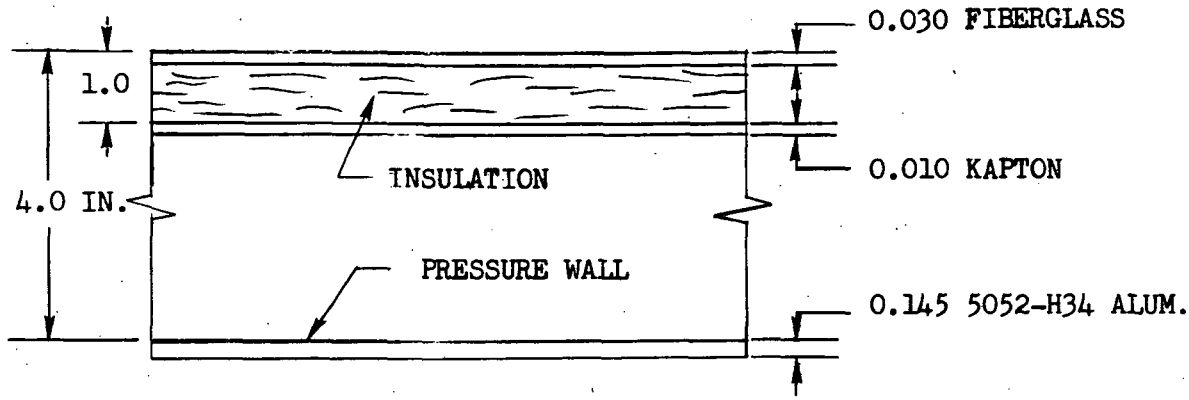
The surface area for each module was determined on the following basis:

1) the cylindrical section of the power module.

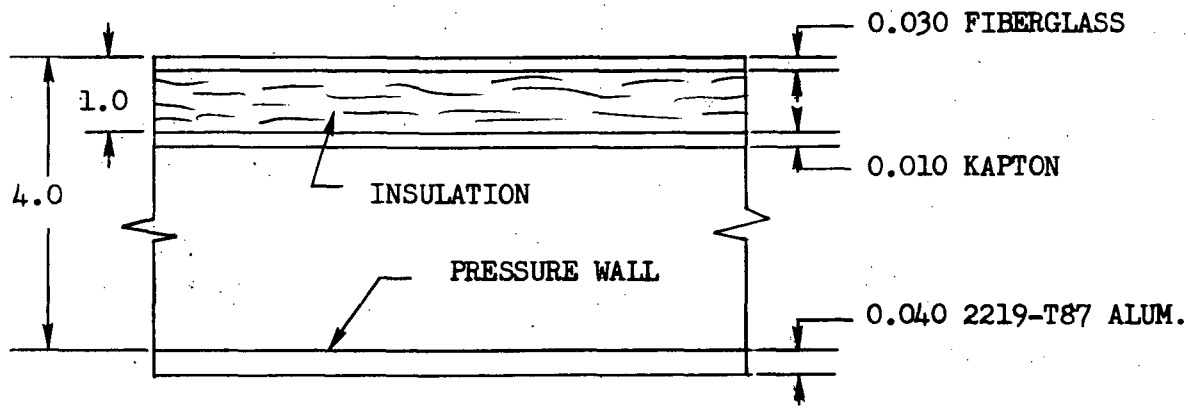
2) the conical sections plus the cylindrical section (minus port areas used for docking) of the core modules.

3) the conical and cylindrical sections of the station modules.

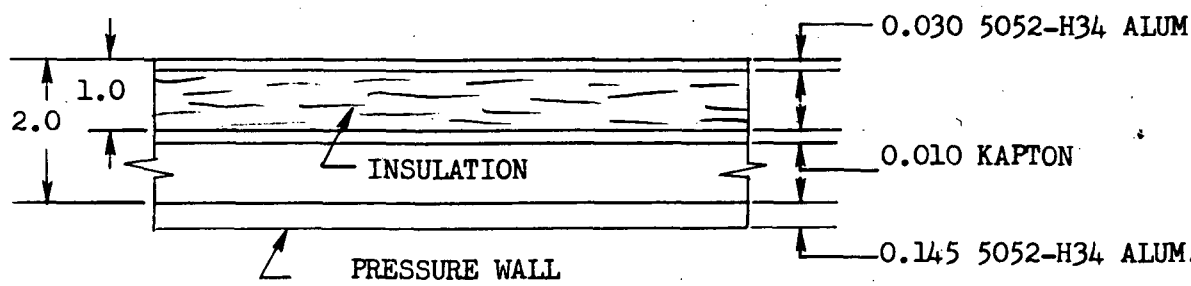
Figure B2-2 illustrates the basic dimensions used in determining vulnerable area for each module type.



(a) POWER MODULE

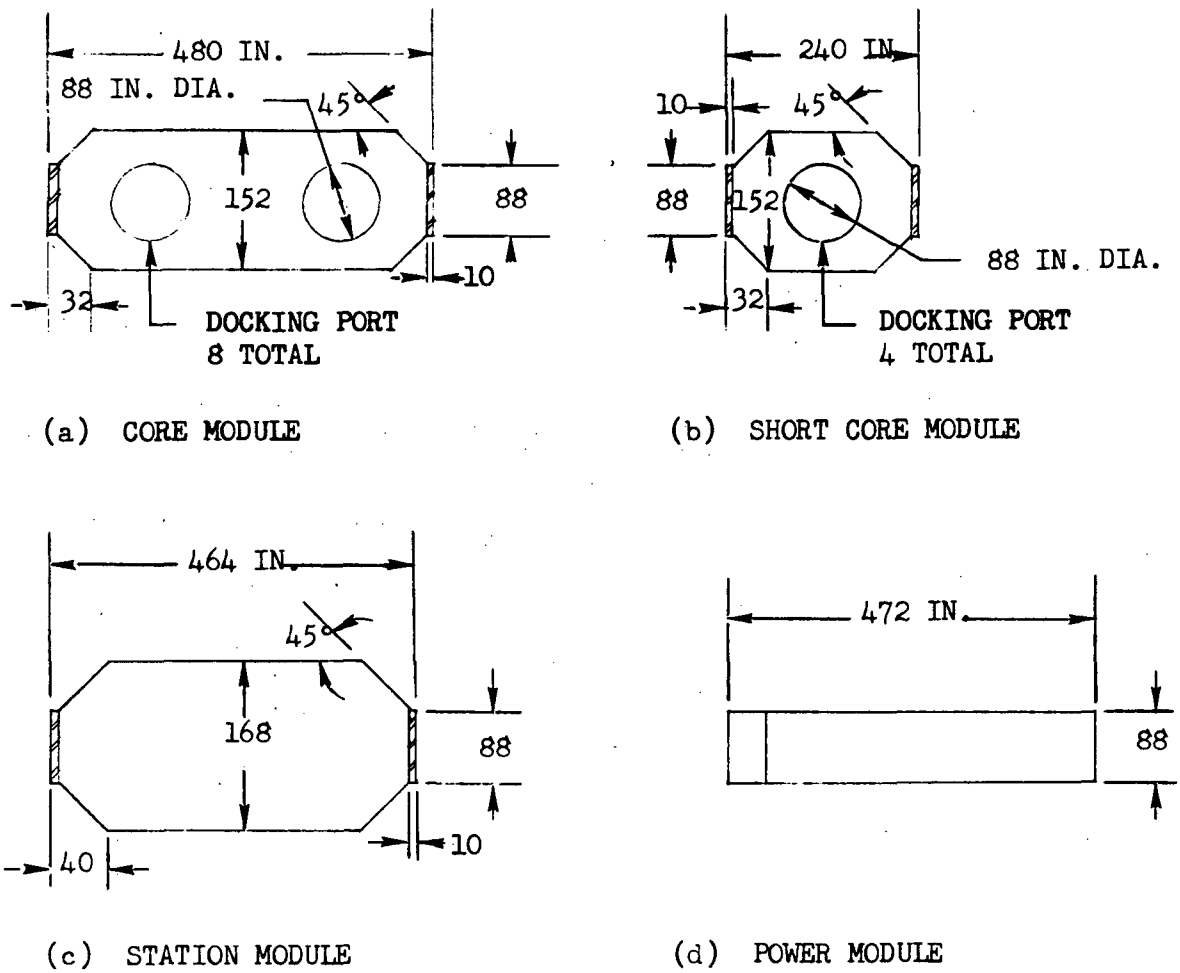


(b) CORE MODULE



(c) STATION MODULE

Figure B.2-1. Space Station Modular Wall Sections Used in Meteoroid Protection Analysis



(a) CORE MODULE

(b) SHORT CORE MODULE

(c) STATION MODULE

(d) POWER MODULE

Figure B.2-2. Basic Module Dimensions Used for Determining Vulnerable Surface Area (Cross-Hatched Area Not Vulnerable)

The exposure time varied for each module because of the buildup process that will be used in developing the Space Station. Each module was analyzed in terms of the actual time it would be in earth orbit during the ten year duration of Space Station operation.

Table B2.1 summarizes computed values for the critical mass, surface area, exposure time and probability of no perforation of the pressure wall for each module. The P_i values shown include a defocusing factor of 0.975 and an earth shielding factor of 0.663. The latter value was applied to only that portion of each module that will be continuous oriented towards the earth. A detailed description of the shielding factor application to each module was not included here because it was not considered necessary for the clarification of this evaluation. The overall probability of no perforation of the pressure wall for all the Space Station modules during its ten year life time is given by

$$P_{np} = \prod_{i=1}^{n} P_i$$

and was computed to be 0.902. This P_{np} value of 0.902 should be viewed as a lower limit case value. The effects of intershielding between modules was not considered due to the complexity of the Space Station configuration. Inclusion of such shielding would significantly increase the probability of no penetration. It should also be recognized that this value applies to the inner pressure wall only and does not consider the probability of failure of the Space Station by damage to the radiator tubes. However, the radiator tubes were extensively analyzed for the 33-foot-diameter station[1] and .145 inch external thickness of aluminum was found to furnish adequate penetration resistance.

[1]DRL No. 13, Solar Powered Space Station Preliminary Design, Volume IV, SD 70-159-4, July 1970

Table B2-1. Summary of Modular Space Station Meteoroid Hazard Analysis

Module	Critical Mass (m) (gms)	Total Vulnerable Area (A) (ft^2)	Total Exposure Time (T) (days)	Probability of No Pressure Wall Perforation (P_i)
Core	0.018	1214	3650	0.983570
Power	0.051	910	3620	0.996575
Station 1	0.027	1650	3590	0.984430
Station 2	0.027	1650	3560	0.984590
Station 3	0.027	1650	3530	0.984750
Station 4	0.027	1650	3500	0.984826
Short Core	0.018	585	1795	0.996125
Station 5	0.027	1650	1735	0.993570
Station 6	0.027	1650	1705	0.993680
Overall Probability of No Perforation = P_{np} = 0.902				

RADIATION PROTECTION

3.0 SUMMARY

This section summarizes the results of the nuclear radiation analysis performed for the initial cruciform space station configuration to evaluate the inherent shielding effectiveness based on preliminary design drawings.

Table B3-1 summarizes the comparison of computed doses and the allowable doses per the Modular Space Station Guidelines and Constraints specification. It is recognized that this computation is conservative because only gross masses were utilized. All doses were computed for a 270 nautical mile circular orbit with a 55 degree inclination. For this mission profile, only the rem dose for the eye exceeds the allowable doses. However, temporary eye shielding (during significant solar flare events) is a practical method of reducing the mission doses below the allowable rem dose constraints for mission duration less than six months. There is no practical solution to the eye dose problem for mission durations approaching one year other than pressure wall structure shielding augmentation.

The most critical shielding requirement for mission durations up to six months is a localized eye shield equivalent to 4.3 grams/cm^2 of aluminum. This shield need be used for a maximum duration of approximately one 36-hour solar event period in six months.

In Table B3-1 the skin of whole body (SOWB) doses are the mean of the eye and skin (at the belt buckle). A more extensive body surface dose survey is required to confirm the mean estimate.

3.1 APPROACH

Doses in Table B3-1 were computed with an 825 elemental volume breakdown of 7 space station modules and the connecting core module. The space station modules are duplicates of the SM-1 module. The SM-1 module model representation includes wall structure, floor, partitions, upper level equipment and both commander and crew quarters.

Spatial integration of point doses was computed with a 512 equal solid angle division of the unit sphere (4π steradians) for each dosimeter location. The areal-density-aluminum equivalent was computed at the center of the 512 solid angle divisions and converted to aluminum equivalents.

Areal densities and doses were computed using the NR/SD Elemental Volume Dose Program (EVDP). To assure accurate calculations, the 825 element geometrical shielding model for the modular space station was checked with the CRT cross section option of the elemental volume dose program. Examples of the verification checks are illustrated in Figures B3-1 and B3-2 by planar

cross sections. The top captions denote the cross section plane and CRT origin location in the Cartesian coordinate systems used for the station modules and the total modular station.

The dose versus areal density values in Table B3-2 were used to compute the EVDP doses in Table B3-1. The eye and skin doses are surface doses at the eye and belt buckle locations. These two doses were averaged to compute the skin of whole body (SOWB) doses. Mission doses in Table B3-1 are based on the 95 percent probability solar flare event, or 5 percent occurrence probability.

One and two events were used for mission durations up to 180 days and approximately one year, respectively.

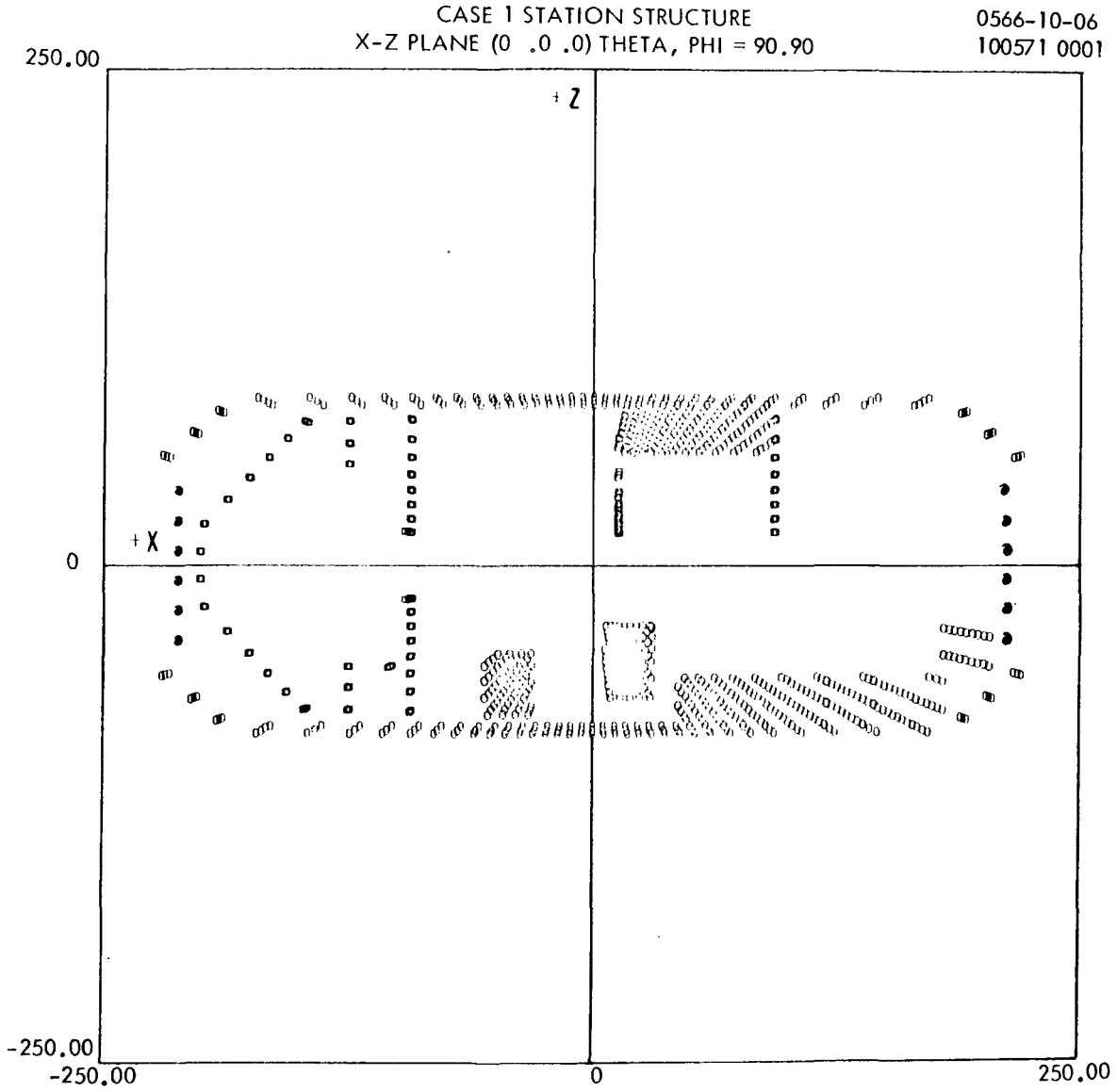


Figure B.3-1. Station Module CRT Cross Section

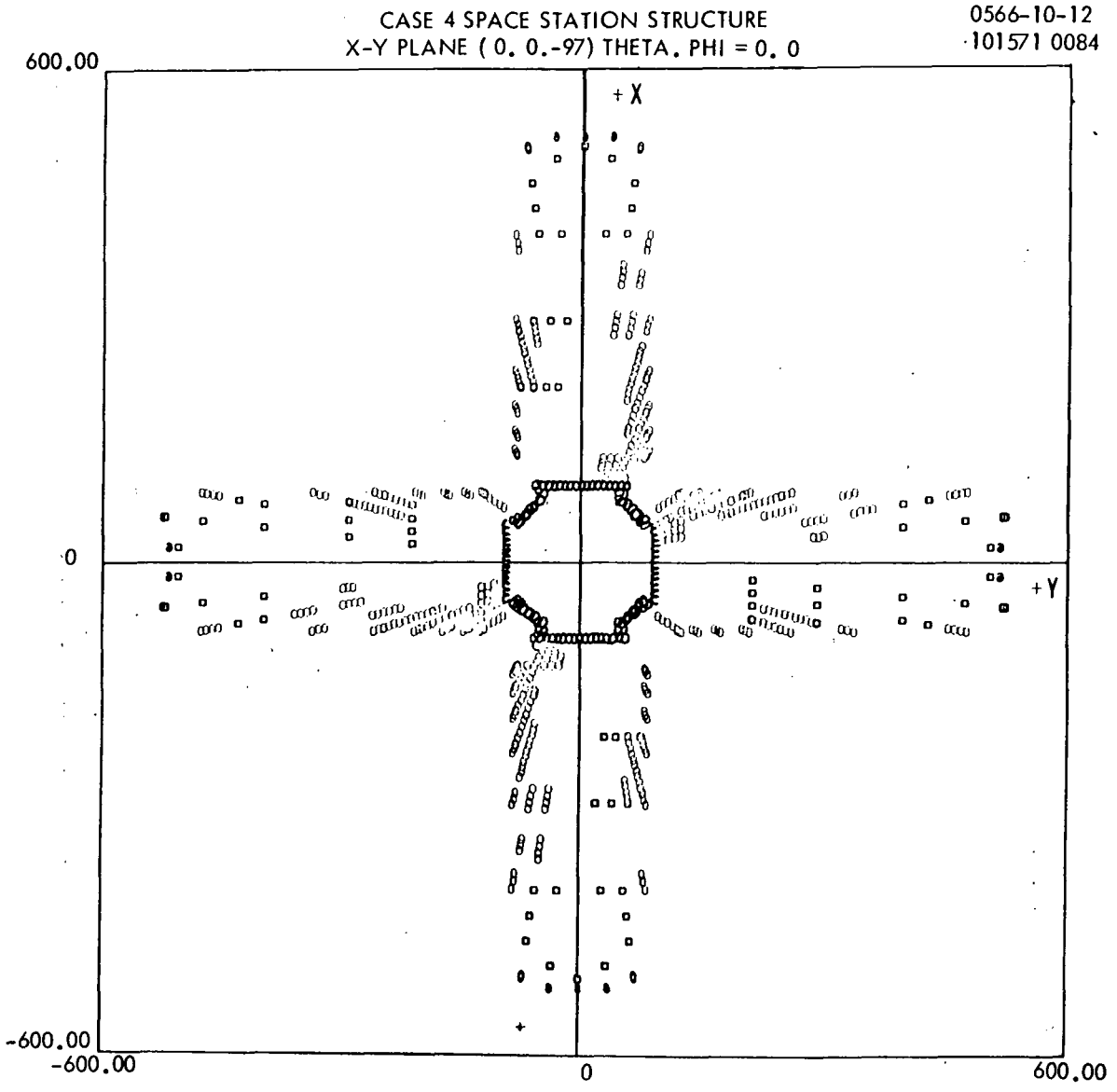


Figure B.3-2. Station Module and Core Module CRT Cross Section

Table B3-1. Comparison of Allowable and Calculated Modular Station Doses

	Station Location Point	Dose Point Coordinates x	y	z	EVDP Dose Components Dose Type	Solar Flare (2)	Earth Trapped (3)	(4) Minimum Areal Density	Modular Station Mission Doses for 270 n mi/55° Orbit Mission Duration Dose Type	30 Days	90 Days	180+ Days	360 Days
1													
2	X-Y Plotter	-54.01	-172.12	121.00	Eye	32.0	0.267	1.275	Eye	40.0	56.03	80.06	160.1
3		-54.75	-172.12	97.00	Skin	2.91	0.0517	3.72	SOWB (5)	22.2	31.8	46.1	92.3
4		-54.04	-172.12	109.00	BFO (1)	0.220	0.0408	12.17	BFO	1.44	3.89	7.56	15.1
5													
6	Control Console	-59.00	-371.10	121.00	Eye	47.7	0.368	1.28	Eye	58.7	80.8	113.9	227.9
7		-59.00	-370.35	97.00	Skin	21.64	0.187	1.29	SOWB	43.0	59.6	84.6	169.2
8		-59.00	-371.07	109.00	BFO	2.56	0.0470	11.14	BFO	3.97	6.79	11.0	22.0
9													
10	Tape Deck	-39.00	-136.02	121.00	Eye	39.9	0.350	1.28	Eye	50.4	71.4	102.9	205.8
11		-39.00	-135.27	97.00	Skin	20.43	0.188	1.30	SOWB	38.2	54.4	78.6	157.2
12		-39.00	-135.99	109.00	BFO	3.14	0.0564	8.72	BFO	4.83	8.2	13.3	26.6
13													
14	Commander Bunk	58.50	-415.40	130.00	Eye	59.4	0.436	1.28	Eye	72.5	98.6	137.9	275.8
5	Looking Up				Skin				SOWB (6)	55.2	75.2	105.1	210.1
16		58.50	-412.40	130.03	BFO	4.09	0.071	8.42	BFO	6.22	10.5	16.9	33.7
17													
18	Commander Bunk	61.50	-415.40	131.50	Eye	49.2	0.372	1.28	Eye	60.3	82.7	116.2	232.3
19	Looking to Side				Skin				SOWB (6)	46.0	63.0	88.5	177.0
20	Wall	61.53	-421.40	131.50	BFO	3.81	0.0661	8.15	BFO	5.79	9.76	15.7	31.42
21													
22									Eye	37	52	104	112
23							REM DOSE		SOWB	75	105	210	225
24							ALLOWABLES		BFO	25	35	70	75
25													
26	(1) Blood Forming Organs (BFO)												
27	(2) Rem/mission (95% probability)												
28	(3) Rem/day												
29	(4) Grams/cm^2 of aluminum												
30	(5) Skin of whole body (SOWB)												
31	(6) Estimated doses by interpolation												
32													
33													
34													
35													

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